MANGOES IN PAKISTAN

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PREFACE

Mangifera indica commonly known as mango belongs to the family `Anacardiaceae'. As a general belief this fruit is considered to be native of Malayan Archipelago. Popenoe states the original home of this fruit to be in Eastern India, Assam, Burma and farther in the Malaya region. Even though the mango might have come to India from Far East yet its greatest development took place in Indo-Pak Sub-continent. It is being grown in this region for several hundred years. It is generally believed that the vegetative propagation of this fruit was established by the Portuguese in Goa. However, the superior varieties had originated in Indo-Pak Sub-continent and from there they have spread to the other parts of the world. It is grown almost in all the tropical and sub-tropical countries namely Malaya, Philippine, Burma, Ceylon, India, Cambodia, Egypt and South American countries. It has also been grown in the West Indies and to some extent in Florida. Its cultivation has not proved much successful in California. Mango growing has commercial importance in Indo-Pak Sub-continent. Indian rulers were very fond of this fruit, Akbar the Mughal Emperor liked it so much that he got 1,00,000 trees planted in a garden near "Darbhanga" giving the name to the garden as "Lakh Bagh" after the number of trees planted in it.

In Pakistan the cultivation of this fruit is as ancient as the civilization of this tract. In the Punjab as well, the cultivation of this fruit is very old. The groves of the mango trees found in the "Shalimar Garden" Lahore which were got established by the great Mughal Emperor "Shah Jahan" bear out this fact.

In Pakistan mango is the second major fruit which occupies an area of about 94,000 hectares. The production is about one million tonnes 5 to 6% of the production is being exported, which is earning foreign exchange equivalent to Rs.2.5 billion. Great potential sum up to be important.

Mango production in Pakistan per unit area is only $^{1}/_{3}$ or ¼ of the proven potentials. Post harvest losses range between 30 to 40 per cent. Quality of fruit to generally acceptable, but does not necessarily needs the consumer preferences in niche markets.

If Pakistan is to estahlish foot hold in foreign markets on sustained basis, all these issues need to be addressed. Particular attention needs to be focused in the production of clean fruit, its handling, packing and export of graded and branded produce to create creditability. Adequate processing must be established and mango juice must be introduced in foreign markets and popularized by strong promotional measures. The book on mango produce 45 years ago, does not answer most of the problems, presently being confronted by mango industry in the country.

The updated information has been compiled to produce necessary guide lines to augment production of quality produce to meet local needs and to have substantial exportable surplus of fresh fruit and products.

Prof. Dr. Muhammad Ibrahim, Dr. Amanullah Malik, Ch. Abdul Haq and Mr. Tariq Malik of Mango Research Station, Shujabad, Ch. Ali Asghar Asi, Director, Horticulture Research Institute, Ayub Agriculture Research Institute, Faisalabad played important role in this compilation. Their assistance is thankfully acknowledged.

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Dr. Saeed Ahmed

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1. ORIGIN, HISTORY AND DISTRIBUTION

Dr. Saeed Ahmed[1]

The mango, *Mangifera indica L.*, belongs to the family Anacardiaceae. The genus comprises 62 species; more than a dozen of these produce edible fruits (5; 9; 35; 40). However, *Mangifera indica* is the only species grown extensively and commercially and is very widely distributed. The mango is one of the most important fruit crops of the tropics and subtropics. The specific name indicates its origin: it has been in cultivation in the Indo-Pakistan sub-continent from time immemorial. Alexander the Great had seen some beautiful mango orchards in the Indus valley as early as 327 B.C. (5; 33; 40). References are not lacking which suggest that it has been in cultivation in India for well over 4000 years (5; 9; 27; 29; 33; 40). The age-old association of the mango with Hindu mythology and the occurrence of numerous wild and cultivated varieties in India are clear evidence in favour of the Indian sub-continent being the original home of this important fruit. In view of the preponderance of many species of *Mangifera* in the Malayan archipelago, some workers have thought that Malaysia might have been the land where the mango had originated. Most workers seem in agreement, however, that its native home is in eastern India, Burma and possibly further in the Malaysia and Indo-China region (5;. 9; 33; 36; 40). The presence of fossil records of a primitive species, *M. pentandra*, in Assam and of the phylogenetically most primitive species such as *M. duperreana* and *M. langenifera* in Laos, Cambodia and Vietnam, further supports this contention (28). In any case, *Mangifera indica* has received the greatest attention in the Indo-Pakistan sub-continent, where many horticultural varieties of high standard have developed. Arabs, Portuguese and Spaniards are to be given credit for the early spread of this species throughout the tropics and sub-tropics (5;. 9; 33; 40). At present, besides India, it is grown extensively in such countries as Pakistan, Sri Lanka, Burma, Bangladesh, Kenya and Tanzania, Thailand, the Philippines, Malaysia, Indonesia, Vietnam, China, Australia, Egypt, South Africa, Nigeria, Israel, Mexico, Cuba, Brazil and the West Indies. In the mainland U.S.A. the southern tip of Florida, which enjoys a subtropical a climate, is the only area where the mango is grown. However, I it is one of the important fruit crops of Puerto Rico and Hawaii (5; 9; 30; 33; 36; 3; 26; 38; 40; 46; 47; 48; 49)

1.1. BOTANICAL RELATIONSHIP

The mango (*mangifera indicia*) belongs to Anacardiaceae family of the Plant Kingdom. There are as many as 39 or even more species of mangifera genus in South Asia and about 13 of them are cultivated for edible fruits. M. odorata Griff, M. foetida Lour, M. altssima Griff, M. langang Mig and M. Similis 81 are some important ones among them. M. sylvatica resembles M. Indicia and grow wild in Sylhet. M. Odorata and M. foetida are growing in Malaya.

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This is an antimophilous and freely crosspollinated plant and as such the genetic seedlings depart very much from the mother parent tree and on account of this character, the mango does not reproduce true from seed, hence vegetative propagation is very important. There is, however, another group of mango plants which in pomological literature is known as seedling race. The races have got more than one embryos in their seeds and are therefore called polyembryonic whereas the horticultural types are mostly monoembryonic. As a result of polyembryonic nature, the races produce many seedlings from a single seed. Out of these only one seedling develops from the zygot which may be very weak and eliminated in its struggle for existence while others come out from false or nuclear embryos (Nucellusis a body tissue of the ovule) which are identical to the mother parent. All Indo-Pakistan mangoes are monoembryonic except a few varieties the Western Coast of India (18; 85) that are poly-embryonic.

(39) considered two view-points of classifying the mangoes, firstly as the "Seedling Races" and secondly, as "Horticultural Varieties".

1.1.1. Seedling Races

As already stated, all the seedling races are known to be polyembryonic and by virtue of this characteristic they reproduce in this way preserve the racial characters.

The racial classification is based on the natural habit and phenological features of the tree. The races of mangoes as found in various countries of the world. They are most commonly found in Cochin, China, Philippines, Island, West Indies and are also grown at present in Florida, Hawaii Island, Cuba, Mexico and Brazil. The origin of various seedling races and other particulars are briefly given hereunder in a tabular form (34).

S.No.	Seedling Race	Original home	Where grown	Characters
1.	Hawaiian sweet	West Indies	Hawaii Islands	Common seedling race of West Indies.
2.	Mango (West Indian)	West Indies	Cuba, Mexico Tropical America, Florida, Jamaica	Open grown, tall and erect tree. High 60-70 ft. 8-12 inches long, panicle with reddish maroon-coloured axis. Fruit colour yellow, often blushed with anthracnose. Flesh orange yellow. Strongly compressed laterally curved and beaked. Fibre long and coarse. Flavour sweet.
3.	No. 11	West Indies	Florida and Jamaica	Same as of Cuba and Mexico and is esteemed over most other seedlings.
4.	Mango	Cuba	Cuba, Florida, Porto Rico	Tree spreading, 35-40 ft high.

Continued

Continued

S.No.	Seedling Race	Original home	Where grown	Characters
	(i) Mango amarilla			Dense round top crown. Turpentine or peach mango (Florida) deep orange colour. Bright orange flesh.
	(i) Mango blanca			Apple or Bombay mango Roundish oblique fruit, Panicle 6-10 inches long, stout, pale green in colour often tinged with red. Fruit plump, not beaked, Bright yellow in colour with whitish flesh. Fibre long and fine.
5.	Cambodiana Saigon Carabao Pico (padero) Pahutan	Cochin China	Cochin, China, Florida	Tree medium size, round headed, large, light green leaves. Most esteemed and generally planted in Philippines. Fruit medium size, yellowish green to yellow with a tint of orange when ripe. With a slight beak and slight neck. Faint disagreeable colour. Skin thin, flesh yellow to organce. Smooth texture. No fibre. Flavour mild and delicious.
6.	Philippines (Cuba) Manila	Philippines	Philippines, Cuba, Mexico, Florida, America	Tree erect 30-35 ft. high. Dense oval crown. Panicle 12-24 inches long pale green Sometimes tinged with red Fruit strongly compressed laterally, sharply pointed rather than curved or beaked at apex. Lemon yellow in colour with deep yellow flesh almost free from fibre. Most delicious and highly esteemed
7.	Mango darora (nose mango)	Mauritius	Brazil	Heart shaped. slightly) beaked and of good size. Colour usually beautiful. Fibre coarse and long. Flavour rich and pleasant.

1.1.2. Horticultural Varieties

The Indo-Pakistan mangoes are monoembryonic and seedlings differ invariably from each other. The wide variations among the seedling progeny have been responsible for the evolution of several choice varieties in both the countries which have been further multiplied by vegetative means and grown on a large scale. These varieties have thus been called as "Horticultural varieties". That is how a large number of standard varieties have come into being and are cultivated in the different parts in Indo-Pakistan. The varietal nomenclature is so much confusing that one variety carries many names at various places and in some cases one name is applied to several varieties.

In a nursery catalogue (1925) as many as 864 different varieties with 1692 different names have been mentioned along with their characteristics. Catalogues containing 1000 varieties are also reported. (18) was perhaps the first one who undertook this work and collected as many as 500 different varieties. Burns and

Prayag (18) described 89 varieties grown in Bombay Presidency, Wester compiled published a description list of about 300 varieties which includes the best known from all parts of the world. 302 varieties with description and 211 coloured plates have been reported in a book "The Mango" published by Indian Council of Agricultural Research in India. (14). Description of 35 important varieties grown in Florida have been given in a bulletin "Mangoes in Florida" issued by the Department of Agriculture. Tallahassee, Florida.

The nomenclature in Indo-Pakistan varieties is very difficult to understand for the reason that naming of the varieties have been unsystematically based on many aspects, namely the place of origin, the garden owner's name, the name of the person who liked it the most, the colour of the fruit (Doodhia), flavour of the pulp (Saunfia), season and month of ripening (Bhadayyan), etc.

Horticultural varieties as has already heen mentioned in the foregoing paragraphs, have come into being as a result of variations in the classification of such a large number of varieties is a stupendous task and would require hard labour extending over a period of many years. (34) has recognized four groups of varieties based on natural resemblances. These groups are Mulgoba, Alphanso, Sandersha, and Cambodian. Their salient characters are described here as under:

Character	Alphanso	Mulgoba	Sandersha	Cambol
Tree	Broad and spreading some times rather tall with an oval crown.	Erect, broad dense crown.	Erect, stiff, less broad crown. Not so umbrageous.	Tree medium size, round-headed.
Foliage	Abundant, light to deep green		Fairly abundant. Deep	Large, light, green-leaves.
Leave	Medium to large in size with primary transverse veins 20-34 pairs, fairly conspicuous.	Slender and small than in some of the other groups. Primary transverse veins 22-24 pairs, moderately conspicuous.	Comparatively small but broad. Primary transverse veins 18-24 pairs, moderately conspicuous.	Medium size to rather large. Primary transverse veins more numerous than other groups. Commonly 26-30 pairs, quite conspicuous. Odour of crushed leaves distinctive.
Panicle	Large, very broad towards base stiff, sometimes about, 10-18 inches long, the axis and laterals pale green to dual rose pink in colour; Glabrous to very finely and sparsely pubescent.	Slender frequently drooping, 12-18 inches in length. The axis and varying pale green tinged pink to rose pink. Pubescent heavier than other groups.	Small to large broad towards base, 8-18 inch long, stiff. The axis and laterals deep magenta pink to bright maroon. The pubescent very minute and inconspicuous.	Very large, broad slender 12-20 inches in length, laterals pale green to dull magenta pink very finely pubescent.
Flower	The flowers are not crowned on the panicle. Staminade are poorly developed.	Very abundant. Staminades strongly developed after fertile. Varieties of	The flowers abundant but not closely crowned on weakly developed,	Some times freely developed and rarely capitate or fertile. Bloom profusely, 3-5

	Produced sparingly or only one side of the tree but a match higher percentage of the flowers develop into fruits than Mulgoba group drop.	this group require dry weather for making them flower profusely. Tendency of the fruit drop present.	rarely capitate or fertile. Varieties often flower in unfavorable weather and they	fruits, develop on one panicle.
Crop	Noi heavy bearer, usually small io fair crop.		Higher degrees of Productiveness	Very productive
Fruii shape	Longer than broad, usually oblique at the base and lacks a beak. Tbe stigmatic point often forms a prominence on the ventral surface above the apex.	Usually oval. Lacks a distinct beak.	Long tapering at both ends and terminating in a prominent beak at the apex. Large in size.	Long, strongly compressed laterally, usually, sharply pointed at the apex.
Colour	Yellowish green to bright yellow blushed scarlet.	Dull green to yellow blushed red.	Deep yellow.	Lemon yellow to deep yellow.
Flesh	Orange-coloured.	Deep yellow to orange blushed red.	Orange yellow	Bright yellow.
Fibre	Absent.	Variable in quantity.	Absent	Almost absent.
Flavour	Rich luscious		Acid.	Springhtly sub-acid.
Seed	One embryo.	Normally one embryo.	Long. Normally one embryo.	Oblong, normally polyembryonic. Cotyledons often not fitting the end ocarp completely.
Varieties	Bennets, Alphanso, Amni, Rajpuri, Bannet and Pairi.	Mulgoba, Haden, Singapore, Safaida.	Sandreshah Brooks Fajri long, totapari, Anderson.	Cambodiana, Carabao, No.11.

1.1.3. Important Horticultural Varieties

As has been said, the varieties of mango are almost beyond number, there are millions of seedling trees, some are excellent, many of which assumed a distinct varietal name. In some cases the same variety ma known under different names in different locations and in number of cases the same may be given to distinct varieties. Different varieties are suited to different sections. It is not necessary that a grower should plant many varieties, successfully in his region. He should have good number of varieties to provide for commercial handling and marketing, even though that limit him to one carefully selected variety. In a commercial orchards it is good to have varieties ripening throughout the season. It is suggested to have 2 to 3 varieties of each seasonal group in an orchard of moderate size.

The important varieties of different places in Pakistan, India and abroad are given below:

S. No.	Country	Locality	Varieties
1.	Bangladesh	B. Desh	Gopal Bhog, Langra, Fazli, Gila, Kanpahari, Bhog, Khirsapati.
2.	Pakistan	Punjab	Langra, Dusehri, Samar Bahisht, Fajri Kalan, Anwar Ratol, Muhammadwala, Khangarhi Bacha
		Sindh	Sindhri, Bangan-Pali, Swarnareka, Khasa, Coil Neelum, Dusehri, Langra, Alphanso (Bombay
3.	India	Uttar Paradesh	Langra, Dusehri, Bombay Alphanso, Sam mar Bahisht Chauga, Fazli, Sofeda No.1. Sufeda Lucknow, Gopal Bhog.
		Bihar	Alphanso, Pairi, Farnandian, Kassji Patel
		Madras	Banglora, Neelum, Swarna-reeka, Banganpall Peter.
4.	United States	Florida	Pairi, Amini, Benette, Malgoba, Haden, E Anderson, Cambodiana, Zill, Keitt, Irwin, Haden, Sensation, Tomy Atkins.
5.	Philippines		Carabao, Pica, Pahutan.
6.	Australia		Kensington.
7	Brazil		Non-plus-ultra, Bourbon, Oliveira-Neto, Hadeb* Extrema, Manga da Rosa.
8.	Burma		Nettes, Tazumeik, Sinbaug, Thou-lou-dal Thalapet, Htaik-pauk.
9.	Cambodia-Veitnams		Xoai voi, Xoai-thanh-ca, Cambodiana.
10.	Cuba		Haden*, Bizcochuelo, Macho.
11.	Egypt		Mabroka.
12.	Indonesia		Golek, Aroomanis, Gadoong, Wangi.
13.	Israel		Haden*, Maya, Nimrod.
14.	Haiti		Madame Francis.
15.	Hawaii		Pope, Momi K, Gouveia, Haden*.
16.	Jamaica		Bombay*, Julie*.
17.	Kenya		Ngowe, Boribo, Apate, Batwawi
18.	Mexico		Manila, Haden*, Irwin*, Keitt*.
19.	Malaysia		Timun, Sourabaya, Serikaya.
20.	Puerto Rico		Mayaguezano, Haden*, Mangotine, Colombo Kidney*.
21.	South Africa		Sabre, Peach.
22.	Thailand		Nam-doc-mai, Tong-dum, Okrong Brahm-Kai-mia, Pen-sen-Man, Prum Kaewsaard.

* *Originated elsewhere but commercially cultivated in this country.*

1.1.4. Description of Some Important Mango Varieties, Important in Pakistan

1. Langra

It has originated as a superior chance seedling near Benares. Size medium to large, ovate, base round to slightly flattened, shoulders equal, beak minute but distinct, sinus slight to absence, skin green and thin, flesh fibreless, yellowish brown in colour, scented, highly melting, very sweet. Stone very small, flattened, oval. Weight of an average fruit is about ¼ kg. Fruit quality very good, bearing heavy. Season (Early to mid season). 1st to 3rd week of July. Heavy yielder.

2. Aman Dusehri

It derives its name from village between Lucknow and Malihabad where it originated as a superior chance seedling. Size small to medium, oblong, ventral, shoulder higher than dorsal, beak and sinus absent, colour yellow when ripe, skin thin, pulp fibreless, flesh firm, very sweet, flavour nice. Stone very small, oblong, variety good to very best, bearing heavy, mid season (July), keeping and peeling qualities good.

3. Sammar Bahisht, Rampur

It has originated as a superior chance seedling in Muzaffarnagar, U. P. It got its name because of its pleasant flavour. Fruit medium, base slight flattened, shoulders equal, sinus very slight, beak prominent, skin green yellow, thin, pulp yellow, very sweet, sparsely fibrous, flavour pleasant delicious. Stone medium and oblong, oval. Quality of the fruit very go keeping and peeling qualities good. Ripening season July-August.

4. Fajri Kalan

It has originated as superior chance seedling in Bihar and got name after the name of lady Fajri who selected and brought up its trees. S big, oblong, obliquely oval, base rounded, shoulder unequal, with ventral higher than the dorsal, beak distinct, sinus very shallow with round all Skin thin, pulp colour pale, fibreless, taste sweet with pleasant flavour moderate to abundant. Stone large, oblong. Fruit quality good to very good bearing late season August, keeping quality good.

5. Muhammadwala

Size small to medium, skin thick, yellow brown, pulp sweet, juicy Stone medium sized, fibre very little. Very hard variety. Season early August

6. Sammar Bahisht Chausa

It originated as choicest seedling in a village Chausa in Malihal Tehsil of Lucknow. It is also known as Kajri or Khajri. There is resemblance between the foilage of Fajri and this variety but there are marked difference in fruit shape and quality. Fruit medium to large ovate to oval, base obliquely flattened, ventral shoulder raised than the dorsal, beak distinct, sinus shall apex round, skin medium in thickness, smooth, flesh firm, fibreless with pleasant flavour and sweet taste. Juice moderately abundant. Stone somewhat large oblong. Fruit. quality good, bearing heavy, keeping quality medium to good. Ripening season in August (late).

7. Rataul (Anwar)

It has originated as superior chance seedling in Shohra-e-Afaq garden in Rataul. Now it has become popular in mango growing areas of Punjab because of its high flavour. Fruit medium, ovate, base flattened with equal shoulders which are rounded, beak not prominent, absent in some cases, sinus absent, apex round. Skin medium thick. Flesh firm, fibre less, flavour very pleasant, with very sweat taste. Juice moderately abundant. Stone medium oval. Fruit quality very good. Ripening season in July (Mid-season). Keeps well in storage.

8. Sindhri

It is a leading variety of Sind. Fruit shape ovalish long. Size big, length 15.0 cm, breadth 8.0 cm. Thickness 7.4 cm. Weight 14.0 oz. Base obliquely rounded cavity absent. Ventral shoulder rising and round, dorsal ending in a curve. Skin colour lemon yellow when ripe. Surface smooth. Pulp colour yellowish cadium. Texture fine and firm fibreless. Stone medium size. Flavour pleasantly aromatic, taste sweet. Heavy yielder, early season.

9. Banganpali

Fruit shape obliquely oval. Size big. Length 14.0 cm. Breadth 9.1 cm. Thickness 8.2 cm. Weight 22.0 oz, when unripe. 20.0 oz when ripe. Base obliquely flattened. Cavity not prominent. Stalk inserted obliquely. Shoulders ventral typically rased, broader and much more higher than dorsal. Back almost rounded. Sinus shallow to negligible. Beak marked by rounded point. Apex obtuse to rounded. Skin colour dark green and glazy when unripe. Yellowish light green with very light crimson patches when ripe. Surface smooth, shining. Dots small distinct. Glands small, crowded.

Pulp colour light yellow with whitish tinge. Texture firm and fine. Flavour pleasantly aromatic. Taste very sweet, and leaves a good taste. Juice scanty. Fibre absent. Stone shape oblongish. Body full in the middle empty t the ends. Size medium middle empty at the ends. Size medium length 16.6 m. Breadth 3.6 cm. Thickness 1.5 cm. Weight 1.8 oz. Veins raised. Fibre fine short fibre at the ventral edge.

10. Suwarnareca

Fruit shape ovate oblong. Size big. Length 12.4 cm. Breadth 9.1 cm. "hickness 8.0 cm. Weight 18.0 oz. when unripe 17.0 oz when ripe. Base obliquely rounded. Stalk inserted ohliquely. Cavity slight. Shoulder unequal. Ventral shoulder more higher than dorsal and rounded. Dorsa! shoulder ending 1 a long curve. Back rounded. Sinus slightly absent. Beak absent. Apex rounded. Skin colour light green when unripe. Pale yellow when ripe. Surface smooth. Dots small close. Gland prominent crowded.

Pulp colour yellowish with slight reddish tinge. Texture firm. Flavour typically aromatic. Taste sweet. Juice scanty. Fibre absent.

Stone shape oblong ish. Body full n the middle empty at the ends. Size medium. Length 10.1 cm. Breadth 4.4 cm. Thickness 1.6 cm. Weight 1.4 oz. reins slightly raised and sometimes to the surface level. Fibre short and soft fibre on the ventral edge only.

11. Neelum

Fruit shape ovate, size small. Length 7.7 cm. Breadth 5.9 cm. Thickness ;.6 cm. Weight 5.0 oz. when unripe, 4.0 oz. when ripe. base rounded. Stalk inserted squarely. Cavity slight to absent. Shoulders unequal. Ventral is higher han dorsal. Ventral shoulder rounded, dorsal shoulder ending in a moderate curve. Back rounded. Sinus slight to shallow. Beak acute to obtuse. Apex runded. Skin colour sea green when unripe. Yellow with reddish tinge when ripe. Surface smooth. Dots small. Glands small, numerous.

Pulp colour pale yellow to yellowish. Texture firm. Flavour insignificant. Taste sweet. Juice scanty. Fibre less and short.

Stone shape ovalish. Body full and thick. Size small. Length 6.0 cm. Breadth 3.4 cm. Thickness 1.7 cm. Weight 1.0 oz. Veins at the surface level. Fibre small fibre allover the body, long on the ventral edge.

12. Sensation

Fruit medium-small to 4½ inches long and averaging 10-12 0 in weight, but individual fruit to 20 ounces; shape oval ground colour bright yellow-orange with a dark plum-red blush, lenticels numerous, small an, yellow. Flesh slightly sweet and of a distinctive milk flavour and with! fibres; quality good. Tree vigorous, moderately open and symmetrical in growth. Season August and September.

1.2. GROWHT IN RELATION TO ECOLOGY AND ENVIRONMENTAL FACTORS

1.2.1. Plant Environment

Temperature: The mango tree thrives under a wide range of a climatic conditions but its profitable cultivation is limited a by temperature and precipitation. It can endure a minimum temperature as low as 32°F (O°C), and as high as 1140° to 118°F (46° -48°C). It is reported that its growth is minimal at 40° - 43°C). However, for optimum growth and productivity, 75° - 80°F (24° - 27°C) is believed to be ideal (9; 43; 2 37; 38; 40; 42). In areas with dry hot summers, with temperatures going beyond 114°F (46°C), the fruits get sun-burnt. High temperature accompanied by low humidity and high wind velocity also proves injurious since this enhances the transpiration rate and upsets the normal physiological balance of the tree (38; 41; 40). The adverse effects of such conditions in hot dry regions can be minimized by irrigation (11; 40). As regards propagation, in Pakistan and northern India, during the hot dry summer, the trees do not show much sap flow and the percentage of success is thus greatly reduced (2; 41).

Frost: The susceptibility of the mango tree to frost varies with its age and state of growth. Young plants of four to five years in active growth are killed outright if the temperature falls below 31° -29°F (-1° to -2°C). Older trees with less growth activity usually escape damage at this range provided the duration of low temperature is not prolonged. Even though the main framework of older trees may not be damaged by exposure to low temperature, tender growth on such trees is seriously damaged (2; 38; 41; 40). Some varieties are known to be more prone to frost injury than others (17). In colder regions the plant ceases growth before the onset of cold weather, hardening causing it to avoid cold damage.

In tropical countries the mango seldom ceases growth and it is possible to propagate it vegetatively the year round. But this is not true for regions where the tree remains dormant during the autumn and winter months. Similarly, in areas with cold winters the mango tree supports one heavy blossoming when the weather warms in the spring. In tropical countries without any distinct change in season most mango varieties bloom more than once; so much so that some fruit may be seen on the trees throughout the year (3; 6; 40).

Precipitation: The mango grows in areas with scanty rainfall and also in very wet regions. The total amount of rain during a year seems to be of less significance than the season in which it falls. Thirty-five to forty inches (890-1016 mm) of well distributed rainfall are considered sufficient for the successful cultivation of the mango (9; 33; 2; 41; 42). Due to its deep and well developed tap-root system, it is well adapted to withstand periods of prolonged drought. In parts of India and Pakistan it can flourish in regions with less than ten inches (254 mm) of annual rainfall. However, in such areas it is generally cultivated under irrigation (2; 41; 42; 40).

It does equally well in areas with very high annual rainfall, provided the weather during flowering is relatively dry. Rainfall is then highly detrimental as it hampers the bees' activity, dilutes the stigmatic secretion, and dampens or washes away the pollen, thus resulting in low fruit-set. Bad weather at flowering time is to a great extent responsible for alternate bearing in mangoes (9; 2; 38; 41; 42; 40).

In certain parts of Puerto Rico, Jamaica, India and Brazil, which receive heavy rainfall during most of the year, mango trees are less prolific. In such areas trees show profuse vegetative growth at the expense of fruiting (16; 38; 40). Success in grafting operations during the rainy seasons in areas of excessive rainfall and high humidity is greatly reduced. Moisture enters the graft incisions and hinders the formation of a graft union. Excessive penetration of water can even cause rotting of the tissues. For profitable cropping the dry season should be well ahead of flowering (9; 33; 43; 2; 23; 38; 41; 40;). This helps the trees to accumulate sufficient carbohydrates, which are conducive to flowering. Once the fruit is set, wet and hot weather assists fruit growth and ripening.

Wind: In regions subject high wind velocities mango trees suffer in many ways, such as crop shedding or even by trees falling. The establishment of windbreaks or shelters in such areas can minimize the loss to some extent. In Punjab, India (12), the establishment of young mango grafts in marginal climatic conditions was greatly helped by planting banana suckers to provide shelter. Almost 90 per cent of the plants survived, compared with 62 per cent under *sesbania aegyptiaca* and 54 per cent under *Cajanus indicus*. The percentage of success in inarching operations is also adversely affected by strong winds. The shaking of the limbs and the shoots during the process of inarching hinders the graft union forming (10; 32; 41; 40;).

Altitude: Mango trees in the tropics grow from sea level up to an elevation of about 4000 feet (1220 m), but they seldom bear at higher altitudes. Commercial plantations are almost all located below 2000 feet (610 m). Altitude has a pronounced effect on the time of flowering. For every 400 feet (120 m) increase in height from sea level, the time of flowering is retarded by four days.

Similarly, for each degree of latitude south or north of the tropics, flower initiation is delayed by four days (20; 40;).

Soils: Mango trees flourish on a wide range of soils. However, they prefer a deep rich fertile soil because of the long tap-root. Excessively sandy soils weaken the tree and

lower the quality, size and quantity of fruit produced. The soil should be well drained and without a hard pan. A mango tree can withstand occasional flooding, but orchards on poorly drained soils are generally unthrifty and far less productive (38). Soils with very fluctuating water-tables are adverse for root growth. For the development of a strong root system, the water-table should not be higher than 2.5 m(8 ft) from the i surface (41). In Florida the mango thrives on a wide variety of soils, trees becoming very large near the coast i where the soils are deep sandy loams (38). In India the mango grows on laterite soils in coastal areas and deep alluvial loams in the plains. The soil pH in most of the well known mango-growing regions in India varies from 5.5 to 7.5 (41). In Pakistan luxuriant plantations are found on deep sandy loam and clay loam soils (2; 21).

On deep, fertile and well-drained soils, rootstock seedlings grow faster and become available for grafting operations much sooner. In very sandy soils transplanting mango plants in balls of soil is difficult.

1.3. GROWTH CHARACTERISTICS OF MANGO TREE (MORPHOLOGICAL AND ANATOMICAL)

The mango is evergreen; it is one of the largest fruit trees and, when planted singly, normally has a spreading form. Several slow-growing varieties are almost prostrate in habit, but usually the tree is erect, either with a broad dome-shaped umbrageous crown or with a tall oval, more or less open crown and ascending branches. A height of 70 feet (21 m) is frequently attained. The height and shape of trees, however, vary considerably among varieties and seedlings. In a climate where neither frost nor wind is likely to kill the tree, it can live to a great age. Trees several hundred years old are reported (5; 9; 33; 38; 41; 40;). The growth habit of the tree is of importance and differs from most other fruit 3ar trees. It is not seasonally continuous, but occurs in periodic flushes from the terminal buds and from the axils of leaves on younger branches (19). The number of these periodic growth flushes during the growing season, the time of their initiation and the period over which their growth extends vary according to variety, climate, cultural practices, age and crop load on the tree. In the plains of Pakistan, where the climate is sub-tropical, the first spring flush may start in late February or early March and the final flush may end as late as October, as is the case with younger trees growing under good cultural and irrigated conditions. But in many mature bearing trees of the Langra variety the common character is to produce as many as five flushes from April to August. Each growth flush continues for some time after initiation, becomes quiescent and then breaks out again until growth ceases for that season. The length of each flush is different and is also variable from year to year. Studies with Langra mango at Lyallpur, Pakistan, have also revealed that not all the shoots which initiate their growth in the spring produce subsequent flushes during the growing season. Some may produce two, three or more flushes, whereas others may flush once only and then growth ceases with the initiation of flower bud differentiation. This type of growth habit has been related to alternate bearing. The growth flushes which make their appearance and cease early in the season are the ones more likely to be fruitful in the subsequent year. The growth made in early flushes matures and accumulates sufficient carbohydrates before the initiation of flower bud differentiation. On bearing trees shoots of the first flush are apt to arise from terminal buds hoots of the preceding year that are not flowering. The second flush arises from lateral buds on shoots that have each a terminal inflorescence that is setting little or no fruit. A third flush may grow from lateral buds on shoots that have ripened a crop, and a fourth c from lateral buds on shoots that have been greatly weakened by a crop in the current or preceding year (9). The presence of foliage of different shades on the same tree shows that all the branches do not flush at the same time.

More recent work in India suggests that growth in mango was largely controlled by endogenous promoters and inhibitors. In the Langra variety the inhibitor level was lowest during peak vegetative growth, and sharply rose when growth ceased. It is expected that the isolation of the endogenous regulators and a study of their physiological properties will help to regulate vegetative growth in relation to fruit bearing and eventually provide an answer to irregular or alternate bearing of :n most commercial mango varieties (47; 48). Nurserymen would be able to use this information advantageously by encouraging and regulating vegetative growth in quantity at a time most suitable for the various propagation operations. Nevertheless, the growth habit and periodicity of the mango is very helpful in regard to its propagation. It ensures the availability of scion wood in active growth over a long period, thus extending propagation operations almost throughout the year in tropical areas. The spreading growth habit also allows inarching and stooling to be undertaken at ground level.

The leaves are of leathery texture and vary in length from six to sixteen inches (15-40 cm) and in breadth from one to five inches (2.5-13 cm) or even more. They are borne upon slender petioles one to four inches (2.5-10 cm) long. They may be oval, lanceolate, oblong, ovate or obovate, with many intermediate variations depending upon the variety. The leaves are simple, alternate and irregularly placed along the branches, sometimes widely separated and sometimes rounded and glabrous on both surfaces. The foliage at emergence shows much variation in colour. Some varieties have light-green leaves, but most others are characterized by having newly emerged foliage in various shades, varying from light copper to a deep carmine colour, turning green with maturity (9; 33; 14; 38; 40). The tree retains its leaves well over a year. Every growth flush is usually followed by a light leaf drop, and the spring flush after the cool winter is followed by an excessively heavy leaf fall.

A grafted mango plant usually flowers in the third or fourth year after planting in the field. In dry areas some seedlings take six to eight years to come into bearing (3; 33; 38; 40;). Depending upon locality and variety, flowers are generally produced in the spring. In cool regions the trees remain dormant during the winter and show one main flowering at the onset of spring. In tropical areas more than one flowering usually takes place during the year. Like the foliage, inflorescences on emergence, depending upon the variety, differ in colour and shade (9; 38). The small yellowish or pinkish flowers are borne in large panicles, one foot (30 cm) or more in length, which are generally terminal but sometimes axillary (3; 9; 33; 14; 18; 40). The inflorescence tends to be large, a panicle containing 300-500 flowers in some varieties and reportedly more than 7000 flowers in others (9). The mango produces two kinds of flower, viz. perfect ones having both stamens and pistils, and others which are unisexual. The unisexual flowers, which are staminate, commonly outnumber the perfect ones. Usually there is only one stamen bearing fertile pollen in each flower, the remaining five or six being staminodes (9). However, in the Pico variety in the Philippines, three fertile stamens have been reported. The perfect flowers are easily distinguished by the presence of the pistil. Sometimes, more than one pistil may be present. The ovary is small, greenish and single-celled, with the style lateral, curved upwards and having a small, simple and terminal stigma (4).

The mango flower has five small green hairy sepals and five small spreading petals, which are red, orange, pink, greenish or yellow in colour. In some varieties more flowers are perfect towards the apex of the inflorescence than towards the base. The presence of a large percentage of perfect flowers on the terminal portion of the inflorescence is the reason why more fruit is borne on the terminal end (38).

For fruit set, pollination is necessary, and most varieties are self-fertile, although cross-pollination seems to be necessary to get good crops (4). Pollination in the mango is chiefly entomophilous (33; 9: 7; 40). Alternate or irregular bearing is a well known phenomenon. This problem is very closely related to the variety, some varieties being more prone to alternate bearing than others. The condition is, however, greatly aggravated by poor husbandry, bad weather and diseases and pests. It has been studied extensively but remains as baffling as ever (9; 33; 39; 40).

In view of this, nurserymen should select varieties not only with good fruit characteristics but also with less tendency to alternate bearing when seeking scion material for propagation.

The fruit is a large drupe. The outermost skin is the epicarp, the flesh is the mesocarp and the hard stone to which many fibres are attached is the endocarp. The endocarp encloses the seed. In size and other characteristics the mango fruit is extremely variable. There are varieties which are hardly larger than a plum and there are others whose fruit weighs as much as four to seven pounds (1.8-3.2 kg) (9; 33; 14; 40;). The shape varies from ovate, ovate oblong, round, oval to oblong. Some of the commonest types are reniform to oblong reniform (9; 4; 14). The skin is smooth, somewhat thicker than that of peach, commonly yellow or greenish yellow in colour. Some varieties assume a beautiful scarlet to deep carmine colour. The pigmentation is more intense on the exposed side of the fruit. The intensity of colour further depends on the climate (4; 14; 40). The flesh is yellow or orange yellow in colour, juicy, often fibrous in seedlings but in d the best varieties mostly free from fibre. The seed varies according to the variety: it is flattened, .tough and woody, the husk or outer covering enclosing a white kernel(9; 33; 4; 14; 40).

The flavour of the flesh is rich, spicy and much esteemed. The time taken by the fruit to mature is greatly influenced hy many climatic factors and also differs between varieties. Under the same climatic conditions, fruit in some varieties takes only two months to mature, while in others it takes almost four months after fertilization (14). The leaf area on the tree seems to have a bearing on the size of the fruit, leaf area per fruit being directly related to fruit size (14). Fruit quality is an important consideration in the selection of varieties for multiplication.

The development of the root system depends on variety, soil, subsoil, soil depth, aeration, the water-table and is also influenced by cultural practices, such as cultivation, irrigation, mulching and fertilization. Trees on deep soils develop deep and extensive root systems (33; 7; 13; 18; 35;40), but information on the root system of the mango tree is rather scanty. However, it is known that the tree possesses a strong tap-root, which penetrates deeply and reaches the water-table. During the elongation phase only a small number of anchoring root branches seem to develop. After this phase the surface roots develop faster and form a dense mass closer to the surface. Information is lacking on the periodicity of growth of mango roots (40). At Lyallpur, Pakistan, the I root system of an 18-year-old seedling mango grown under irrigation in a clay loam soil was exposed. The branched taproot penetrated to 30 feet (9 m). However, the effective root zone was found to be four feet (1.2 m) in depth and six feet-(1.8 m) in spread. A large number of feeder roots were concentrated within this zone. Most roots originated from the base of the trunk rather than from a single tap-root; most were straight with but a few coiling (25). In Queenslar Australia, and at Pusa, India, mango roots reaching 18 feet (5.5 m) have been recorded (18; 40; 45; 44). Due to its deep and well developed root system, the mango is well anchore and well adapted to withstand prolonged periods of drought in South Africa, the study of the root system of a tree of the variety Sabre revealed that 80 per cent of the fibrous roots were below the canopy and within one metre (39 in) depth The strong tap-root causes difficulties when potting seedlings and when transplanting young grafted plants from nursery rows (15).

1.4. CHARACTERISTICS ANATOMICAL

The Tree

The young mango stem has the following distribution and arrangement of different tissues (Figure 1-1):

Epidermis: It forms the outermost layer, and consists of a single row of cells, flattened radially and fitting closely alnng their radial walls, with a well defined cuticle extending over it.

Figure 1-1. **Showing T.S of Mango Stem**

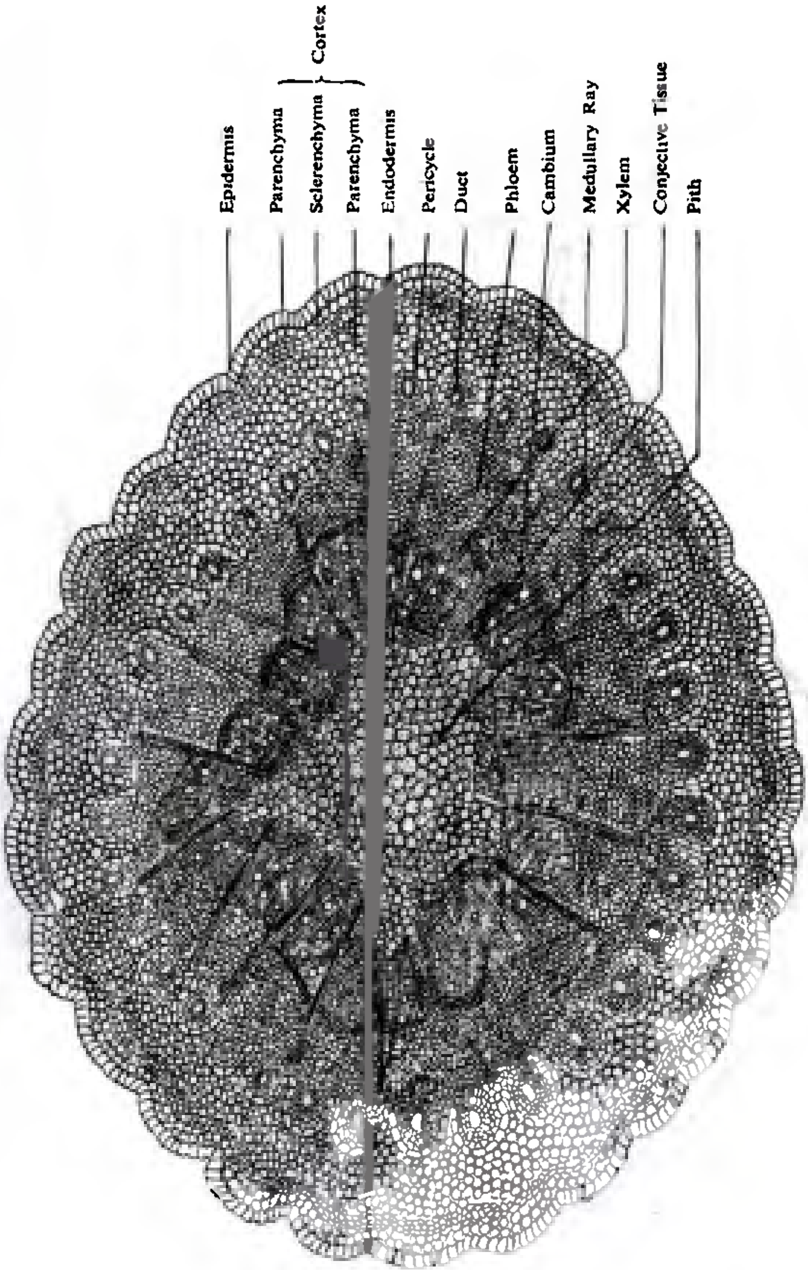


Plate 1. Showing T. S. of Mango Stem

Cortex: The cortex consists of many layers. The hypodermis is a sclerenchymatous layer lying below a chlorenchyma band. On the Inner side of sclerenchyma their is a wide parenchymatous zone. The innermost layer of which forms the wavy endodermis.

Pericycle: It is the region lying in between the endodermis and the vascular bundle and is represented by a 10:12 layered continuous band of sclerenchyma. There are ducts arranged in a ring in this zone.

Vascular bundles: These are collateral and open, and are arranged in a ring. Each bundle consists of (a) Phloem lying externally, (b) Cambium made of a few layers of small, thin walled, roughly rectangular cells, and (c) radial rows of xylem lying internally with protoxylem towards the centre and metaxylem towards the periphery. Excepting the vessels (protoxylem and metaxylem) nearly the whole of the wood (xylem) is packed with fibres. A 3-5 layered band of wood parenchyma is seen on the inner side of the bundles surrounding the protoxylem.

Medullary Rays: Each ray consists of 2-3 layers of radially elongated parenchyma cells, lying in between 2 vascular bundles.

Pith: It is large and well developed occupying the whole central part of the stem. It extends from below the vascular bundles to the centre and is composed of round, thin walled, parenchymatous cells.

Root System

The mango tree has a long tap root with less fibrous root system. This long tap root has often been considered as hindrance in transplanting of young trees, especially the grafted or budded trees, and for this reason there is relatively higher mortality at planting time under our conditions.

The anatomical studies of the mango root as illustrated in Figure 1-2, have shown the following layers of tissues.

The outermost layer, the phelloderm or the cork layer consists of 2 rows of cork cells. The cortex consists of 2-3 layers of parenchyma cells, having inter cellular spaces.

The endodermis, as usual, is a single layer of very distinguishable barrel-shaped cells with their radial walls thickened.

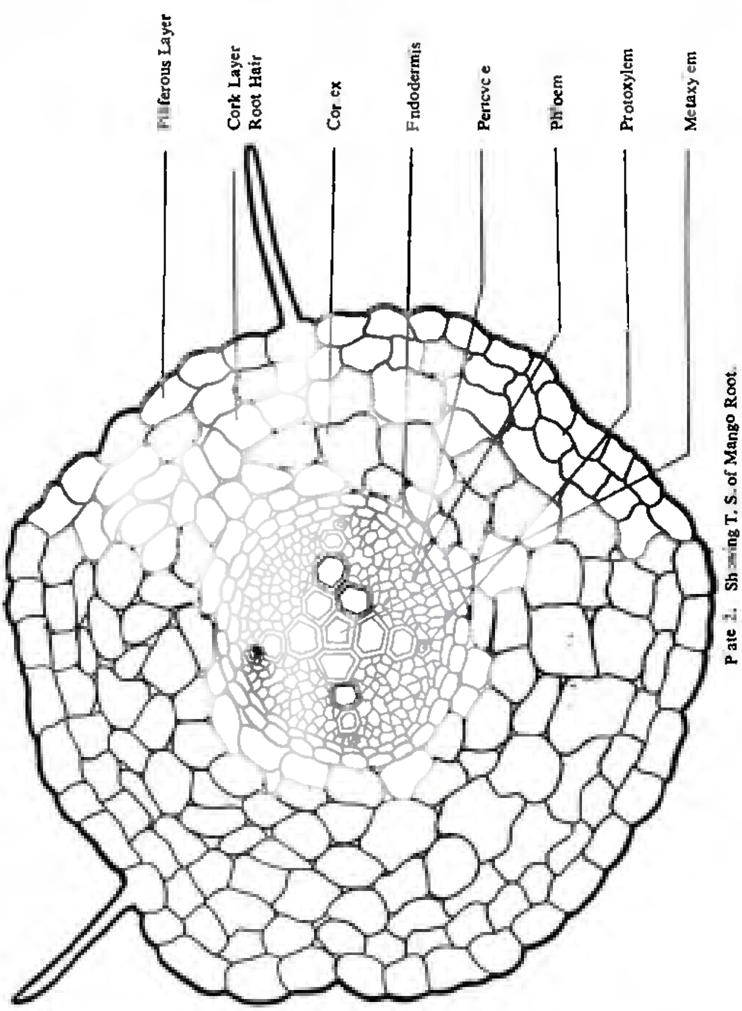
Pericycle consists of a single layer of brick-shaped parenchymatous cells.

There are four xylem and 4 phloem bundles. These are radial and alternate with one another. The protoxylem vessels of the xylem bundles meet in the centre so that the pith is lacking.

The Leaves

The lanceolate green leaves of leathery texture varying in length from 6-16 inches or even more are borne upon slender petiole 1-4 inches long. Leaves are simple, alternate and irregularly placed along the branches, sometimes widely apart and sometimes rounded, glabrous on both surface. Base of. the leaf is acute to cuneate, apex is acute to acuminate.

Figure 1-2. Showing T.S of Mango Root



The study of an internal leaf structures (Figure 1-3) have shown that the epidermis consists of single layer of cells with thick cuticle. It does not contain chloroplast and stomata. The lower epidermis similarly has a single layer of cells, but it is interspersed with numerous stomata. Internal to each stoma a large cavity known as respiratory cavity is seen. A single layer of hypodermis is present beneath the upper and abOve the lower epidermis.

The mesophyll is differentiated into palisade and spongy parenchyma. The palisade parenchyma consists of 1-2 layers of elongated, more or less cylindrical cells closely packed with their long axes at right angles to the epidermis. The chlorenchyma is composed of closely packed polygonal parenchyma cells. The mesophyll contains numerous chloroplasts and fits closely around the vein Of vascular bundle.

Growth Habit

The growth habit of the mango is also of importance which differs from most of other fruits. It is not continuous in the season but occurs in periodic flushes from the terminal buds and from axils of leaves on younger branches. The number of these periodic growths or flushes during the growing season, time of their initiation and period over which their growth extends are variable according to the variety, climatic conditions, cultural practices, age and load of the crop on the tree. In general under local conditions the first spring flush may start in late February or early March and the final flush may end as late as October as is the case with younger trees growing under good cultural and irrigation conditions. But in many mature bearing trees of Langra, the common character is to produce as many. as five flushes from April to August. Each flush after initiation, grows for some time becomes quiescent and breaks out again till the growth is permanently stopped for that season. The length of each flush is different and is also variable in different years. Studies with Langra mango at Lyallpur have also revealed that not all the shoots which initiate their growth in spring produce subsequent flushes during the growing season. Some may produce second, third or more number of flushes where- as others may grow for one period -only and then cease growing to initiate flower parts. This type of growing habit of mango tree has been correlated with alternate bearing which has been discussed at length elsewhere in this Special Number.

On bearing trees shoots of the first flush are apt to be from terminal buds of shoots of the preceding year that are not flowering, the second flush from the lateral buds on shoots that have each a terminal inflorescence that is setting little or no fruit. A third flush may grow from lateral buds on shoots that have ripened a crop and fourth from lateral buds on shoots that have been greatly weakened by a crop in the current or preceding year.

When a new flush makes its appearance its leaves are usually reddish wine. coloured or pale green, the colour changing green , as the leaves mature.

Leaves of the mango tree tend to live more than a year but of course eventually fall. There may be wave of leaf-fall, t following a growth flush, specially a large rather general flush such as follows a ; winter, cool period or a dry period.

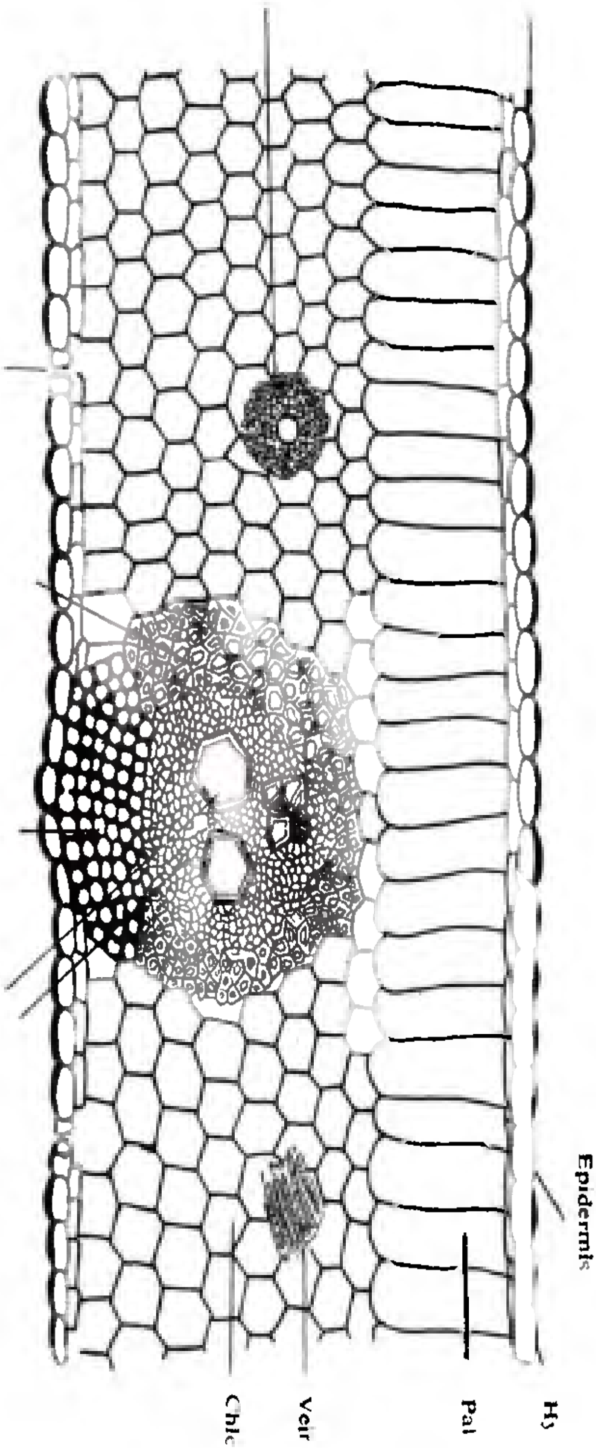
Leaves when crushed emit an odour of turpentine pronounced in some varieties and almost lacking in others.

Young tender mango leaves are said to be eaten by cattle and other animals and in some districts by people as salad. The leaves contain a material which cause skin eruptions.

The Flower

The small yellowish or pinkish flowers are borne on large panicles 1 ft. or more in length which are generally terminal but sometimes axillary, produced in spring. Hays (1953) has quoted Greec to have indicated that removal of terminal bud during the flowering period induced inflorescence from the axillary buds and if such shoots were girdled below 15 or 20 leaves, induction of flower parts took place from axillary buds within four days.

Figure 1-3. **Showing T.S of Mango Root**



Time of emergence of flowers:

Tract	Season
Multan Division	February, March
Northern India	February
Bombay Southern India	Late Nov. and December
Hyderabad Division	January to March

Maximum number of flowers open early in the morning (24). The mango inflorescence (Figure 1-4) tends to be a large one. A branch panicle containing 300-500 flowers in some vaneties, more than 7,000 flowers in others is reported. (24) found 885 in Langra, 324 in Dusehri and 470-1958 in seedling types at Lyallpur.

The mango flower is polygamous, that is, it produces 2 kinds of flowers viz. perfect ones having both stamens and pistils and others which are unisexual. The unisexual flowers which are staminate commonly outnumber the perfect ones. Usually there is only one stamen-bearing fertile pollen in each flower, the remaining 5-6 being abortive (staminodes). In certain varieties such as Sammar Babisht Chiunsa and Alphonso 6 to 7.2 per cent flowers were found to have 2 functional stamens each whereas in Sammar- Bahisht Rampur as many as four fertile stamens have also been noted by the senior author in one case out of 275 flowers.

Figure 1-4. **Showing** Mango Inflorescence

The perfect flowers (Figure 1-5) are easily distinguishable by the presence of pistils: Sometimes there is more than one pistil. Ovary is small, greenish and one-celled. Style lateral, curved upward, stigma simple, small and terminal.

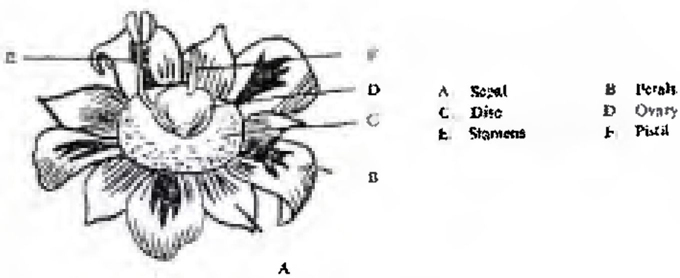
Sepals are 4-5 in number, shorter than petals, yellowish green or light yellow, concave on both surface, ovate oblong.

Petals are ovate to lanceolate, commonly 5 in number, deciduous, spreading free from the disc, twice .the length of calyx lobes, colour yellowish white.

(24) calculated the following percentages of perfect and staminate flowers in inflorescences of different varieties:

Varieties	Perfect	Staminate
Langra	66.8%	33.2%
Dussehri	77.9%	22.1 %
Seedlings	8.9 to 36.2%	91.1 to 63.8%

Figure 1-5. Showing Perfect Mango Flower



While studying sex distribution in mango varieties at Lyallpur the following observations were made with regard to the percentage of perfect and staminate flowers:

Variety	Perfect	Staminate	Pistillate
Langra	85.23	14.77	...
Mudhi	24.56	72.81	2.63
Sammar-Bahisht Rampur	82.33	17.67	...
Neelum	86.07	13.18	.75
Alphonso	82.40	16.00	1.60
Dusehri	78.73	21.27	...
Gulab Khas	51.80	48.20	...
Sammar Bahisht Chaunsa	91.00	9.00	...
Sobhi-di-Ting	55.36	37.32	7.32
Zafrani	100.00		
Nur-ul-Huda	95.88	4.12	...
Sukh-Tara	87.80	2.20	...

The percentage of shoots of each flush producing inflorescence as calculated by Khan (1946) is as under:

April flush	**37%**	**shoots bear inflorescence.**
May flush	29c%	do.
June flush	20%	do.
July flush	12%	do.
August flush	7%	do.

Nakasone, Bowers and Beumont (1955) have shown that on Pairi mango in Hawaii the flushes that occur in Summer and fall are more likely to flower than flushes appearing early in the year.

In some varieties a large percentage of flowers towards' the apex of the inflorescence are perfect than towards the base and in some pistils may become receptive earlier (protogynous). The presence of larger percentage of perfect flowers on the terminal portion of the inflorescence is attributed to be the cause for the fruit to be on the terminal end. This is known as "end season fertility" as in some grapes and self sterile Nicotiana plants.

It means the flowers appearing late in the season are more fertile particularly with regard to pollen and thus result in greater set of fruit at the terminal than at the basal or median parts of the inflorescence.

In Bombay (18) it has been found that I/10 per cent of flowers mature which is sufficient to yield an average crop of 200 fruits per tree.

Mango is mostly, if not solely, wind pollinated plant but it has non the characteristic of an anemophilous but possesses characters for insect pollination (entomophilous).

Many varietie are, however, self fruitful but cross pollination, seems necessary in order get good crops. (24) at Lyallpur found out that with bagging 1 to 6 fruits were set on a panicle but the average setting in open pollination done by insect was about 18 fruits per panicle.

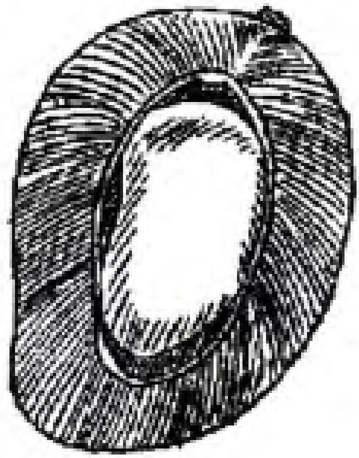
The mango shows poor set of fruit which is very variable with different varieties under different conditions and age of the plant. The following table shows the average number of mature fruits per panicle reported by various workers.

Name of the, Variety	**Average No of fruits per panicle**	**Place of study**	**Reference**
Langra	.38	Lyallpur	Khan (1946)
Dusehri	1.2	Lyallpur	Khan (1946).
Not Known	2- 7 fruits	Kodur Naik	(Hays, 1953).
Not Known	1/10 of 1%	Poona	Burns & Prayag.
Not Known	0.5	Bihar	Sen (Hays, 1953).

The Fruit

The fruit of mango is a large drupe. The outermost skin is epicarp, flesh is the mesocarp and the hard stone to which many fibres are attached is the endocarp. The endocarp encloses the seed. (Figure 1-6).

Figure 1-6. **Showing L.S. of Mango Fruit**



A. Epicarp B. Mesocarp
C. Endocarp D. Seed

In size and characters, mango fruit is extremely variable. There are varieties which are scarcely larger than a plum (Sobbewali Ting) and there are others whose fruit weigh as much as 4-7 lbs. (Tennesu-Gangolly et al 1957).

The shape varies from ovate (Anwar Ratoul, Langra), ovate oblong (Malda), round (Kishan Bhog), oval (Zafrani) to oblong (Aman Dusehri). Some of the commonest types are reniform (Benazir Kalan) to oblong reniform (Karelia, Ali Pasand).

The skin is smooth somewhat thicker than that of peach, commonly yellow or greenish yellow in colour, but in some varieties bright yellow over spread with scarlet or crimson and of extremely beautiful appearance. The colour depends to a certain extent on the climate in which the fruit is grown.

Mango is considered to have the richest flavour among all fruits. The aroma is often spicy and alluring. The flesh is yellow or orange in colour, juicy, often fibrous in seedlings but in the best sorts entirely free from fibre and of smooth melting texture.

Seed

The seed varies according to variety. It is flattened, tough and woody. Husk or outer covering encloses a white kernel.

The mango contains much sugar which vary from 11.-20% and water contents from 76 to 86% according to variety. The principal sugar is sucrose. The acid (citric 0.20 to 0.54% and proteins (0.5%) are low in the ripe fruit. The mango is one of the richest fruits in vitamins particularly vitamin A and vitamin C (119 mgm per 100 grams of edible portion).

Pope gives the following analysis of 8 varieties of mangoes:

Edible	Total Solids	Carbo-hydrates	Acids	Ash	Protein	Fats
63.77%	More than 20%	12-25%	.122/.37%	.277/.469%	.438/1.075%	.032/.53%

Mango fruits develop rapidly after they set. In some hot climate fruit of an average Saigon variety may reach full size in 7 weeks from the flowering stage and be ready for harvest in 12-13 weeks. When a fruit becomes fully mature on the tree it is abscised with its receptacle from the apex of the pedicel. Fruit for market of course cannot he left on the tree to be abscised, it would become over ripe too soon.

Mango fruit is most commonly eaten as a fresh fruit but it can be utilized in all stages of its development. When green, it is used for making chutneys, achar and preserves. It can also be dried as `amchoor'. Mango squash from the ripened flavoured fruits furnish a delicious and pleasant drink in hot summer of Punjab province.

1.4.1. References

1. AHMED, S. *et al.* Races and varieties of mango Punjab Fruit J., 1960, 23 (82/83): 5-11.
2. AHMED, S. *et al.* Response of mango to difference in climate and soil conditions. Punjab Fruit J.,
3. AHMED, S. Propagation of mangoes. Punjab Fruit J., 1960, 23(82/83): 49-53.
4. Ali, N. and HAMID MAZHAR. The tree, flower and fruit characteristics of mango. Punjab Fruit J., 1960, 23(82/83): 81-6.
5. BAILEY, L. H. The standards cyclopedia of horticulture. Macmillan, New York, 1927, 3 vols.
6. BARBADOS. A. R. Dep. Sci. Agric. 1941.
7. BURNS W. and PRAYAG, S.H. The book of the mango dep. Agric., Bombay, 1921.
8. CHACKO, E. K. *et al.* Inhibition of flowering in mangifera indica L. by gibberellic acid. Acta horticuluturae, 1972, No. 24, pp. 206-9
9. CHANDLER, W. H. Evergreen Orchards. Lea and Febiger, Philadelphia, 2nd ed., 1958.
10. CHAUDHURI, J.M. *et al.* Changes in endogenous growth regulating substances in the Mangifera indica L. Shoot in relation to growth and development. ACTA Horticulturae, 1972, No. 24, pp. 196-205
11. CHEEMA, G. S. *et al.* commercial fruits of India Macmillan and Co. Ltd., London, 1954.

12. DHILION, R. S. *et al.* Studies on the establishemt of young mango grafts with various green sheltersw. Punjab hort. J., 1970, 10 213-21.

13. GANDHI, S.R. The mango in India. Farm. Bull. I.C.A.R., New Delhi, 6, 1955.

14. GANGOLLY, S.R. *et al.* The mango. I.C.A.R., New Delhi, 1957.

15. GARDNER, D.E. and PIPER, R. B. Base of propagation of some sub-tropical fruits by cuttings from young seedlings. Proc. Fla st. hort. Soc., 1943, 56: 124-6.

16. HARRIS, W. The mango. Bull. Bot. Dep. Jamaica 8, 1901.

17. HARTLESS, A.C. Factors influencing mango crops. Trop. Agriculturist, 1914, 43; 307.

18. HAYES, W.B. Fruit growing in India. 3rd Ed. Kitabistan, Allahabad, 1957.

19. HOLDSWORTH, M. intermittent growth of the mango tree. J.W. Afr. Sci. Ass. 1963, 7: 163-71

20. HOPKINS, A.D. Bioclimatics - a science of life and climate relations Publ. U.S. Dep. Agric. 280, 1938

21. JAGIRDAR,A.P. and MANIYAR, A.K. Mango culture in Sind. Punjab Fruit J.1960, 23(82/83):

22. JULINANO, J.B. Embryos of Carabao mango (Mangifera Indica L.) Philipp. Agric., 1937, 25: 749.

23. Khan, A. A. Mango budding "in situ". A new technique likely to revolutionise mango industry. Punjab Fruit J., 1960, 23(82/83): 55-8.

24. Khan, M. D. and Khan, A. H. studies on malformation of mango inflorescence in West Pakistan. Punjab Fruit J., 1960, 23 (82/83): 247-58.

25. Khan, M. D. Root system of mango (Mangifera indica L.). Punjab Fruit J., 1960, 23(82/830: 113-16.

26. KRISHNAMURTHY, S. Mango: in other countries. In The mango - a souvenir, Dep. AGRIC., Hyderabad, [1964] pp. 45 - 9

27. MACMILLAN, H. F. Tropical planting and gardening with special reference to Ceylon. Macmillan, London, 1935

28. MUKHERJEE, S. K. and MAJUMDAR, P. K. 'Veneer' grafting in mango has its own advantages. Indian Hort., 1961, 6(1): 3.

29. MOWRY, H., Toy, L. R. and WOLFE, H. S. miscellaneous tropical and sub-tropical Florida fruits. Bull, Fla agric. Ext. Serv. 109, 1941, pp. 96.

30. OCHSE, J. J. Fruits and fruit culture in Dutch East Indies. G. Kolff & Co., Batavia, English ed., 1931.

31. PLESSIS, S. F. Du and SMITH, J. H. E. Irrigation and fertilization of mangoes. Citrus sub-trop. Fruit J., 1973, No. 471, pp. 4-7.

32. POPE, W. T. Mango culture in Hawaii. Bull. Hawaii agric. Exp. Stat. 58, 1929.

33. POPENOE, W. Manual of tropical and sub-tropical fruits. Macmillan, New york, 1920, pp. 474.

34. POPENOE, W. The mangoes of Cuba. Pap. Amer. Pomol. Soc. Berkeley, 1915.

35. POPOENOE, W. Mangoes in tropical America. Proc. Mango Forum, 1951, p. 18.

36. PURSEGLOVE, J. W. Tropical crops. Longmans, Green, London, 1968-1972, 4 Vols.

37. RAO, V. N. M. Propagation practices. In The mango handbook. I.C.A.R., 1967, pp. 32-69.

38. RUEHLE, G. D. and LEDIN, R. B. Mango growing in Florida. Bull. Fla agric. Exp. Stats 574, 1955, p. 90

39. Sen, P. K. *et al.* Flowering and biennial bearing in Mangifera indica L. Acta Horticluturae, 1972, No. 24, pp. 164-9.

40. SING, L. B. The mango. Leonard Hill (Books) Ltd., London, 1960.

41. SINGH, K. K. and JAWANDA, J. S. mango cultivation in the Punjab. Indian Hort., 1962 6(4): 7-10.

42. SINGH, K. K. Climate and cultivation. In The mango handbook. I.C.A.R., 1967

43. SINGH, S., KRISHNAMURTHI, S. and KATYAL, S. L. fruit culture in India. Indian Council of Agricultural Research, New Delhi, 1963.

44. STEPHENS, S. E. Mango growing in Queensland. Qd agric. J., 1960, 86: 761-6

45. STEPHENS, S. E. The mango (in Queensland). Qd agric. J., 1948, 68: 71-81, 146-53, 208-15.

46. WHEATLEY, S. M. The mangoes of the Kenya Coast. E. Afr. Agric. J., 1956, 22: 46-54.

47. WOLFE, H. S. the Florida mango industry. Punjab Fruit J., 1960, 23(82/83): 212-14.

48. WOLFE, H. S. The mango in Florida - 1887 to 1962. Proc. Fla St. hort. Soc., 1962, 1963, 75: 387-91.

49 YEE, W. The mango in Hawaii. Circ. Hawaii agric. Ext. Serv. 388, 1958, p. 26.

2. THE GENUS *MANGIFERA* RE-DISCOVERED: THE POTENTIAL CONTRIBUTION OF WILD SPECIES TO MANGO CULTIVATION

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2.1. ABSTRACT

IBPGR-WWF surveys of the wild mangoes of Borneo and West Malaysia in 1986-88, and extensive study of herbarium mango collections have resulted in a deeper knowledge of the genus *Mangifera*. The genus *Mangifera* and its main natural divisions are briefly presented. Available information on experiments using *non-indica* species in mango breeding is reviewed. Special emphasis is given to the breeding potential of several noteworthy species which are of particular interest for horticulture and may open new possibilities for mango cultivation.

A significant fraction of this rich genepool, including wild and semi-cultivated species, is currently on the verge of disappearance. Adequate practical measures must be rapidly implemented to ensure the long term survival of mango genetic resources, by both *ex situ* and *in situ* conservation. Representative samples of the diversity of selected species other than *M.indica* need to be established in living collections for investigation.

In order to exploit fully the potential of wild mango species, a cooperative effort involving all those concerned with mango cultivation and conservation must be made before it is too late.

2.2. INTRODUCTION

The information presented here is part of the results of the work on tbe genus *Mangifera* undertaken in cooperation with Prof. Kostermans, of the Bogor Herbarium in Indonesia. It is based on extensive study of herbarium mango collections and the .results of surveys sponsored by IBPGR and WWF in 1986-88 in Borneo and Peninsular Malaysia. Detailed surveys were carried out in 1986-1988 in Kalimantan in cooperation with the Indonesian Institute of Science (LIPI) and the Indonesian Commission on Germplasm and in Malaysia in cooperation with the Forest Research Institute of Malaysia (FRIM) (Lee Ying Fah, 1987; Saw, 1987; Bompard 1988). Investigations were first conducted in old orchards and secondary forests in the village .g surroundings, often starting from local markets in remote areas, The next step was to move on to primary forests, especially protected forest areas.

2.2.1. Mango and Mangoes

Most people are unaware that there are olany mallgo species-other than the Indian mango with edible fruit. Yet, many other species are locally well-known. Tlley Catl be II) found in cultivation or semi-cultivated, but not spread much outside their native area. At least a dozen of species have local commercial importance.

Wild local fruit and nut resources were integrated into indigenous arboriculture systems very early. Most of the 200 native fruit species regularly consumed in Borneo are found in traditional, multi-purpose tree gardens ("lembo" in E.Kalimantan, "tembawang" in W. Kalimantan) established around (former) long houses or settlements of Dayak people who practice shifting cultivation. Only a minor production is exclusively wild-harvested. Several species produce fairly good quality fruits, which are sometimes even locally preferred to the common mango. To illustrate this point no less Lhall 16 different species can be found in local markets or Borneo, though some species may be for sale only very occasionally or in limited quantity.

Most of the mangoes planted in old fruit gardens often originate from fruits or seedlings collected from wild trees particularly appreciated for the quality of their fruit. There is generally no clear-cut boundary between wild trees and semi-cultivated ones which are still very similar to their wild ancestors. Some have undergone selection, giving rise to local races with better quality fruits. In all cases, they have the great advantage of being well-adapted to local climatic conditions.

It was the Indian mango which stole the stage, probably as a result of a coincidence of biogeographical and cultural conditions. Had the pre-Indian and Indian cultures evolved in a different geographical environment, this mango, which we call *'indica'*, might have remained a poorly kllown species. We would today be discussing a different species. This fictitious scenario is a remained not to regard the *non-indica* species as poor relations. At least that should incite us to learn more about these species.

2.2.2. The genus *Mangifera L.*

Wild mangoes occur in tropical Asia: India, Sri Lanka, Burma, Thailand, Indochina, Southern China, Malaysia, Indonesia, Papua New Guinea, tile Philippines, and as far as the Solomon and Carolines Islands in the east. There are more than 60 species worldwide. The highest specific diversity is found in the heart of the distribution area of tile genus *Mangifera:* tile Malay Peninsula, Borneo and Sumatra.

The Indian mango *(Mangifera)* originates from North Eastern India (Assam), tile Indo-Burma border region and Bangladesh (Chittagong Hill tract), where it is found as a wild tree with very small fruits. It may also occur in the lower Himalaya tract, near Nepal, Bhutan, and Sikkim. Detailed surveys in these areas and investigations using molecular" markers will be necessary to assess whether other species might have contributed to tlle composition of tlle cultivated Indian mango.

2.2.3. Ecology and Habitat

Wild mango trees are chiefly found in tropical rain forests, from sea level to 600 m, up to 1,000 m, alld for some species up to 1,700 m. They are large trees 30 to 40 m (up to 54 m) in height, with tall cylindrical boles. Several species are exploited for their timber.

A few species are gregarious in certain types of swamp forest: *M.gedebe, M.griffithii* and *M.palyifolia*. Some species are found in deciduous or semi-deciduous forests *(M.caloneura, M.collilla, M.timorendis, M.zeylanica)*. The majority occurs as a rule as scattered individuals at very low densities in lowland forest on well drained soils -1 to 3 trees above 40 cm in diameter per 10 ha; some are very rare. This gives an idea of tlle difficulty of locating wild mango trees in the wild.

In Western Malesia (Malesia: the botaIlical region that includes Philippines, Malaysia. Brunei, Indonesia, and Papua New Guinea), *Mangifera* species flower and fruit very irregularly. When collecting mangoes in rain forest, if a tree is located, the chances are overwhelming tllat it will not be Ul flower or fruit. As in many other genera in the region, mast (or general) fruiting at intervals of2-8 years is tile dominant pattern. In mast years, the ground beneatlI the trees can be covered with fruits, whose strong smell attracts many aIlimals. Isolated flowering may occur at shorter intervals, and is generally followed by a poor fruit crop. The rate of flowering of a few species (e.g. *M.lagenifera)* is only once every 5 to 10 years.

Most of the Mangifera trees of wild origin growing in village areas, in a more open environment, tend to flower more regularly though their flowering habit is basically similar to that of trees growing wild in surrounding forests.

2.2.4. Taxonomy

A comprehensive report of the progress achieved in the economic study of the genus will be given in the monograph which will soon be published (Kostermans and Bompard, 1992). For information, 69 species will be recognized in the monograph, 20 of which new combinations were made.

The genus is subdivided into two natural groups based on the shape of the flower disc:

- subgenus *Limus* (Marchand) Kosterm.: disc narrower than the base of the ovary, stalk-like or even lacking, -Limus is a vernacular name of *M. Foetida* in West Java-;
- and sub-genus Mangifera (Ding Hou) Kosterm.: disc: broader than the base of the ovary, cushlon-1ike, often divided in 4 or 5 lobes.

In the subgenus *Limus*, two species have 5 fertile stamens *(M. decandra, M. Lagenifera) and* the other 9 species only 1 (rarely 2) fertile stamen. This group includes notably *M:foetida, M. Odorata and M. caesia, which* are widely cultivated in the Malay Peninsula, Sumatra, Borneo and Bali.

The subgenus *Mangifera* is divided into 5 sections:

- Section *Marchandora* Pierre: with only one species, *M.gedebe*. Widely distributed from Burma to New Guinea, *M.gedebe* grows in inundated areas, along rivers or lakes. Unique in the genus is the labyrinthine seed with the inner integuments penetrating the cotyledons into numerous irregular folds. The pulpy part is very thin; the fruit can be consumed only at a very early stage.

- Section *Euanrherae* Pierre (flowers with 5-6 fertile stamens) has 3 species *(M.caloneura, M.cochinchinen. M.pentandra)* which are restricted to Burma, Indochina and Northern Malaysia; *M.petandra* is also found in North Borneo, probably introduced.
- Section *Rawa* Kosterm.: a group of 9 species with characteristic black or partly red, hardly flattened fruits. They usually grow in periodically or permanently inundated areas. Representative of this section is *M.grifithii*. The fruit is small (3-4 cm long), rose red turning grayish purple or purplish black at maturity. Slightly larger atld sweet- acid varieties are found in cultivation.
- Section *Mangifera* Ding Hou: witl1 more than 30 species, this is the largest section, to which belong the common mat1go and related *M.laurina*. The fruits of the latter species are like small mat1goes, wit11 watery pulp, often consumed unripe as pickles.

There is also a group of 12 species of uncertain position, which can not be placed properly because available material is insufficient.

Monoembryony is the rule in all the *non-indica* species investigated so far, with exception of cultivated *M.casturi, M.launna,* and *M.odorata* the latter sometimes monoembryonic.

In this symposium, Schnell and Knight present the results of an attempt, made for the first time in *Mangifera,* to determine phylogenetic affinities using molecular markers.

2.2.5. Use of wild species in mango cultivation

To date, tile improvement of mango has depended on tl1e use of genetic variability in only one species, *M.indica*. Yet, as noted by Mukherjee (1957) "similarity in chromosome number and pollen morphology in different species suggests close compatibility during hybridization and stock-scion relationship if other species are used as stock for the common mango".

2.2.6. Available information

Recorded experiments and trials concerning species other than *M.indica* are so few that they can be briefly summarized as follows:

1. Graft between M. Indica and other species

- budding M.indica on M. foetida and M. odorata

Ochse (1931) reports that *M.odorata* and *M. foetida* were tried as stocks in Java. Budding was performed after the modified Forkert method with buds of non-petioled wood on of one-year-old stocks. But, obviously, *M. foetida* has proved to be fit only for moist regions. Nowadays, *M. odorata* and *M. foetida* are not used as stocks in Indonesia or in Malaysia. Wester (1920) mentions that in the Philippines *M.odorata* was budded and did well on *M. indica.*

- budding M. indica on *M.zeylanica*

According to Gunaratman (1946), *M.zeylanica* varieties in Ceylon were round to be unsuitable as stock plants for budding purpose. The seedlings, with long tap root and few lateral roots, did not stand transplanting well; a drawback likely to be encountered when using other wild species.

- In recent trials *M. casturi* has been grafted on M. indica cv. Madu, in Java, and in Sahah on *M. Laurina*. In East Kalimantan *M. gedebe* has being tried out as stock for *M. indica*.
- It is not surprising that trials of grafting *M.caselia* on *M.indica* (Wester, 1920) or using *M.kemanga* or *M.caesia* as stocks (Ochse, 1931) were not successful, as these two species have distinct bark features and only remote affinity with tlIe common mango. Better compatibility can be expected using species more closely related to the Indian mango, for instance *M.laurina or M. sylvatica*.

2.2.7. Sexual compatibility

Existing information ahout interspecific hybridization is scarce. According to Mukherjee *et al.* (I.968) successful crosses between *M.odorata* and *M.zeylanica* were ohtained in uldia, suggesting the possibility of facing no problem of sterility from such crosses.

Field observations made during our surveys lead us to believe that interspecific crossing naturally happens though rarely. Cases were observed between:

- wild *M.gedebe* and cultivated *M.laurina* sympatric in the lakes area along the MahakaJl1 River, in East Kalimantan, where important populations of *M.gedebe* occur;
- cultivated *M.foetida* and *M.pajang,* two species showing close affinity, in different areas of Kalimantan where both species are grown together in old mixed gardens;
- and also between closely related *M.caesia* and *M.kemanga* in cultivation.

Such cases are not commonly found but were consistently reported from different areas in Kalimalltan. Tl1eir establishment in collection is highly desirable as utilization of natural hybrids (also known in the same area for *Durio spp.* and *Artocarpus spp.)* may considerably reduce the time required in the breeding.

A hybrid origin *(M.indica* x *M.foetida)* has been suggested for *M.odorata* which is unknown in the wild (Hou, 1978) but this remains unproved and is not very likely.

2.2.8. Breeding potential of wild species

There is little doubt that wild mangoes have potential value in improvement and hreeding programmes. Some may have far reaching horticultural implications. Results of surveys and available information show that wild mangoes exhibit desirable characteristics such as:

2.2.9. Adaptation to continuously wet clinlate

In the West Malesian botallical region, wild mangoes tl1five well under ever-wet climate, without prolonged a dry season, for instance in areas with all annual rainfall exceeding 4,000 mm and no monthly mean less than 100 mm, where the Indian mango can not be grown satisfactorily.

2.2.10. Resistance to anthracnose and other pests and diseases

The sub-glabrous and laxly flowered pallicles of *M.laurina,* a species closely related to the Indian mango, show no sign of attack by antllracnose. This species is well adapted to areas with ever wet climates and where damage caused by anthracnose prevents a good fruit setting of the common mango. These observations were corroborated by Mr. A. Lamb in Tenom Agriculture Research Station. Comprehensive investigations are necessary to establish whether this is inherent to the morphological characteristics of the panicle or if there is a proper resistance.

Interestingly, Sharma *et al.* (1976) observed that trees of an unknown wild race found in the Tripura State (North-Eastern India) were free from mango malformation, a serious disease threatening the mango industry in tile region. In the Philippines, Angeles (1991) reports that *M.altissima* does not seem to be affected by mango pests such as leafhppers, tip borers and seed borers.

2.2.11. Ability to grow in inundated areas

Wild mangoes growing in swamps or seasonally inundated areas (e.g. *M.gedebe, M. Griffithii, M. quadrifida)* represent a promising source of rootstock for the development of mango cultivation on poorly drained soils or in areas liable to prolonged flood. In West Kalimantan *M.laurina* is occasionally used as a rootstock for commercial varieties of the Indian mango on periodically inundated river banks. It is now being tried out as a rootstock by the Department of Agriculture in Sabah, where it also shows potential for the production of mango nectar (A. Lamb, 1990, pers.comm.).

2.2.12. Possibility for adaptation in subtropical and Mediterranean areas

While most wild mangoes is found in the lowlands, a couple of species are restricted to mountain forests between 1, 000 and 1,700 m.a.s.l. (notably *M.orophila,* a new species from Malaysia, or the poorly known *M.dongnaaiensis* from Vietnam). They should be tested for cold hardiness and may eventually open new possibilities for mango cultivation in subtropical or even Mediterranean areas. Of particular interest are also the poorly known species described from Southern China (Yunnan and Guangxi).

2.2.13. Absence of fibre

Outstanding and unique in the genus, the fruit of *M.mangifica* is completely free of fibres. With not a single fibre attached to the seed, it can be easily separated from tlle stone by making a transverse cut and twisting the two halves in opposite directions. The white pulp is generally rather sour and acid, but sweeter varieties are reported. Several forms of *M.quadrifida* var. *spathulaefolia* (with small fruits) have pleasant sweet-acid fruits which are scarcely fibrous.

2.2.14. Better pollinating qualities and firuit setting rate

As already noted by Fairchild (1948) about Indochinese species, there is a possibility that crosses between 5-stamened mango and the Indian mango will produce hybrids witll better pollinating quality. Belonging to the subgenus

Mangifera and having 5 perfect stamens, are *M.caloneura* and *M.cochinchinensis* and *M.petandra* from mainlatld Southeast Asia. Prolific bearing has been observed on *kipentandra,* a 5-stamened mango related to *M.indica,* which is grown in Peninsular Malaysia and Sabah.

2.2.15. Out of season fruiting

In Borneo, *M.rufocostata* and *M.swintonioides* (two newly described species) have the peculiarity of flowering and fruiting out of tile main season. Since in East Kalimantan their fruiting time usually coincides with the famine season, they are locally called the famine food. Though their flesh is extremely sour and acid, the fruits are then eaten.

Moreover, some species hold direct potential economic value, for their intrinsic characteristics. For example:

- *M.pajang,* endemic to Borneo, has the largest fruits in the genus (up to 20 cm in diam.). The rough, potato brown, 1 cm-thick rind can be peeled off like that of a banana, and the fruits can be stored for weeks without refrigeration. Its bright deep yellow, fibrous flesh is sweet with a distinctive taste.
- A kind of *M.foetida* has high quality fruits witl1 sweet and hardly fibrous flesh. Of this, we found a tree with almost seedless fruits (abortive seeds).
- The "wani" from Bali and Borneo, the best variety of *M.caesia,* has a green skinned fruit and milky white, soft flesh with a sweet distinctive taste somewhat reminiscent of peal'. Excellent juices are made from it in Bali.
- *M.casturi,* a new species, is a very popular fruit among Banjarese people in South Kalimantan. The small black fruits are very sweet. This is a prolific bearer. There exist several varieties in cultivation.

Improvement of several cultivated species is desirable owing to their local economic importance. Use of vegetative propagation methods must be encouraged. There is every reason to believe that, with proper selection, some species can become valuable commercial fruits. Species with distinctive qualities might have potential use for specific purposes (making juices, flavoring yoghurts and ice creams, etc).

Although progress have been made in the knowledge of wild mangoes, especially those native of Western Malesia, our knowledge remains very superficial. In Western Malesia we are still at the stage of doing all inventory. Totally new species were discovered on local markets in Borneo, and species were collected for the first time in Peninsular Malaysia, which has been combed by botanists for more than a century and has one of the highest collecting indexes in tile region.

A great deal has to be learned even about the best-known species, and the breeding potential value of many lesser known species remains unknown.

2.2.16. A threatened genepool

As SE Asian tropical rain forests are vanishing due to extensive logging and development projects, many wild mango relatives are endangered and being lost before they can be preserved and even before they are discovered. Several species are exploited for their timber despite protection from forestry regulation. Simultaneously, semi cultivated species also suffer genetic erosion and are inexorably vanishing. As stressed above, old tree gardens in remote areas of Borneo (and to a lesser degree elsewhere) are sanctuaries of an amazing diversity of fruit germplasm. In areas now completely devoid of natural forests, owing to over-exploitation during the past decades, tile only wild relatives of many fruit species (such as mangoes, durians, or rambutans) still to be found there are those which have been integrated into indigenous agroforests. Yet, under the increasing pressure of socio-economic changes, these fine examples of 'gene banks' inherited from the past are on the verge of being lost. Old fruit gardens are sometimes converted into cash-crop plantations. Most commonly, they are gradually impoverished. In many areas, rare local varieties, even those with promising potential are gradually lost. It is increasingly common that productive fruit trees such as durians *(Durio spp.)* and mallgoes *(Mangifera spp.)* are cut for their timber, securing a providential income during years of rice cropping failure. As a rule, all the old trees of minor fruit species and local races with little commercial value are not replaced. Customary laws regulating the felling of fruit trees are fading in most areas and are generally not strong enough to prevent these changes to occur.

If we believe that tile mango wild relatives may be used in mango breeding, that tile unique genepool of semi-cultivated species must not be lost, then rapid action is essential. From our own experience as plant collector, we simply attest that every passing year makes the Chance of finding wild mango relatives represented by old trees in old gardens more uncertain. And in the next century, if the raw material is still present in the forest, it will be much more difficult, time consuming and costly, to locate and to gain information on rare wild mango trees without assistance of the main keepers of tile local knowledge, mostly elder people.

2.2.17. Wild mango genetic resources in living collection

The need for widening the germ plasm base for future breeding programmes has been stressed by many authors, in various occasions. Yet, species other than *M.indica* are hardly represented in living collections. Though not exhaustive, the list given in the IBPGR Directory of germplasm collections (1934) gives an idea of the situation. In 25 countries, out of 33 mango germplasm living collections listed, only 7 include non-indica species, generally as a single accession. In the best cases, they are represented in collection by only a few accessions often fortuitously introduced and not representative of the existing infraspecific diversity. So far, the most important collection is that of the Sabah Department of Agriculture at Tenom (Lamb, 1987).

There are man reasons for this situation: the already great number of *M.indica* varieties to be maintained in collection, the vague belief that the breeding potential of wild species might be small, or sometimes the force of habit, but it is more certainly related to a general lack of knowledge about non-indica species and the difficulty to obtain the desired material.

These last few years, the situation has changed. A small but increasing number of researchers and users from different countries are demonstrating their keen interest in obtaining material for evaluation, research and breeding.

This interest needs to be encouraged, but it must be made clear that, without coordination at an international level and further collecting work, many requests will probably remain unsatisfied as the material is not readily available, or in limited quantity only, from the very few, and very incomplete, existing collections.

2.2.18. Recommendations

1. Selected wild mangoes, and semi-cultivated forms must be established in collection and made available for users.

It is acknowledged that one should start with the expectation that all the mango relatives might prove useful for one reason or another. But dealing with more than 60 species, for most of which there are semi-cultivated forms and varieties, there is much advantage to set up priorities. Based on the existing knowledge of wild mangoes, incomplete as it is, a list of priorities could be devised taking into account the various needs (root stock for marginal soils, dwarfing root stock, selection for disease resistance, general breeding or research purpose, etc.).

Core collections must be established in the main biogeographic entities where wild mangoes occur, preferably on a regional basis, and replicates in research institutions in other parts of the world.

2. A great effort is urgently needed to collect wild and semi-cultivated material aJ1d local knowledge attached to it.

There is a special need to rescue promisl1l1g local races and semi-cultivated species found in traditional agroecosystems which are endangered.

Surveys should be initiated in the following areas which are of particular i significance: North-Eastern India, Bangladesh and Burma; Thailand, Laos, Cambodia, and Vietnam; Sumatra and Sulawesi; and in Eastern Indonesia (Lesser Sunda Islands and Moluccas).

3. Research efforts to assess the breeding potential value of wild species must be initiated.

4. Last, but not least, to ensure maintenance and continuing evolution of wild mangoes, it is essential to actively support the conservation of large tracts of rain forest in tropical Asia. This is a matter of international concern, and must mobilize support at al1 international level. The burden of conservation should not put on the shoulders of only a few countries, while all producing countries will potentially benefit from it.

Of utmost importance are lowland areas (0-500 m), notably the much threatened dipterocarp forests which represent the main habitat of two thirds of the

Mangifera species found in Western Malesia (Peninsular Thailand. Malaysia. Sumatra. Borneo),

It is worth stressing that the coverage of existing protected areas in the region shows a bias towards the less threatened mountain forests which are poor in *Mangifera* species, and a paucity of the faster eroding habitats, especially the lowland dipterocarp forests (IUCN-UNEP, 1986). An inventory of the mango species occurring in forests reserves has been initiated and must be pursued. Candidate gene reserves, rich in wild mangoes but also in otller tropical fruit relatives, can already be identified.

To reach these goals before it is too late, more energies must be mobilized in a cooperative effort associating more closely all those concerned with the future of mango. We must be fully aware that it is the responsibility of the present generation to preserve some representative samples of the existing diversity in the genus *Mangifera,* likely to be tlle only ones available for study and use in the future.

2.2.19. List of species mentioned in the text

Maltissima Blanco
M.caesia Jack
M.caloneura Kurz
M.collina Kostermans *
M.caloneura Kurz
M.Kasturi Kostermans *
M.cochinchinensis Engler
M.decandra Ding Hou
M.dongnaiensis Pierre
M:foitida Loureiro
M,gedebe Miquel (syn, M.camptospefma Pierre, M.inocarpoides Merrill & Perry, *M.reba* Pierre)**
M.griffithii Hooker f.
M.indica ***L.***
*M.*kemanga Blume
*M.*lagenifera Griffitll
M.laurina Blume *(syn. M.longipes* Griffith*)***
M.inagnfjica Kochummen
M.orophila Kostermans *
M.pajang Kostermans
M.parvifolia Boerlage & Koorders *(syn. M.havilandii* Ridley*)***
M.pentandra Hooker f.
M.quadrijida Jack
M. rufocostata Kostermans *
M.swintonioides Kostermana *
M.sylvatica. Roxburgh
M.timorensis Blume
M.zeylanica Hooker f.

Note: Refer to Kostermans & Bompard (1992) for descriptions of new species (*) and new combinations (**).

2.2.20. References

Angeles, D.E., 1991. *Mangifera altissima.* In: E. W .M. Verheij & R. E. Coronel (eds.), Edible Fruits and nuts, Plant Resources of South East Asia 2 (PROSEA). PUDOC, Wageningen: 206-207.

Bompard, J.M., 1988. Wild ,*Mangifera* species in Kalimantan (Indonesia) and in the region Malaysia. Final report on the 1986-1988 collecting missions. Report to *WWF/IBPGR. 50 pp.*

- 1991. *Mangifera caesia and M. Kemanga; M. foetida and M. pajang; M. Laurina and M. petandra; M. odorata. In:* E.W.M. Verheij & R. E. Coronel (eds.), Edible Fruits and nuts, Plant Resources of South East Asia 2 (PROSEA). PUDOC, Wageningen: 207-211,216-220.

Fairchild, D., 1948. The mango relatives of Cochin China; those with five-stamen flowers. Proc. of the Florida State Horticultural Society 61 : 250-255.

Gunaratman, S.C. 1946. The cultivation of the mango in the dry zone of Ceylon, II. Tropical Agriculturist. 102 : 23-30.

Hou, D.H., 1978. Anacardiaceae.4.*Mangifera* In: Flora Malesiana 1(8): 423-440

IBPGR, 1984. Directory of germplasm collections 6.1. Tropical and subtropical fruits and tree nuts. IBPGR, Rome, 191 pp.

IUCN-UNEP, 1986 Review of the protected areas system in the Indo-Malayan realm. IUCN, Cambridge and Gland, Switzerlalld. 284 pp.

Kochummen, K.M., 1989. Anacardiaceae. In: F.S.P. Ng (ed.), Tree Flora of Malaya. A Manual for Foresters. Longman Malaysia, vol. 4: 9-57.

Kostermans, A.J.G.H. & Bompard, J.M., 1992. The Mangoes. A handbook of the species of *Mangifera* L.(Anacardiaceae): Botany, nomenclature, horticulture, cultivation and utilization. (forthcoming)

Lamb, A., 1987. The potential of some wild and semi-wild fruit trees in Sabah and the progress made by the Department of Agriculture, Sabah, in establishing a germplasm pool. Paper to a FRIM meeting, Kepong, Malaysia. 8 pp. + app.

Lee Ying Fah, 1987. A preliminary survey of *Mangifera* species in Sabah. Report to WWF Malaysia. 21 pp. + ill.

Mukherji, S.K., 1949. A monograph of the genus *Mangfera* L. Lloydia 12(2):73-136.

Mukherjee, S,K., 1957. Cytology of some Malayan species of *Mangifera.* Cytologia 22: 239-241.

Mukherjee, S.K., Singh, R.N., Majumder, P.K. and Sharma, P.K., 1968. Present position regarding breeding of mango *(Mangifera indica* L.) in India. Euphytica 17: 462-467.

Narasimham, B., 1977. New approaches for improvement of mango In: G.S. Nijjar (ed.) Fruit breeding in India. Oxford and IBH Publishing. Co., New Delhi: 31-38.

Ochse, J.J. and Bakhuizen, R.C., 1931. Fruits and fruit culture in the Dutch East Indies. G. Kolff & Co, Batavia: 11, 16.

Saw, L.G., 1987. Conservation of the mallgo and its wild relatives in Peninsular Malaysia. Report to WWF Malaysia. 17 p. + tables.

Sharma, D.K. & Choudhury, S.S., 1976. Occurrence of an unknown wild race of *Mangifera* in Tripura. Current Science 45 (8): 305-306.

Wester, P.J., 1920. The mango. Bulletin no. 18, Bureau of Agriculture, Department of Agriculture alld Natural Resources, Manila: 14-15.

3. HYBRIDIZATION

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3.1. MANGO HYBRIDIZATION STUDIES IN TROPICAL SAVANNAH ("CERRADOS") OF BRAZIL CENTRAL REGION

3.1.1. Abstract

Mango production in the tropical savannah ('Cerrado') of Brazil central region has greatly increased in the last decade. However, the yield and quality of mango are still low due mainly to a lack of superior cultivars adapted to the environmental conditions of 'Cerrado' region. A mango hybridization program using controlled hand pollination was initiated in 1980 with the objectives of improving fruit yield and quality, bearing consistency of plants, and mainly of developing cultivars with small tree size. Dwarf genotypes have been introduced and first hybrids selected. However, the hand-pollination of mango is time-consuming and expensive because of poor fruit set, and of the tall and difficult-to-handle trees. A method for decreasing / the cost of mango hybridization is proposed and the expected results discussed.

3.1.2. Introduction

Mango is an important tropical fruit in Brazil and its cultivated area has increased greatly in the last decade. In the tropical savannah ("Cerrado') of Brazil central region, which represents about 20% of the whole area of the country, large mango orchards have been established in the last decade representing an area larger than 2 thousand hectares (ANUARIO ESTATISTICO DO BRASIL, 1985). The planting of mango orchards has been encouraged by federal tax deductions for reforestation, with an increase in mango supply. This increase in mango supply has lowered the price of the fruit, and increased local consumption and interest in export of the fruit to Europe and USA.

However, monoclonal orchard cultivation with too much dependence tn a few exotic cultivars from Florida, e.g. 'Tommy Atkins', is fraught with undesirable consequences. This variety is highly productive but exhibits alternate bearing. With red blush color and fiberless fruit, it accounts for more than 60% of the cultivated area. Its plant is tall, vigorous, and susceptible to floral malformation whereas fruits show high incidence of spongy tissue of the pulp. Although Brazilian and Indian mangos are less productive and poorer in color as compared to Florida ones, they have better taste (Indian) and the availability of dwarf genotypes is higher. In addition, some genotypes, like Amrapali', show regular bearing character and high fruit quality. Thus, a hybridization program was initiated at the Cerrados Agricultural Research Center, EMBRAPNCPAC in 1980 with the consultation of Dr. D. K. Sharma from the Indian Agricultural Research Institute (JARI). This program attempts to develop a dwarf cultivar with high yield per unit of area (high density orchard), regular bearing, and high quality fruit for the "Cerrado" region. The objective of this paper is to evaluate the preliminary results of this research, and propose a novel method which may improve the efficiency and reduce the cost of the hybridization program.

3.1.3. Material and methods

The Cerrados Agricultural Research Center, EMBRAPNCPAC, is located in Planaltina, Federal District, Brazil (latitude 17° 35' 30" S, longitude 47° 42' 30", elevation about 1100 mm above sea level. The climate has two distinct seasons: a rainy (rainfall 1400 to 1800 mm/year) and warm (25 to 30°C) period from September to April and, a dry (relative humidity 40%) and cool season (mean temperatures from 20° to 23°C) from May to August (Pinto *et al.*, 1981). The Cerrado soil is mostly latosol (yellow or red) which is chemically poor and acid (pH 4.3), although structurally it is considered reasonable for perennial crops.

The germplasm collection work was initiated at the EMBRAPNCPAC in 1975, and so far 74 accessions have been introduced from other regions or countries. Other accessions such as 'Bhadauran', which is resistant to mango malformation, 'Malindi', 'Julie', and 'Divine', exhibiting dwarf character, and 'Ratna', with regular bearing and high fruit quality, will be introduced soon in the future. Although all the mango accessions have been use9 in mango improvement, the hybridization study has concentrated mostly on monoembryonic genotypes which readily produce hybrid seedlings. A total of 293 hybrid seedlings have been obtained so far from 18 parents used in the hybridization work. These parents are from the Northeast and Southeast of Brazil ('Ametista', 'Coracao Magoado', 'Imperial', 'Maca', 'Santa Alexandrina'), from the North of India ('Amrapali', 'Dashehari', and 'Mallika'), and from Florida, USA ('Edward', 'Florigon', 'Winter', M13269, 'Palmer', 'Ruby', 'Smith', 'Tommy Atkins', 'Van,Dyke', and 'Zill').

Data on tree growth, fruit yield, and physico-chemical parameters of fruits have been collected from the parents and intervarietal mango hybrids as follow: a) Tree growth -Height (m), stem girth (cm) at 20 cm from the ground, mean diameters (m) of the canopy within and between rows; b) Fruit yield -No. of fruits, weight of fruits; c) Physico-chemical parameters of fruits -Fruit weight (g), shape, pulp (%), peel (%), stone (%), Brix (%), acidity (%), and the ratio' Brix/acidity. Fruit was weighed on a Sartorius scale, and its shape was determined by using the description of Gangolly *et al.* (1957). The percent of sugar (Brix) was measured with an AT AGO refractometer, and acidity (%) was determined by using procedures of the Instituto Adolfo Lutz (1976).

The characteristics of some female grafted parents ('Espada' as rootstock) 7 years old are described as follow:

a) Amrapali -Intervarietal ('Neelum' x 'Dashehari') Indian hybrid with dwarf character (1.85 m), stem girth 45 cm, mean diameter of canopy 3.5 m, regular bearing, medium yield (140 fruits/tree), small size fruit (147 g) with oblong shape and yellow to apricot-like color, 89% pulp, 5% peel, 6% stone, 21 % Brix, acidity 0.25%, and a ratio Brix/acidity of 84.0.

b) Imperial -Brazilian cultivar with tendency for dwarfness (2.0 m). stem girth 38 cm, mean diameter of canopy about 3.5 m, irregular bearing, low yield (93 fruits/tree), large size fruit (600 g) with obliquely-oval shape and yellow color, 84% pulp, 10% peel, 6% stone, 14% Brix, 0.350,0 acidity. and Brix/acidity ratio of 40.

c) Maca -Brazilian cultivar with tendency for dwarfness (2.1 m), stem girth 38.5 cm, mean diameter of canopy about 3 m, irregular bearing, low yield (90 fruits/tree), small size fruit (146 g) with apple-like shape and yellow color, 81 % pulp, 8% peel, 11 % stone, 10% Brix, 0.4% acidity, and Brix/acidity ratio of 25.

d) Winter.: -Florida selection with tall (3.7 m) and semi-vigorous plant (stem girth 57 cm and mean diameter of canopy 4.7 m), regular bearing, high and precocious yield (306 fruits/tree), medium size fruit (320 g) with oblong-oval shape and yellow-reddish color, 75% pulp, 11 % peel, 14% stone, 18.0% Brix, 0.26% acidity, and Brix/acidity ratio of 69.

e) Tommy Atkins: -Florida cultivar with tall (4.2 m) and vigorous plant (stem girth of 59 cm and mean diameter of canopy 4.2 m), irregular bearing, high and precocious yield (220 fruits/tree), medium size fruit ($\approx$ 530 g) with ovate-oblong shape and red blush color, with 82% pulp, 9% peel, 9% stone, 12.8% Brix, 0.30% acidity, and Brix/acidity ratio of 43.

f) Zill -Florida cultivar with tall (4.6 m) and vigorous plant (stem girth 61 cm and mean diameter of canopy 5.0 m), irregular bearing, low yield (113 fruits/tree), medium size fruit (357 g) with ovate shape and red-yellowish color, 74% pulp, 14% peel, 12% stone, 18% Brix, 0.3% acidity, and Brix/acidity ratio of 60. The hybridization work is done between July and early August in order to facilitate the crosses between early flowering (June to early July) Brazilian varieties and late flowering Indian or American varieties (late July and August). The female plants are kept in protective cages $\approx$ 4.8 m height and about 16 m2 of area. The hybridization technique of Mukherjee *et al.* (1961), which recommends few flowers per panicle and more panicles per tree, was used from 1981 to 1983. After 1983. this technique was improved by selecting flowers in the internal primary rachises of the inflorescences. by rubbing a maximum of one anther on two stigma (ratio 2:1), and by spraying the young fruits beyond the marble stage twice a week with water and/or fungicide (Pinto, 1987). For those female plants without cage protection, the panicles (with pollinated flowers) were kept in plastic bags (0.01 mm thick) with several needle perforations to improve aeration inside the bag. A new hybridization methodology has been proposed based on the work of Mukherjee *et al.* (1968) in which topworking desirable parents top-worked on self-incompatible female cultivars is suggested to improve mango hybridization efficiency.

3.1.4. Results

Hybridization techniques

The new technique of Mukherjee *et al.* (1961) greatly improved the fruit set in mango as compared to the old hybridization technique (table 3-1). This new technique was used from 1981 to 1983 at EMBRAPA/CPAC. The success of 1.45% of hybrid seedlings obtained was similar to the result (1.52%) of the Indian Agricultural Research Institute, IARI (table 3-1).

Table 3-1. Comparison of mango hybridization techniques from 1946 to 1987.

Technique and Source	Site and Period	No. of flowers pollinated	Hybrid seedlings	
			No.	%
Old technique				
Sen *et al.* (1946)	Sabour (1941-1944)	9,737	77	0.79
Jawanda and Singh (1963)	Oadian (1941-1958)	7,775	31	0.39
New technique				
Mukherjee (1961)	Krishnagar (1959-1961)	26,911	361	1.34
IARI	New Delhi (1961-1974)	67,000	1018	1.52
EMBRAPA/CPAC	Brasilia (1981-1983)	2,000	29	1.45
Improved technique				
EMBRAPA/CPAC	Brasilia (1984-1987)	3,220	264	8.20[z]

[z]*Hybrid fruits beyond "marble" stage.*

However, the improvement of Mukherjee's technique from 1984 to 1987 promoted a five- fold increase in the number of seedlings obtained, Besides the selection of flowers in the internal position of the rachises and a maximum 2: 1 anther to stigma ratio, the great increase in fruit set (beyond "marble" stage) and final seedlings was mainly due to the spraying oaf procedure. In fact, cool and dry weather (RH of 40%) during mango bloom has favored the attack of the fungus Oidium mangiferae and the increase in dropping (abscission) of young fruits ("pea" stage) in the "Cerrado" region. Inflorescences with all other improved procedures, except spraying treatment, had a lower percentage of hybrid fruits (3,5% to 6,0%) than those which included the spraying procedure (8.2%), However, this percentage (8,2% of hybrid fruits beyond the "marble" stage) is still low considering the tremendous effort spent during approximately 30 days of hand-pollination on tall and difficult-to-handle trees.

Mango is typically an outcrossing crop and insects from several orders visit its flowers, but those from order diptera show the highesı (51,6%) visitation frequency (Jison and Hedstrom, 1985), Horse and house flies are frequently found visiting mango inflorescences from June to August, This finding is important because chicken manure, which is an important substraıe to hatch house flies, is easily obtained in the several poultry farms near Brasilia, Therefore, a new methodology of using dwarf material and insect-aided pollination has been proposed to improve efficiency and decrease cost of mango hybridization. This methodology includes the selection of a dwarf genotype e,g., 'Amrapali' or 'Malda', which is top-grafted with selected cultivars and kept in smaller and less expensive cages (2 m height and about 6.5 m^2 of area) than those used in the past hybridization work. Insect-aided pollination, in which flies are hatched in wet chicken manure inside the cage, is substituted for the time consuming hand-pollination,

Since self-incompatibility has been observed in mangos (Mukherjee et ai" 1968), polycross method can be established with, e,g" 4 top-worked varieties which, theoretically, will each have a similar genetic contribution (25%) to the progeny population obtained. Another possible approach could be by keeping the dwarf genotype in the cage and introducing panicles from selected cultivars. With this methodology, the cost of the hybridization program is expected be cut by half and its efficiency doubled since a larger hybrid population will facilitate the selection of the desirable types possible (Sharma and Majumder, 1988). The use and improvement of selection procedures described in the literature (Iyer *et al.*, 1988; Majumder *et al.*, 1972) have also been tried.

Tree growth and fruit yield

Although several hybrids have demonstrated selectable characteristics, 5 of them have shown important behavior so far in growth, fruit yield and quality. The tree growth varied among these 5 hybrids and the male parents 'Amrapali' and 'Imperial' showed higher propensity to transfer the dwarf trait to their progenies than 'Ma<;a' (table 3-2). The tree height of hybrid No. 03/86 ('Tommy Atkins' x 'Amrapali') was almost twice as short as that of the hybrids from cross between two vigorous parents ('Winter' x 'Zill'). Although the dwarf character of 'Amrapali' was detected in the progeny, its compact and dense canopy creates excellent conditions for the development of the white scale (Aulacaspis tubercularis Newstead) whose attack reduces the fruit value for the market. A cross between' Amrapali' and a genotype with open canopy like 'Palmer' or 'Cora<;ao Magoado' may produce a dwarf progeny with a less dense canopy which would be less susceptible to the attack of this scale. Although trees of the hybrid No. 01/84 fram the parent combination 'Tommy Atkins' x / 'Imperial' were as short as those from 'Tommy Atkins' x 'Amrapali', they had a more spreading growth habit (table 3-2) which may be a problem in a high density orchard situation. The hybrid No. 10/84 from 'Winter' x 'Maca' showed a yield of 290 fruits/tree corresponding to 89 kg/tree, which was higher than the other intervarietal combinations. This yield was also higher than the average yield of the parents, suggesting that a mid-parent heterosis performance of 24.5% may have occurred (Fehr, 1987).

Table 3-2. Tree growth and fruit yield of some inter-varietal mango hybrids developed at EMBRAPA/CPAC, Brasilia-DF, Brazil[Z]

Present combination	Plant height[Y] (m)	Stem girth[Y] (cm)	Diam. Of canopy[Y] (m)	Fruit yield[X]	
				No.	Weight (kg)
Hybrid No. 010/84					
Winter X Maca	2.2	28	2.2	290	89
Hybrid No. 004/84					
Winter X Zill	2.8	28	2.2	161	74
Hybrid No. 003/86					
T. Atkins X Amrapali	1.6	25	2.1	150	35
Hybrid No. 001/84					
T.AtkinsX Imperial	1.8	25	2.2	15	11
Hybrid No. 012/85					
T. Atkins X Maca	2.0	26	2.0	191	51

Z *No. of plants per hybrid varies from 2 to 35.*

Y *Data from hybrid plants at 3 years old.*

X *Data from hybrid plants at 6 years old.*

Physico-chemical parameters of fruits

In general, these 5 hybrids showed intermediate performances of the physico-chemical parameters of the fruits as compared to their parents. This inheritance pattern suggests that these traits are controlled by additive gene action (Sharma and Majumder, 1988). Fruit weights of the hybrids No. 04/84 ('Winter' x 'Zill') and No. 01/84 ('Tommy Atkins' x 'Imperial') were larger than the parents. However, when the same female parents were crossed with male parents which had smaller fruit weight ('Maca' and 'Amrapali'), hybrids with intermediate fruit weight were obtained (table 3-3).

Fruit from the progeny 'Winter' x 'Zill' (hybrid No. 04/84) had a higher percent of pulp (82%) due to its smaller stone (6%) as compared to the other hybrids. Although its Brix (16%) was lower than both parents, its acidity was also lower (0.18%), and consequently the Brix/acidity ratio was as high as 90 indicating that the fruit is high quality.

Table 3-3. Physico-chemical parameters of fruits of some intervarietal mango hybrids developed at EMBRAPNCPAC, Brasilia-DF, Brazil[z]

Hybrid No. and Combination	Fruit wt. (g)	Shape	Pulp (%)	Peel (%)	Stone (%)	Brix (%)	Acidity (%)	Ratio (B/A)[Y]
Hybrid No. 010/84								
Winter X Maca	309	Ovate	77	13	10	17	0.38	45
Hybrid No. 004/84								
Winter X Zill	460	Oblong	82	11	6	16	0.18	89
Hybrid No. 003/86								
T. Atkins X Amrapali	230	Oblong	75	12	12	17	0.18	94
Hybrid No. 001/84								
T. AtkinsX Imperial	700	Roundish	78	11	10	16	0.32	50
Hybrid No. 012/85								
T. Atkins X Maca	205	Roundish	74	13	13	15	0.30	50

Z *Data from 10 to 40 mature fruits of 6 years old plants.*

Y *B/A=Brix/acidity.*

Hybrids from crosses with 'Maca' and 'Amrapali' as male parents had higher percent of peel and. as a consequence, lower percent of pulp than the parents (table 3-3). The best fruit quality in terms of taste was observed in fruits of 'Tommy Atkins',x 'Amrapali' (hybrid No. 03/86) with Brix/acidity ratio of 94.

The ideal mango variety for the Cerrado region which combines several useful characters (dwarfness, regular bearing, high fruit yield and quality) is very difficult to obtain since low fruit set is still obtained. However, preliminary results have shown that is possible to combine a moderate level of dwarfing from Brazilian/Indian parents with a reasonable level of the yield and quality traits derived from Florida varieties. This combination strategy with the hybridization protocol of top-working and insect-aided pollination, which will increase the progeny population size, may result in the development of vastly superior dwarfing varieties for the Brazilian mango industry.

3.1.5. Acknowledgements

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3.1.6. References

ANUARIO EST A TISTICO DO BRASIL, 1985. IBGE, Rio de Janeiro, 600 p.

Fehr, E.L., and Holly, J.J., 1987. Heterosis. In: Principles of cultivar development. Macmillan, New York: 115-119.

Gangolly, S.R., Singh, R., Katyal, S.L., and Singh, D., 1957. Description of varieties. In: Mango. Indian Council of Agricultural Research New Delhi: 19-462.

IINSTITUTO ADOLFO LUTZ, 1976. Normas Analiticas do Instituto Adolfo Lutz. IAL, Sao Paulo. Vol. I. 92 p.

Iyer, C.P.A, Subbaiah, M.C., Subramanyam, M.D., and Prasada Rao, G.S. 1988. Screening of germplasm an,d correlation among certain characters in mango. Acta Hort. 231 :83-88.

Jison, L.F., and Hedstrom, I., 1985. Pollination ecology of mango (Mangifera indica L.) (Anacardeaceae) in the neotropic region. Turrialba 35(3):269-277.

Majumder, P.K., Sharma, D.K., Singh, R.N., rind Mukherjee, S.K., 1972. Preliminary studies on inheritance in Mangifera indica L. Acta Hort. 24: 120-125.

Mukherjee, S.K., Majumder, P .K., Chatterjee, S., 1961. An improved technique of mango hybridization. Indian J. Hort. 18:302-304.

Mukherjee, S.K., Singh, R.N., Majumder, P.K., and Sharma, O.K., 1968. Present position regarding breeding of mango (Mangifera indica L.) in India. Euphytica, I7: 462-467.

Pinto, A.C.O., 1987. Estabelecimento da cultura da mangueira nos Cerrados brasileiros. Relatorio Final de Projeto. EMBRAPNCPAC. Brasilia, Brazil. 52 p.

Pinto, A.C.O., Pedrazzi, R.G., and Genu, P.J.C., 1981. Avaliacao de sete variedades de mangueira (Mangifera indica L.) introduzidas na regiao dos Cerrados. In: VI Congresso Brasileiro de Fruticultura, Vol. 6. SBF, Recife:930-942.

Sharma, O.K, and Majumder, P.K., 1988. Further studies on inheritance in mango. Acta Hort. 231: 106-111.

3.2. PARTHENOCARPIC MANGO DEVELOPED THROUGH HYBRIDIZATION

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3.2.1. Abstract

Parthenocarpic mango hybrid-117, perhaps the first of its kind, is a result of intensive backcrossing between hybrid variety Ratna ('Neelum' x 'Alphonso') and 'Alphonso' at the Regional Fruit Research Station, Vengurla. This comparatively dwarf hybrid with regularity of bearing has inherited most of the desirable qualities of its parent. Medium-sized fruits (215 g) with very high pulp to stone ratio (26:1) and very thin (30 mm) and small stone (6.72 g), are ovate to oblong in shape, with attractive red blush on the shoulders. Fruits are deep orange fleshed (82.3%). Fiberless, it has a spongy tissue-free, with a pleasant taste and a sugar-acid blend that is better than 'Ratna'. It is very rich in ascorbic acid (52.22 mg/l00 g) s-carotene (11850 g/100 g). The non-viable cotyledon-free stone, which makes up only 3.I per cent of the total fruit weight, encloses a small degenerated ovule (1.12 g) inside the very soft endocarp (5.3 g). With these striking features, Hy-117 is being released for cultivation in the Kankan region of Maharashtra under the name 'Sindhu'.

3.2.2. Introduction

The mango breeding program being carried out at the Regional Fruit Research Station. Vengurla since 1970 has already yielded a hybrid mango variety 'Ratna' (Limye *et al.* 1983). This hybrid variety is a result of intensive reciprocal crossing between 'Alphonso' and the south Indian regular bearing mango variety 'Neelum'. Although 'Ratna' is a regular bearer unlike 'Alphonso', a good yielder with good fruit qualities and free from spongy tissue (unlike 'Alpnonso'), this variety lacks an attractive blush fruit shape and a typical 'Alphonso' flavor. Hence, intensive work involving backcrossing between 'Ratna' and 'Alphonso' was undertaken with an objective to bring about the improvement over the hybrid 'Ratna'.

3.2.3. Materials and Methods

From 1982 to 1991, about 1800 backcrosses were made between 'Ratna' and 'Alphonso' adopting the technique of Mukherjee *et al.* (1961). In all, 87 backcross hybrid seedlings obtained in different years were planted in respective years at 3 x 3 m spacing under uniform cultural practices. Out of these six backcross seedlings obtained during the year 1982 started bearing in 1986 were evaluated for various quality aspects. Out of these six seedlings, only Hy-ll7 was found promising in many respects; hence it was studied in greater detail in comparison with its parent in subsequent years. Morphological description of the plant in respect to growth habit, flowering and fruiting behavior was made as described by Gangolly *et al.* (1957), whereas quantitative qualitative observations were made using standard methods of analysis.

3.2.4. Results

Growth habit

The tree of Hy-II7 is relatively dwarf (volume 11.05 m^3) as compared to an average volume by five other hybrid seedlings (62.67 m) of the same age. Leaves are medium, intermediate, elliptical, lanceolete and a little wavy.

Flowering

Flowering initiation was observed from second week of December to second week of January. The inflorescence is broadly pyramidal with coppery red color of the main axis and rachis with a very high percentage of bisexual flowers (35.1%) as compared with' Ratna' (27%) and 'Alphonso' (13%).

Fruit Flowering

Eight year old seedlings of Hy-117 started flowering and fruiting at the age of the fifth year after planting with a tendency to bear regularly (Table 3-4). Fruits mature in the month of May and harvesting is over before the onset of the monsoon. Most of the fruits are borne in clusters and are exclusively parthenocarpically developed. Base of the fruit is obliquely rounded with square stalk and little cavity; ventral shoulders are higher that dorsal. Beak is absent or just a point, slightly sinus. Skin is medium thick with dominant red blush on both the shoulders. Flesh is firm, fiberless, deep orange color and taste pleasant with sugar-acid blend better than 'Ratna' and free from spongy tissue. Ripe fruits of Hy-117 secured an average score of 7.24 in organolaptic evaluation (Table 3-5).

Table 3-4. Fruiting behavior of mango Hy-117 and its parent

Years	Age (Years)	Yield		Remarks
		Number of fruits	Weight of fruits (g)	
1988	5	34	6.970	47 budsticks
1989	6	62	13.330	Were removed
1990	7	20	5.200	In 1989-90
1991	8	167	30.150	Cropping year

Table 3-5. Organoleptic evaluation of ripe fruits of Hy-117 (on 1-9 points hedonic scale

Particular	Score
Color	7.77
Flavour and taste	6.66
Pulp consistency	7.16
Size and shape	6.66
Lesh color	7.94
Total	36.19
Average	7.24

Physical characteristics of fruit and stone of Hy-117

Physical characteristics of fruits and stone of Hy-117 in comparison to its parent are presented in Tables 3-6 and 3-7. This revealed that as happens in most of the parental combinations (Sharma *et al.*, 1986), the fruit size of this hybrid (215 g) is also smaller than the parent. However, due to very thin (0.30 cm), non-viable stone (6.76 g), hybrid fruits recorded very high percentage of pulp (83.13%) and pulp to stone ratio (26:1) over both parents, with pulp weight nearer to 'Alphonso'. Similarly, in comparison to well developed viable cotyledons of 'Ratna' (27.0 g) and 'Alphonso' (19.0 g), a very thin and soft endocarp of this hybrid enclosed a small post-fertilized, aborted and degenerated ovule of 1.12 g.

Table 3-6. Physical characters of Hy-117 fruits and its parents

Characters	Hy-117	parents	
		'Ratna'	'Alphonso'
Average weight fruit (g)	215	315	250
Average length fruit (cm)	8.52	10.69	8.89
Average breadth fruit (cm)	6.52	8.36	7.5
Average weight pulp (g)	178.75	233.0	184.14
Average weight stone (g)	6.72	37.0	28.0
Average weight peel (g)	29.35	45.0	37.86
Average pulp percentage	63.13	73.96	73.65
Pulp to Stone ratio	26.59	6.29	6.57

Table 3-7. Physical characters of stone of Hy-117 and its parents

Characters	Hy-117	parents	
		'Ratna'	'Alphonso'
Average weight stone (g)	6.72	37.0	28.0
Average length stone (cm)	6.30	9.5	7.0
Average breadth stone (cm)	3.50	5.5	3.6
Average thickness stone (cm)	0.30	2.0	2.2
Average weight seed coat (g)	5.30	9.0	8.5
Average weight testa (g)	0.30	1.0	0.6
Average weight cotyledons (g)	1.12	27.0	19.0

Chemical composition of fruits of HY-117

A perusal of data (Table 3-8) regarding the chemical composition of ripe fruits of hybrid-117 in comparison with its parent indicated that Hy-117 has inherited more desirable fruit quality attributes from 'Alphonso' as compared to 'Ratna'. Fruits of this hybrid recorded more acidity (0.313%), ascorbic acid (52.22 mg/100 g) and β.carotene (11850' g/ 100 g) without inheriting the undesirable character of dev- eloping spongy tissue.

Table 3-8. Physical characters of Hy-117 fruits and its parents

Particulars	Hy-117	Parents	
		'Ratna'	'Alphonso'
T.S.S (°B)	21.11	23.00	19.00
Acidity (%)	0.313	0.256	0.341
Total sugar (%)	16.22	16.96	14.93
Reducing sugar (%)	4.81	4.80	3.50
Non-reducing sugar (%)	11.41	12.16	11.43
Ascorbic acid (mg/100 g)	52.22	44.21	62.15
s.carotena (g/100 g)	11850	10327	11845
Occurrence of spongy tissue (%)	0.0	0.0	22.00

3.2.5. Discussion

The phenomenon of parthenocarpy in single-seeded fruit like mango is a rare event. Although its natural occurrence (Oppenheimer, 1947; Laximinarayana *et al.*, 1975; Thirnmappaiah, 1982) and hormonally induced (Chacko *et al.*, 1969) has been reported by earlier workers, the stenospermocarpically developed fruits of Hy-117 are entirely different from these earlier evidences. Natural parthenocarpy in Indian cv. Dashehari fruit (Thirnmappaiah, 1982) has been reported to be of occasional and only to the extent of 5.44 per cent of total fruits. Moreover, as per earlier reports, fruits developed parthenocarpically are reported to be much more inferior and undersized (99.9 g) in comparison with seeded fruits with pulp to stone ratio not more than 8.6 and found under the influence of extreme temperature conditions (80 C or 440 C). Similarly, hormonally induced parthenocarpic fruit of 'Dashehari' (Chacko *et al.*, 1969) did not grow over 65 g. However, Hy-117 developed through hybridization is perhaps the first of its kind in which every fruit developed parthenocarpically to attain the average size of 215 g under natural temperature conditions and encloses no-viable cotyledon-free small 'stone (6.72 g) making up only 3.1% of total fruit weight with very high pulp to stone ratio in addition to good qualities inherited from its parents. Due to the desirable attributes, this hybrid has been recently released under the name 'Sindhu' as an additional variety for general cultivation in the Konkan region of Maharashtra in India.

3.2.6. References

Chacko, E.K., and Singh, R.N., 1969. Induction of parthenocarpy in mango (*Mangifera indica* L.) using plant growth regulators. Hort. Science 4: 121-123.

Gangolly, S.R., Singh, R., Katyal, S.L., and Singh, D., 1957. The Mango. Indian Council of Agricultural Research, New Delhi.

Laxminarayana, S., and Augilar, F.R., 1975. Effect of orchard heading in reducing parthenocarpic fruits in 'Haden' mango. Proc. Fla. State Hart. Soc. 83: 502-505.

Limaye, V.P., Patil, M.M., Lad, B.L., Magdum, M.B., Gunjate, R.T., and Salvi, M.J., 1984. 'Ratna' a new mango hybrid. J. Maharashtra Agric. Univ. 9: 60-61.

Mukherjee, S.K., Majumdar, P.K., and Chatterjee, S.S., 1971. An improved technique of mango hybridization. Indian J. Hart. 18: 302- 304.

Oppenheimer. C., 1947. The acclimatization of new tropical and subtropical fruit trees in Palestine. Bull. Agric. Exp. Sta. 44: 1.

Sharma, D.K., and Majumdar, P.K., 1989. Further studies on inheritance in mango. Acta Hort. 231: 106-111.

Thirnmappaiah, and Singh, H. 1982. Natural parthenocarpy in Dashehari cv. of mango. Indian J. Hort. 39: 195-198.

3.3. ADVANCES IN MANGO HYBRIDIZATION

Prof. Musaluh-ud-Din Khan

The primary purpose of plant breeding is to obtain or develop varieties or hybrids that are efficient in their use of plant nutrients, that give the greatest return of high quality products per unit area, that are adopted to the needs of the grower and consumer. It is also desirable that cultivated varieties are able to withstand adverse conditions of cold or drought and show resistance to diseases and insects pests.

3.3.1. Cytological Studies

Cytological investigations of the species found in the Indian sub -continent show that all of them have the chromosome number n:20. Mango is an allopolyploid and highly heterozygous. Morphological studies have shown that the genus Mangifera consists of' two groups of species based on the character of the flower discs. The first which includes 34 species, has flowers with well-developed swollen discs; whereas the second consisting of seven species has absolute or pedicellate discs. Eleven chromosome types have been reported in Mangifera indica and Mangifera sylvastica. Inter-varietal hybridization in nature may perhaps be important factor in the production of new varieties.

Floral Biology and Sex Distribution Floral biology implies the various phenomena occurring from the inception of the bud burst stage until the flowers set. Mango exhibits five growth flushes. The inflorescences are polygamous, bearing hermaphrodite and staminate or pistillate flowers on the same panicle. The flowers are sessile. The calyx is usually five partite and the corolla consists of five petals. The and-roecium consists of one fertile and four sterile stamens. Perfect flowers are easily distinguished by the presence of pistils. The ovary is small, greenish, located on a disc and consists of a single locule with a short style and a minute stigma. It is highly cross pollinated by insects. The period of flowering is likely to vary under f different climatic conditions. The development of the panicle in mango is a continuous - process, which .lasts up to about third week of March under Shujabad conditions. The panicles, which emerge a little later, show their most rapid extension in growth. Flowers start opening long before the panicles reach their full growth and there is no sequence in flower opening. Flowers start opening early in the morning and complete anthesis generally in the forenoon. Maximum opening takes place between 9 to 10 a.m. after dehiscence the anther assumes a bluish color due to the pollen and with the increase in temperature, anthesis and dehiscence are hastened. Receptive condition of the found to stigma has been found to continue up to seventy-two hours after the opening of the flower. The best receptivity has ,been noted on the first day of the opening. The percentage of viable pollen grains is quite high in mango. All mango varieties possess oblong-oval pollen grains. These have no furrows but only distinct points at which they have germpores.

3.3.2. Pollination

Pollination is essential for fruit setting in mango. After the flowers open, the anthers dehisce and the pollen grains appear as a dry and bluish powdery mass on the surface of the anther lobes. The activities of the insects become brisk at the midday. The disc acts as a secreting-organ an{f insects visit flowers for the sweet secretion and for pollen grains. pollination in mango is chiefly entomophilous. Either freshly dehiscend pollen grains, if not eaten by insects, are stuck to the anther and consequently cannot be transferred by wind or artificially and thus wind does not play any significant role in pollination.

3.3.3. Breeding Objectives

Existing varieties are good in quality and production but suffer from many problems such as alternation in bearing, malformation, fruit drop, susceptibility to various insects pests and diseases.

- Improvement in yield, fruit size, total soluble solids and fruit color.
- Reduction in acidity, fiber content and long shelf life.
- Incorporation of dwarf-ness, regularity in bearing, uniformity in ripening, late in cropping season and immune to fruit drop.
- Resistance to various insects pests and diseases.

3.3.4. Methodology Adopted

During the flowering season of each year, 3000-9000 flowers were crossed. Before the onset of crossing, the healthy inflorescences were selected. The lateral flowers were trimmed off leaving about 200 unopened flowers at the tip of each rachis. The selected panicles were bagged with muslin cloth ringed bags. Before crossing, the anthers were collected early in the morning in petri dishes with the help of fine-headed sterilized forceps. Then these anthers were placed for three hours in incubator at 25 °C to become dehiscent. After three hours the androecium of each variety were :removed from the incubator and stirred in 10ml of 5% Glucose solution at the magnetic ,stirrer; After five minutes of stirring, the availability of the pollen grains in Glucose solution was confirmed under the microscope. Then this solution was kept overnight and on the next day at about 8.0 a.m. the muslin cloth bags were removed and the opened flowers were pollinated with the help of fine cosmetic camel hair brushes by placing one drop of the prepared pollen solution in the cup of petals on the stigma. After the completion of pollination of all the flowers, the bags were permanently removed and the crossed panicles were tagged accordingly.

From the year 1989 to date the following crosses have been made among different elite varieties of mango:

Anwar Retaul	vs	Sanglakhi
Sanglakbi	vs	Anwar Retaul
Langra	vs	Suwamareeka
Suwamareeka	vs	Langra
Sensation	vs	Chaunsa
Chaunsa	vs	Sensation
Dusehri	vs	Neelum
Neelum	vs	Dusehri

After harvesting the hybrid fruits, the stones were sown under intensive care. Up till now 30 hybrid mango plants {FI) have been produced at Mango

Research Station Shujabad, which are passing through the juvenile phase. However, the following hybrid of mango have given very encouraging results.

Characteristics of the Hybrid Mango (Neelum x Dusehri)

Sr. No.	Salient Traits	Hybrid (F1) Neelum x Dusehri	Parents	
			Neelum	Dusehri
1.	Year of cross	1994		
2.	Time of ripening	25th July	20th August	10th July
3.	Bearing habit	Regular	Regular	Regular
4.	Shape of fruit	Oblongish ovate	Obliquely ovate	Elliptical oblong
5.	Av. Weight per fruit (g)	306.0	141.0	210.0
6.	Position of shoulders	Ventral higher than dorsal	Ventral broader and higher than dorsal	Nearly leveled
7.	Back of fruit	Roundish	Roundish	Flat and slightly roundish
8.	Basal sinus of fruit	Shallow	Slight	Wanting
9.	Beak of fruit	Roundish obtuse	Point only	Point only
10.	Apex of fruit	Roundish	Roundish	Obtuse
11.	Color of fruit	Capusine yellow	Capusine yellow	Light Yellow
12.	Surface of fruit	Smooth	Smooth	Smooth
13.	Colour of pulp	Cadmium yellow	Primuline yellow	Cadmium yellow
14.	Taste of fruit	Very sweet	Delightful	Very sweet
15.	Presence of fiber	Very scanty	Absent	Absent
16.	Shape of stone	Ovatish round	Roundish	Elliptical
17.	Av. Weight of stone (g)	30.0	35.0	37.0
18.	Body of stone	Medium and thin	Thin	Thin
19.	T.S.S. of fruit (%)	20.0	17.0	24.0
20.	Acidity of fruit (%)	0.19	0.21	0.19

Characteristics of the Hybrid Mango (Chaunsa x Sensation)

Sr. No.	Salient Traits	Hybrid (F1) Chaunsa x Sensation	Parents	
			Chaunsa	Sensation
1.	Year of cross	1995		
2.	Time of ripening	25th July	End of July	First week of Sepctmber
3.	Bearing habit	Regular	Alternate	Regular
4.	Shape of fruit	Ovatish round	Oblongish ovate	Obliquely flattened
5.	Av. Weight/fruit (g)	290.0	340.0	275.0
6.	Position of shoulders	Ventral higher than dorsal	Ventral slightly higher than dorsal	Almost leveled
7.	Back of fruit	Roundish	Roundish	Roundish
8.	Basal sinus of fruit	Absent	Slight	Slight
9.	Beak of fruit	Pointed	Much varied	Point only
10.	Apex of fruit	Obtuse	Round to pointed	Acute to roundish
11.	Color of fruit	Creamish yellow	Sea green to canary yellow	Yellowish
12.	Surface of fruit	Smooth	Smooth	Smooth to slightly coarse
13.	Colour of pulp	Maize yellow	Cadmium orange	Cadmium yellow
14.	Taste of fruit	Sweet	Sweet	Mild
15.	Presence of fiber	Scanty	Much	Very scanty
16.	Shape of stone	Ovatish	Oblongish ovate	Roundish
17.	Av. Weight/stone (g)	45.0	38.0	40.0
18.	Body of stone	Full and thick	Full and thick	Thick and full
19.	T.S.S. of fruit (%)	23.0	27.0	18.0
20.	Acidity of fruit (%)	0.19	0.16	0.21

When transplanting into the field top soil fortified with 40 to 50 grams of commercial fertilizer or a shovelful of well-rooted manure or compost is mixed into the planting hole. Soil is firmly packed around the roots and then well watered. It is a good idea to cover the soil with a mulch to conserve moisture and maintain a cooler temperature.

4.1.2. PLanting Distance

Fruit production on mango tree is mostly on the outer canopy of the tree. For this reason growers in Florida plant very densely.

This closer spacing coupled with regular pruning gives us more outer canopy per hectare. It is important not to allow side branches of adjacent trees to overlap, as this results in fewer fruits per unit area: those produced are usually poorly coloured because of less exposure to sunlight. Over crowding, because it results in higher humidity in the micro-climate around the fruit and makes spray coverage difficult, results in more diseased fruits.

Trees are planted in a north to south orientation for best exposure to the sun. Varying distances between trees and rows are used. Many growers in Florida use 5' x 8 meters and hedge and top the trees annually after harvest. AT these close distances unless this sort of pruning is practiced at least every other year (some growers will prune one side one year, the other side the next), trees will lose their lower leaves. Leaf loss at close planting distances is due to insufficient light levels. As trees grow taller, adjacent rows will shade one another. Growers who do not hedge and prune will often remove every other tree in the row as trees mature, resulting in 8 x 10m spacing.

In drier countries, or in areas without irrigation, wider spacing is necessary in order to decrease competition between trees for the limited amount of water. If growers use flood or ditch irrigation they could plant 7 m x 8 m or 7 m x 7 m and top and hedge on all 4 sides. To prevent shading the height of the trees should not be more than two times the width.

4.1.3. Cultivation

Herbicides are usually used in the row to control weeds which compete for water and nutrients. Mowing is commonly practiced every 6 to 8 weeks. Hand Hoeing may be more practical in small groves and where labor costs are not excessive as they are in Florida.

Cover crops must be controlled the year round by herbicide or mowing. Mulches of dead weeds and grass can be used to help keep down weeds and maintain soil moisture.

4.1.4. Nutrition and Fertilization

Fertilizer programs vary greatly in mango orchards, being primarily dependent on soil conditions, and tree size. Young trees beginning to bear might receive ½ kilo of nitrogen to provide for tree growth, or 1 kilo for mature trees. Nitrogen is easily leached from Florida's non-organic soils. Phosphorus is used in relatively small amounts as compared with nitrogen and potassium. It is not so rapidly leached from the soil, and for this reason only ¼ the amount of nitrogen is sufficient.

Potassium is important in growth and yield of fruit. Because there is considerable loss due to rainfall, it is applied in quantities slightly higher than nitrogen.

Microelements are important on Florida's calcareous soils. Magnesium usually included at the rate of 15 to 20 percent of the potassium. Manganese, zinc and copper are needed in trace amounts. Manganese and zinc are applied as foliar sprays. Iron deficiency is controlled by soil applications of chelated iron when necessary.

In Florida approximately 4 to 5 kilograms per year of a formula such as 8-2-10-3 is commonly applied to young trees; I2 to 15 kilogram per tree per year to mature bearing trees. It is important to have sufficient nutrients especially nitrogen in the sol during late spring and summer to promote strong shoot growth uniformly over the tree. Fertilizer is applied in one to three applications in the late summer just after harvest and pruning. It is spread uniformly from the trunk to a few feet beyond the drip line. As trees develop the area fertilized is increased gradually until the spread is from trunk to trunk.

4.1.5. Soil pH

It is advisable to maintain the pH between 6 and 7 on acid mineral soils by applying dolomite or high calcium limestone. This will probably require 1000 to 2000 kilograms per hectare.

4.1.6. Leaf Analysis

Foliar analysis is an important aid in proper planning and diagnosis of potential deficiencies. Desirable ranges of 5 mineral elements in mango leaves have been established for nitrogen (1.0 to 1.5%), phosphorus (0.8 to 175%), potassium (.3 to 8%), calcium (3.0 to 4.0%) and magnesium (.15 to .40%). Samples for foliar analysis are taken from the middle shoots; and consist of 30 to 60 leaves for every 4 hectares. These samples are taken from the summer or fall flush prior 1o, rather than noon after, fertilizer application.

Conditions in Pakistan are considerably different from those of Florida, where soil organic matter is lower and rainfall considerable higher than here. Recommendations will also vary according to the soil nutrient levels here which are almost certainly higher than in Florida.

4.1.7. Pruning

Until bearing trees start to crowd each other it is only necessary to remove dead weeds and branches weakened by diseases or broken by heavy winds. Large cuts can be protected from sunburn with white latex paint. Training for young trees by pruning may be desirable with certain varieties which spread irregularly with long branch growth. In such varieties back and trimming side branches will give a stronger and more symmetrical framework.

To prevent over crowding, pruning is done regularly unless every other tree is removed from the row. Trimming can be done from ladders with chain saws or with power saws from hydraulic lift picking machines. Most commonly heavy self-propelled hedging and topping machines are used. Pruning is done in July and August as soon as possible following the harvest. If growers wait much later, they risk removing foliage that would be productive for next years crop. The equipment for pruning the sides of trees consists of several large circular blades attached to an arm which can be adjusted to cut at various angles. Some machines have two arms attached to either side of tractor-like heavy equipment machinery that prunes both sides of the middle of row while making a single pass. Middles are opened to a width of 2 to 2.5 meters at the bottom and 4 meters at the top. Topping is done with a machine carrying a large single rotary blade at a height of 5 to 5.6 meters. The resulting trapezoid shape gives better exposure to sunlight along the canopy without shading the lower branches. The large amount of resulting brush can be shredded and used as mulch.

Pruning in this manner gives better light penetrating inside the tree so as to improve flowering. A greater percentage of fruit gets well coloured from exposure to sunlight. The fruit also has less disease problems because spray coverage is improved when the canopy is less dense.

These trees would be considered short by Pakistan standards, but height below 8 meters is preferred by our growers because trees are easier to harvest and spray. With our humidity problems it is necessary to spray with fungicide every 14 days. Fruits in the tops of unpruned trees at greater height will not be well-covered by fungicidal spray. Resultant anthracnose makes fruit unsalable.

In countries where labor is less expensive and mechanical equipment unavailable, pruning is practiced differently and consists of removing a few major branches from the inside, and a few from all around the tree, allowing penetration of light to the inner canopy. Terminal clusters of shoots and young flushes of leaves should be thinned from the commonly found 3 to 5 down to 1 or 2. This is done all around the periphery and inside the canopy. This practice has been found especially productive for trees between 20 to 50 years of age. Yields are reported to increase several fold, and alternate bearing is reduced or eliminated. Quantity, size and appearance of fruit all improve as a result of this practice.

Timing of pruning is very important. It should be carried out approximately 4 to 4.5 months prior to the anticipated time of flowering.

4.1.8. Irrigation

Young groves benefit greatly from a high level of soil moisture near the roots through irrigation when, rainfall is not sufficient. Growers in Florida commonly use Micro-jet sprinklers or drip irrigation.

Growers in other countries dig shallow basins around each tree trunk to confine water delivered by flooding. Frequency of flooding is reduced once trees are established.

A dry period preceding flooding helps induce heavy bloom on bearing trees. For this reason growers will often stop irrigation several months before bloom and begin again only after fruit set.

4.1.9. Production and Yields

Although grafted mangoes will bear some fruit in the first and second year after planting, it is advisable to remove these early fruits to encourage vegetable growth.

Productivity of a particular variety in a given year depends on a number of factors -weather, consequent flowering during the bloom period, control of pest problems, fertilizer program, pollination and of course the particular variety. Thirty to thirty-five tons per acre are common with Tommy Atkins, Kent and Keitt varieties.

4.1.10. Timing Harvest and Harvest Practices

The correct date for harvesting mangoes in Florida varies each year according to the time of bloom, and daily temperatures during the developmental period. Most fruit from a particular variety will be harvested over a 3 to 4 week period. Usually beginning in mid June for the early varieties, and terminating in mid August for the late varieties.

Unlike many fruits, acid or sugar content is not a reliable test for maturity. The usual practice is to harvest fruit when there is a change from green to yellow or purple in the ground colour of the skin. This generally occurs 15 to 20 weeks after hloom. Many growers feel that the optimum time to pick a fruit is when the stem end is plump and well filled out. At this time the fruit inside near the seed is yellowish in colour rather than white. In Florida, where successive bloom cycles result in fruit at different degrees of maturity, a single tree should not be stripped in two or three harvests; ideally, it is picked 6 to 10 times over a three to five week period.

Careful handling at all times is essential for preventing losses. Fruit picked by hand either from the ground or from a ladder or platform is shaped from the stem. If part of the stem is still attached, it is removed by hand to prevent damaging adjacent fruit when placing it into the picking container. For picking fruit out of reach, long picking poles are used. A metal hoop with a canvas bag is attached to the distal end of a pole 5 to 7 meters long. Inside the hoop at the farthest end is a blade which severes the fruit from the stem, allowing the mango to fall into the bag.

After picking 3 to 6 fruits, the bag is lowered into a picking bucket or crate. Fruit which falls to the ground will usually ripen unevenly due to bruising. This bruising shows up much later, and is usually not evident when packing. For this reason it is important to supervise picking and he sure that harvesters do not shake fruit from the branches, or place dropped fruit into the same harvest buckets.

Larger farms or even small farms contracted with packing houses use self-propelled cherry packers, machines controlled by one operator on a hydraulic lift platform. Workers can move in several directions when picking the trees. Fruit is plucked by hand, and placed in a canvas bag about one meter deep for later transfer to bushel field or bulk bins of approximately 20 bushels.

Fruit which is newly harvested should not be placed in the hot sun, rather in the shade under nearby trees. In Florida it is transported in open trucks to nearby packing sheds. If the trip to the packing shed is more than twenty minutes from the field, the tops of crates or bins should be loosely covered to prevent excessive heat buildup in the fruit.

If ambient temperatures are excessive, as they usually are during the summer months in the tropics, and distances are such that the trip from the farm to the packing takes several hours, fruit should be transported in refrigerated trucks.

4.1.11. Grading and Packing

Before talking about grading and packing, we should briefly mention two physical characteristics peculiar to each variety which determine shelf life. These are fibre and thickness of the outer skin. Consumers prefer to eat mangoes with very little fibre, but commercial shoppers prefer varieties with at least a moderate degree of fibre because it helps maintain the shape and original form of the fruit. Fibre keeps fruit from collapsing when shipping over long distances, and helps prevent it from becoming mushy when bruised.

Preparing fruit for packing usually consists of bringing it to a packing louse where it is washed by mechanical brushes, and sent by conveyer to computerized or automated sizers. Along the way to the sizers, bruised, over ripe, under ripe, scarred, scratched, spotted, and malformed fruit is removed by hand. These culls are sold in local markets

In less sophisticated packing houses, fruit is delivered to grading tables where it is selected by hand and packed into cartons. It is then placed onto pallets, transferred into cooling rooms, loaded into refrigerated trucks within 48 hours.

It has been found useful to treat fruit at 55 °C for three minutes to control anthracnose, the most serious post-harvest disease of mangoes. It is then cooled prior to packing.

Mangoes are packed in ventilated corrugated cartons, referred to as flats or lugs. Most shippers do not line the cartons to prevent bruising, but pack them snugly to prevent them from rolling about. Growers in some countries use polyethylene sleeves wrapped around each fruit for added protection.

To enhance the appearance of fruit, many shipper will place brightly coloured stickers on the fruit. This is especially useful for dull coloured varieties which lack eye appeal.

Inside dimensions of cardboard flats are 34.6 cm x 28.7 cm wide x 10.3 cm deep. The carton should be strong enough to withstand handling and transfer involved with export marketing. A carton with bursting strength of 250 pounds per square inch should be sufficient.

The number of fruits that fit into a carton varies with the shape and size of the fruit. Our market prefers a size twelve, but will accept some fruit as small as size sixteen. Fruit in the box must be of the same variety, uniform in size and degree of maturity. It should fit snugly in the box and weigh as much as is indicated on the side of the carton.

All cartons of fresh agricultural produce should bear the name of the country, the name of the product, and the net weight. Mango cartons should also indicate the name of the variety and the number of pieces of fruit in the carton.

4.2. RESPONSE OF MANGOES TO DIFFERENCES IN CLIMATE AND SOIL CONDITIONS

Dr. Saeed Ahmed, Kr. Daud Ahmad Khan and Mr. Waseem Ahmad

4.2.1. Climate

Mango is a fruit which can be grown at different heights ranging from sea-level to an altitude of 5,000 ft. Due, to its tenderness to cold it is mostly limited to tropical climate.

In areas of heavy rainfall like Bombay mango can be grown without irrigation but at places where rainfall is less than 80 inches per year, irrigation is required for its cultivation. Its success becomes doubtful if the flowering period has disturbed weather such as rain, cloudiness and frost. Total amount of rainfall is not as important as the season during which it occurs. Where dry season coincides with normal flowering, a good crop can be expected. Rainfall is highly detrimental during blossoming season as it hampers with the bees activity, dilutes the stigma secretions, washes away the pollen and cause it to remain damp thus resulting in low setting of fruit. Bad weather at the time of blossoming is to a great extent responsible for bringing into operation the vicious circle of alternate bearing in mangoes.

In humid, regions mango trees are in ragged appearance, with unhealthy foliage and the fruit does not ripen well. A dry and hot season is required at the time when fruit ripens. Mango is very susceptible to frost and hot winds. Susceptibility to frost varies with age, variety and health of the plant. Younger trees up to the age of 4-5 years should be protected, from frost and hot winds. Young trees in growth are damaged by a low temperature of 290 to 310 F. Trunks of the trees should be covered with dried grass, straw or gunny bags. Trees should be wrapped before frost danger threatens and wrapping material may be removed as soon as the danger of frost is over. No doubt climate Influences flowering; but greater differences occur in period of flowering in different regions. Main crop in Madras (Hayes, 1953) ripens from May to July, while late varieties ripen from July to November. Mango blossom generally appear during December to March. There are some varieties of mangoes which have no definite time of flowering. They bloom more or less throughout the year. In Florida where winters are milder blooming in certain varieties can be seen even in December and January. However in West Pakistan it is not earlier than February and March. In Sind areas the mango season commences in May and drops away in July. However peak of mango season reaches late June till July. There are varieties which will even ripe in the month of August and September.

Constant temperature is very important during ripening period. G. N. Collins states "The fact that the tree may thrive in a given locality and yet fail to produce fruit should always be kept in mind. It may be considered as proven that the mango will be prolific only in regions subjected to a considerable dry season. On the moist north side of Porto Rico the trees grow luxuriantly but they are not nearly so prolific nor is the fruit of such good quality as on the dry south side. In Guatimala and Mexico the mango was found at its best only in regions where severe dry seasons prevailed".

4.2.2. Soil

Mango prefers deep, rich fertile soil because of its long tap root system. Mango may be found flourishing on wide range of soil. In Florida (U.S.A.) .it thrives on a wide variety of soils. Trees become huge on the lower coast, where the soils are deep sandy loam.

In India mango is seen to grow on laterite soils of Ratnagiri, Goa, and in black medium soils of Thana, Surat, Poona and Satara to heavy deep black soils of Solarpur and Bigarpur districts. Luxuriant plantations are also found in alluvial loams of United Provinces, Bihar and Bengal. Poor rocky light loam soils of the hilly and lower mountainous regions. In brief it can be said that mango relishes deep alluvial and well drained soils. Excessively sandy soils weaken the tree and lessen the quality, size and quantity of the fruit produce. Soil reaction' is important than soil type. In Florida for profitable citrus fruit production maintenance of pH of the soil between 5.5 to 6 is recommended.

The maintenance of pH value in this range is brought about through the use of soil amendments. In sandy acidic soils pH is raised by use of dolomite limestone whereas on calcareous soils efforts are made to lower pH by use of acid forming' fertilizers. On calcareous .soils crops show up the deficiencies symptoms of copper, manganese and zinc. In these soils elements even if present in the soils are not present in the form available to plants. In soils addition of these elements does not help the plants, due to high pH value of the soil. These elements arc therefore supplied through foliar sprays.

Mango in Pakistan is large being grown on soils with high pH value in most of the cases pH value being more than 8.5 Deficiency of micronutrients of such soils is therefore a natural phenomenon. The efficiency of such grove will increase many folds if they al sprayed with micronutrients such as zinc copper and manganese at least twice year- three pounds of copper sulphate four pounds of manganese sulphate an two pounds of zinc sulphate per 10 gallons of water, is tentatively suggested as dose per application. Spraying ma be done in the months of April and September.

4.2.3. References

1. Hayes, W. B. J.953. Fruit Growing in India.
2. Chandler, W. H. 1958: Evergreen Orchards.
3. Popenoe, W. 1939: Manual, of Tropical and Sub Tropical Fruits.
4. Cheema, G. S., Bhatt, S. S. and Naik, K. C. Commercial Fruits in India.
5. Lynch, S. Jand M. J., Mustard- Mangoes in Florida. Department of Agriculture Thallahassee, Florida
6. ________ Porto Rico Agri. Expt. Sta Bul1. No. 24.

4.3. MANGO ORCHARD LAYOUT, PLANTING AND AFTER CARE IN PAKISTAN

Dr. Saeed Ahmed[2]

4.3.1. Planting and Layout

Unlike other annual farm crops, a mango tree occupies the land for many many years. It is, therefore, very important that every care should be taken in the planning and layout of the mango orchard. Since in the following years it will not be possible to remove any mistake committed at this time. The following points should be kept in view for ascertaining good results

1. Selection of site and preparatory tillage.
2. Actual layout of the orchard.
3. Proper spacing and digging of pits.
4. Selection of grafts and their planting.
5. Aftercare of young plants and intercultural operations.

Layout: Proper layout of an orchard is essential for sound foundation and strong building. If any mistake in laying out is committed that will count for the whole life of mango plants and the loss will go to the owner of the garden for whole life. Therefore very careful planning is necessary before the actual layout in the field.

Before planting the orchard, it is necessary to reserve some space for planting trees to serve as wind breaks on the sides from which high winds and frost are expected. These trees may be tall with dense foliage and keep the surrounding atmosphere humid. Wind break trees reduce the wind velocity and bring down the high rate of evaporation by inducing low rate of transpiration from leaves and shedding of immature fruits is also thus minimized. The following systems of layout are used by the growers for planting orchards. The square system is convenient to follow and is generally used.

Square System: This is the simplest and easiest method of laying out a garden. Row to row and plant to plant distance is kept equal so that the inter-culture of the garden be-comes easy. Small sized crops can be grown easily. The total number of plants that can thus be accommodated in an acre of land with the distance commonly allowed between one trees to another are given below.

Distance between plants in ft.	Area for each plant in square ft.	Number of plants per acre.
35x35	1225	35
37x37	1369	32
40x40	1600	27
45x45	2025	21
50x50	2500	18

Rectangular System: The layout is almost the same as in the square system with the only difference that the distances between the rows and plants differ according to the length and breadth of the field.

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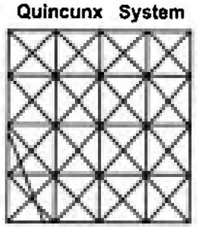
Quincunx System: The layout is as in the square system with an additional temporary plant in the centre of four permanent plants. This method of layout is useful when intercropping is not aimed at.

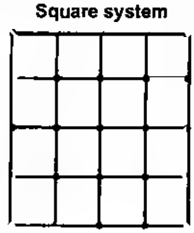
Triangular or Hexagonal system: This layout accommodates approximately 15 per cent more trees per acre than the square system. The distances between rows and plants are equal and all space is properly utilized.

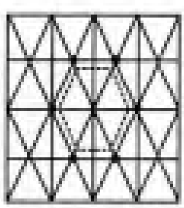
The object of planning the orchard is to space the trees at suitable distance from each other to allow sufficient space for the normal development of plants and at the same time keeping in view that inter-cultural operations are undertaken easily and allow easy passage of sunlight for the maintenance of orchard sanitation. The distance between the trees varies according to soil fertility and texture. However for grafted mango trees the distance ranges from 35 ft. to 45 ft. even upto 50 ft., which is determined by variety, soil type and climatic conditions. In Florida, close spacing and accommodating large number of plants per unit are is being advised.

Quincunx System

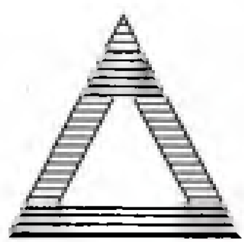


Square system





Hexagonal System



Planting Triangle

4.4. CULTURAL OPERATIONS

Most of the mango orchards in the country have not been planted on any systematic and scientific lines. Mango trees are usually in poor conditions of growth and present a devitalized look. Main defects are selection of unsuitable soil and varieties, improper spacing, manuring, irrigation and interculture. Proper knowledge of different cultural practices is essential for the successful cultivation of this important fruit.

Planting: Before planting, pits 3 x 3 x 3' are dug at the site and kept open for a period of about a month. These pits are then filled with equal quantities of well-rotten farm yard manure, silt and upper 6 to 9 inches of soil. Size of the pit may be increased if the soil is clayey, impervious or has gravel.

Mangoes are generally planted in the field during the rainy season or just after it i.e., August to mid October depending upon the locality. They are also planted during February-March. There are certain drawbacks in both the planting seasons. Hot and dry winds during May and June, coupled with shortage of irrigation water may cause splitting of bark especially on the south western side. The common practice therefore followed is that bananas, janter or some other kind of plants are planted to provide partial shade. Sometimes earthern "gamlas" about 3 feet high are made around the plant. This practice has additional advantage of protection against animal damage. There is very short growing period for the plants planted during August-October.

It is necessary to plant windbreaks to provide protection from hot desiccating winds, cyclones, wind storms, frost, etc. Windbreaks should be planted on the side from where damage is expected by winds. Tall growing trees like sheesham, Jaman or seedling mangoes should be selected for the purpose and should preferably be planted a year or two earlier.

Plants should be obtained from a reliable source from the same locality. The grafts should be correct, with strong union, free of disease and in large pots. If the grafts are not planted in the field within the next six months, they should be shifted to bigger pots. The mango is sensitive to root cutting for transplanting. For this reason sometimes seeds are planted at position and seedlings are budded in situ with the desired variety. Planting may be done by hexagonal or square system. Although by the hexagonal 15% more plants can be planted out actually most of the growers follow square system. It is easy to interculture and intercrop an orchard planted by this system.

Distance of planting may vary from 35 to 50 feet depending upon the soil, locality and the variety. Varieties like Aman dusehri require a spacing of 35 feet, whereas Langra should not be planted at a distance less than 45 to 50 feet.

It is better to plant early, mid-season and late varieties so that the supply is maintained for a longer period. Early and late varieties fetch handsome income. Varieties should be such which command a ready market, have a non-fibrous pulp, good flavour and taste, small stone and good keeping quality. Above all they should be hardy, resistant to disease and insect pests and high yielding.

Frost Protection: Protection against frost is necessary during the first three or four years where winters are severe. If the young trees are not protected they may be killed outright. The cover is provided on all sides except the south east side and the thatch is brought together and tied on the top. During the next two or three years only trunk and main limbs are covered by wrapping the gunny bag pieces, or dry grass. This ensures protection in case of exceptionally severe frost which may cause death of 4 to 7 year old trees. Covers and wrappings are removed in February when there is usually no danger from frost.

Cultivation: In the early life of the plant, protection from hot and dry winds and frost is necessary. Growing of medium sized crops like tobacco and cotton have proved beneficial in districts where summers are severe. Such crops provide partial shade which is required for the healthy growth of the young plants.

Direct sun rays injure the bark on the south-western side of plant and cause it to split. Trunks of plants are sometimes white washed to avoid this injury. Intercropping gives income during the non-bearing period and indirectly assures regular irrigation, manuring and culture of the orchard. Any vegetable or leguminous crop, like gram, berseem or peas can be grown as intercrop. While Intercropping newly planted mango orchard, care should be taken that crops which grow too tall and thus overshadow the young plants or require too much irrigation should not be grown. The cultivation of deep-rooted vegetable near the trees should also be avoided because their roots will hinder the development of mango roots. While intercropping an orchard care should be taken that no sowing is done close to the tree so as not to deprive them of nourishment. To be on the safe side an area of one to two feet, around the spread of the trees should be left unsown.

As the trees grow in size the area for intercropping decreases accordingly. After about 10 to 12 years it is not possible to intercrop a mango orchard. The shade of the trees will not allow the crops to grow properly. At this stage regular cultivation is essential. A number of ploughings' are necessary to keep down weeds. Underneath the spread of the trees where ploughing is not possible, hoeings with spade should be done. Ploughing regularly, ordinarily once in winter, at the beginning of monsoon and in October or November is recommended, by Sen and Hayes (1945).

Experiment conducted by Burns and Prayag indicated that the trees give better crop each year when the soil is dug than when it is not cultivated. In another experiment conducted on different varieties Sen found that uncultivated trees were in poor condition and that at least three ploughings a year were necessary for good health.

Irrigation: During the first 3 or 4 years plants require frequent irrigation especially during hot and dry spells. Some authorities have recommended irrigation as often as every 2 or 3 days during the first dry period. This, however, seems to be too frequent. Copious irrigation at greater interval is to be preferred to frequent wetting of surface soil. The irrigation requirements of small trees and those bearing fruit are different. The young trees should be watered according to the season and the moisture in the soil. Ordinarily watering after about 10 to 15 days time is considered sufficient except during hot and dry months of May and June when it may be necessary to irrigate too frequently. In case of bearing trees the heriviest irrigation should be given from the time when flower buds are about to open until several weeks after the fruiting is over, withholding large amount of water during 2 or 3 months preceding the flowering season (Popenoe 1939). Some authorities recommend complete stopping of irrigation after the harvest of the fruit. Main purpose of this practice is to discourage vegetative growth in order to encourage fruit bud formation.

Heavy and frequent irrigation after the fruit set helps to increase the size of the fruit and reduces the amount of shedding off fruit prematurely.

Manuring: Manuring the pits in which trees are to be planted is commonly recommended for the quick growth of the young plants. The problem of manuring the mango is intimately connected with its periodicity of bearing. The doses and the time of application of fertilizers should be planned in such a way that the tree gives a good crop regularly every year.

The general principle is to apply manure at the end of the winter season and before the advent of new growth. Artificial fertilizers are applied about 2-3 weeks and farm yard manure 5-6 weeks before the start of new growth and flowering. Manure should be uniformly applied up to the spread of the tree leaving a space of I to 1/3 rd. feet round the stem. Land should be thoroughly hoed in order to mix the manure well into the soil.

Pruning: Very little pruning is done in young as well as in old trees. In the early life pruning is done for training of young plants to build good shape and frame-work. Branches arising up to 2 to 2 1/2 feet from the main stem should be trimmed off. Efforts should always be made to keep the tree low headed and its stems should not be exposed to direct sun. As the tree grows, the top portion will tend to become increasingly dense, and it is desirable to do a little thinning to allow the sun to enter. A fully grown tree does not require any pruning, except the removal of broken, diseased or withered limbs.

4.4.1. Technology for High Quality Mango Production

M. Khan, Ch. Abdul Haq**, Dr. Ishfaq Ahmad*, Ikhlaq A. Khan***

Importance

Mango (Mangifera indica Linn.) is the second major fruit crop both in area and production in Pakistan. Mango is rightly called "The king of all fruits", not only due to its delicious taste and high flavour but also due to its dietetic value and being rich source of Vitamin C. The attractive and excellent products of mango are canned mangoes, mango juice squashes, jam, jelly, chutney and pickle. Its juice is used as additive in ice cream and confectionery items. Its timber is of high value. The mango orchards are contributing good impact on environment.

Area and Production

The area of mango fruit according to Agricultural Statistics of Pakistan 1998-99 was 93.5 thousand hectares and production was 916 thousand tonnes. The area and production of mango fruits in provinces of Pakistan are given below.

Suitable Climate

Mango is fruit of humid tropical region, where it is exposed to heavy rains throughout the year, but it definitely requires stimulus of dry season to fruit abundantly. Freedom from rain, clouds and frost during flowering period is of prime importance. Mango should not be grown commercially in regions, which are subjected to frost and severe cold.

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(Area '000 ha)

Year	Punjab	Sind	NWFP	Balochistan	Pakistan
1995-96	48.0	39.5	0.2	1.8	89.5
1996-97	48.1	40.3	0.2	1.8	90.4
1997-98	48.2	42.5	0.2	1.9	92.8
1998-99	48.4	42.9	0.2	2.0	93.5
1999-2000	48.4	43.5	0.2	2.0	94.1
Share of the Provinces	51.76%	45.88%	0.2%	2.1%	

(Production '000 Tonnes)

Year	Punjab	Sind	NWFP	Balochistan	Pakistan
1995-96	598.8	291.7	2.2	15.1	907.8
1996-97	602.4	293.5	2.2	16.4	914.5
1997-98	586.2	311.9	2.3	16.4	916.8
1998-99	582.8	314.6	2.3	16.7	916.4
1999-2000	603.8	3207	2.3	10.9	937.7
Share of the Provinces	63.59%	34.32%	0.25%	1.8%	

Selection of Proper Site

Mango can be grown successfully on a wide range of soils but deep and well drained sandy loam soil is most suitable for its cultivation. Stiff heavy and water logged soils should however be avoided. Soil with rich humus contents having pH 5.5 to 7.5 is an ideal for mango nourishment. Soil should be free from hard pan or sand layer up to 5 feet depth.

Propagation

In July-August well matured seeds/stones of ripe and juicy fruits are spread in well prepared nursery beds with a damp layer of well rotten farm yard manure. Water is sprinkled regularly to keep it moist. When the stones germinate and the leaves color becomes pinkish to greenish then the seedlings should be uprooted and planted in the nursery beds at a distance of 30-45 cm line to line and 22-28 cm plant to plant. After every fourth line, leave a distance of 60cm for ease in grafting and hoeing processes. After planting the nursery, it should be irrigated immediately. Healthy scion wood should be selected. Grafting season is March-April and July-September. Inarching, T. budding, Veneer grafting and T. grafting are successful in 'mango. Take intensive care of nursery plants. Plants will be ready after one year. Take out plants from the soil with earth ball 12-15 inches and wrap in gunny bag.

Layout

There are several layout systems used for mango plantation but most Common used are square and rectangular system.

Plant to Plant Distance

1. Dwarf varieties i.e., Sensation 20-24'
2. Medium size varieties i.e. Dusehri & Malda 30-35'
3. Large size varieties i.e., Langra and Chaunsa 40-45'

Planting Season

1. Spring March -April
2. Autumn September -October

Selection of Suitable Varieties

Following varieties have been recommended by the Department for early, mid and late season cultivation.

Early Varieties	Malda	Tree size large, maturity season early (June 4^{th} week),fruit size medium (180g), fruit colour pale yellow, with good aroma, pulp fiber less, TSS:23%,acidity:O.20%. Shy bearing cultivar.
	Langra	Tree size large, maturity season early (June 4^{th} week), fruit size L. medium-large (275g),fruit colour green, with fair aroma, pulp fiber less, TSS:27%,acidity:O.30%. Typically, alternate bearer.
Mid varieties	Dusehri	Tree size large, maturity mid season (mid July),fruit size medium (200g),fruit colour greenish yellow, fruit is slightly aromatic, pulp fiber less, TSS:25%,acidity:O.32%. Regular heavy bearing cultivar.
	Anwar Rataul	Tree size large, maturity mid season (mid July), fruit size small (130g), fruit colour pale yellow, with good aroma, pulp fiber less, TSS:23%,acidity:O.20%. Shy bearer as well as alternate bearer.
Late Varieties	Chaunsa	Tree size very large, maturity late season (August 2ndweek),fruit size large (280g),fruit colour deep yellow, fruit is good aroma, pulp fiber less, TSS:26%;acidity:O.20%. Heavy bearing cultivar with supreme quality fruits.
	Fajri	Tree size large, maturity season late (August 3^{rd} week), fruit size large (380g),fruit colour green, with poor aroma, pulp fiber less, TSS: 18%, acidity:O.21 %. Fruit is tasteless and used for milk shake only.

Irrigation

The quantity of water and its frequency would depend upon the climatic conditions, age of the tree, plant-"to-plant distance, system of 4cultivation followed, type of soil and method of irrigation.

Young Plant

S. No.	Season	Irrigation Interval
1.	Summer	34 days for nursery plants and 7 days for young plants.
2	Winter	10-15 days
3	Spring and Autumn	7 days

Bearing Orchards

1.	Flowering stage	March	Restricted irrigation
2.	Post fruit set to monsoon	April to July	irrigation i.e. thrice in a month Judious
3.	Monsoon	July to August	Twice a month if rains are moderate, no irrigation when rains are heavy.
4.	Autumn	September to October	Restricted irrigation due to bud differentiation.
5.	Winter	November to February	Light irrigation i.e., once a month but more frequently if there is danger of frost and after the application of GYM and inorganic fertilizers.

Nutritional Requirements

Fruit plants need a complete fertilizer programme, which is generally distinct and much different from annual crops. The following programme should be adopted. Soil type, soil fertility, precipitation, variety and age of trees determines the quality and frequency of nutrients.

Young Plants

Age of plant	FYM/Plant/Year	Ammonium Sulphate/plant
1st year	-	50g in four split doses
2nd year	10 kg	100g in four split doses
3rd year	15 kg	100-250 g from April to September after every alternate irrigation to get maximum vegetable growth.
4th year	20 kg	
5th year	25 kg	

Bearing Plants

Age of plant (year)	**FYM**	**Urea**	**S.S.P**	**S.O.P**
	Kg/plant/year			
6-7	30	1.00	1.5	0.5
8-9	40	1.50	4.5	1.0
10-12	60	2.00	4.0	2.0
13-15	80	2.50	6.0	2.5
Above 15	120	3.00-4.00	8.0	3.5

- FYM during August
- 1/2 Dose of Nitrogen, Full dose of Phosphorus and Potash in August.
- Remaining ½ dose of Nitrogen when fruit is at pea stage(April)

Micro Elements for the Bearing Orchards

Gypsum (Soil amendment)	10/kg/plant
Element Zinc(Zn)	Zink Sulphate
Ferrous(Fe)	Ferrous Sulphate
Magnesium(Mg)	magnesium Sulphate
Copper(Cu)	Copper Sulphate
Boron(B)	Borax
EACH @ 100 g PER PLANT IS APPLIED TO THE SOIL UNDER. CANOPY IN THE SEPTEMBER. Soil pH influences uptake of tree elements.	

Interculture : During the first 5 or 6 years, intercropping is recommended to meet the initial expenses.

Pruning : To provide healthy skeleton/good shape to the plant, pruning is required but after five years, only the crossed branches crowding the center of the tree should be pruned .off. Dead, diseased branches and malformed inflorescence should be removed and buried under or burnt.

4.5. NUTRITIONAL MANAGEMENT OF MANGO ORCHARDS

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4.5.1. Introduction

Mango is the choicest fruit, equally liked by young and old and is regarded as king of fruits. It is mostly eaten fresh and is also processed into various preserved products. Area under mango was 93.5 thousand hectares during 1998-99 which progressively increased from 57.2 thousand hectares in 1980-81. Likewise its production has increased from 546.6 thousand tonnes in 1980-81 to 916.4 thousand tonnes in 1998-99. Over the last about 20-years the acreage under mango increased by 63.5 per cent and production by 67.7 per cent, indicating only nominal increase in yield which was on average 9.8 tonnes per hectare in 1998-99 and this should be a matter of concern to both scientists and farmers. However, the yield in Punjab, which produces about 64 per cent of total production, was about 12.0 tonnes per hectare against 7.3 tonnes in Sindh. Considering the 20- year period performance one can take average yield for Punjab as 11.5 tonnes and for Sindh 7.5 tonnes per hectare and production 60 per cent and 40 per cent for Punjab and Sindh respectively.

4.5.2. Mango acreage and production

Year	Area 000 ha	Production Tonnes	Yield t/ha	Punjab		Sindh	
				% prod	Yield (t/ha)	% Prod	Yield (t/ha)
1980-81	57.2	546.6	9.6	50.1	12.3	48.9	7.8
5-yr av '85	66.9	649.2	9.7	59.0	11.7	40.0	7.8
5-yr av '90	79.0	732.8	9.3	63.6	10.5	35.5	7.7
5-yr av.'95	85.6	816.0	9.5	65.0	11.4	34.4	7.3
1998-99	93.5	916.4	9.8	63.6	12.0	-	7.3
Increase % /80-81	63.5	67.7	2.0	-			-

Source: Government of Pakistan, Agricultural Statistic of Pakistan, 1998-99, Ministry of Food, Agriculture and Livestock, Economic Wing,

Only five districts of Multan region i.e. Multan, Vehari, Muzaffargarh, Bahawalpur and Rahim Yar Khan produce about 75 per cent of Punjab's total production. In Sindh mango is largely grown in Mirpur Khas and Hyderabad districts.

Mango fruit besides local consumption has an important role in foreign exchange earnings. Pakistan's mango export share in world market is about 8 per cent and 85 per cent of its exports are to Dubai. However, export of mango falls far short of what it could be. Europe, UAE and Saudi Arabia constitute about 30 per cent of world imports; Pakistan could exploit this market

Pakistan's mango exports seem to be constrained by the lack of proper orchard management to grow quality fruit for export and improper grading and marketing abilities of exporters. With the recent incentives extended by the government for export of fruits, it is important to consciously make efforts for increasing share of mango in exports to South Asia, Gulf States and Europe.

4.5.3. Varieties and Agronomic Practices

Nutritional management of mango is closely related to varieties and their, agronomic practices. However, neither the precise information is easily available specific to varietal behavior and agronomic practices, nor the scope of this general paper allows this description. Nevertheless it is necessary for the fuller understanding of the subject. Keeping in view the title of the paper, only guidelines for nutritional management of mango orchards are provided.

4.5.4. Orchard Management

Before nutritional management of mango is discussed, it is important to remember that improving nutrition is a part of total orchard management practices. The aim of the grower should be to keep the fruit trees in perfect heath and vigour. Management of mango orchards varies greatly from grower to grower; while there are very progressive orchards one also finds orchards in a poor state of management.

Production technology of mango is mostly acquired through experience. The focus of studies in Pakistan has been on varietal performance and less on evolving production technology specific to varietal and soil-climatic-management factors. It would be worthwhile to standardize for farmers' guidance the varietal and area specific production technologies bringing out precisely the orchard practices leading to high yield and fruit quality.

4.5.5. Nutritional Requirement

It is complex subject and very little attention has been paid to it with respect to fruit orchards in Pakistan. Mango is not an exceptional to this apathy. Whatever information is available is mostly based on personal experiences and precise scientific data are lacking. In principle, the nutrition of food trees differs from annual crops in that fruit trees have a long pre-bearing season, have a deep and extensive root system, and have defined and distinct vegetative, flowering and fruit setting development phases.

Nutrient availability to plant is largely determined by soil and management factors which affect the plant ability to utilize nutrients from soil. Mango tree has a long taproot which can use moisture and nutrients from the deeper layer of soil even during drought. For successful orchard management an adequate supply of nutrients in the root zone has to be maintained.

4.5.6. Alternate bearing of mangoes

Alternate bearing or biennial bearing is a habit of fruit plants, bearing heavy fruit in one year (On year) followed by a year of lighter crop (Off year). While this phenomenon is serious in mango, it is also reported in fruits like apple and citrus. There could be a variety of factors for this phenomenon; nevertheless, it is generally conceded that proper nutritional management can minimize this problem. When a fruit tree produces a heavy crop in a season, it gets .exhausted nutritionally and is unable to put forth new flushes the following season. It is the earlier flushes during the April-May period, which bear major fruits as shown by the following data:

Name of flush	Number of flower in shoots %age)
April flush	36.7
May flush	29.4
June flush	19.8
July flush	11.0

Source: Muhammad Hussain, et al., Some practical steps to manage alternate bearing of mango, in Mango, the .Horticultural Foundation of Pakistan, 1991

Through nutritional and irrigational management it should be possible to produce more flushes earlier in the season to guarantee good harvest the following year. It is important that proper fertilizer application is done soon after fruit harvest during "On" years but not during "Off" year; this will encourage vegetative growth in the beginning of the next fruiting year. Once the tree is out of alternate bearing dilemma regular manurial and fertilizer management should be followed.

4.5.7. Soil and its Nutrient Status

Mango can adapt to a wide range of soils. However, a well drained deep alluvial loam soil, free from alkalinity is ideal for mango cultivation. Waterlogged, alkaline calcareous, sandy or shallow rocky soils are not suitable for successful mango cultivation.

Pakistan soils are generally calcareous and low in nutrients content and their availability to plants. Therefore, a proper fertilizer management program requires application of nitrogen, phosphorus and potash in appropriate and balanced quantities besides micronutrients, where required. Nitrogen and phosphorus in Pakistan soils are generally very low while potash is medium but it is required by fruit plants both for yield and quality. It is generally estimated that 5 tonnes/ha yield of mango removes from soil about 100, 25 and 110 kg per hectare of nitrogen phosphorus and. potassium respectively. Nitrogen is generally associated with vegetative growth and phosphorus with root development and fruit setting and ripening. Potash improves fruit quality and helps the plants to fight the adverse effects of drought, frost, salinity, attack of pest and diseases besides improving the keeping quality (shelf life) of fruits. Potassium also improves the colour and physical features of fruits.

While deficiency symptoms of nitrogen are visible and identifiable but of phosphorous are generally not seen in mangos. However, potash deficiency could exhibit in high yielding orchards in the form of margins and tips of preceding year's growth losing their green color and subsequently brown and dying. Leaves are smaller with narrow blades. Symptoms appear first on .older leaves and may finally spread to younger leaves. Typically leaf tip and margins become necrotic (leaf scorch).

Fertilization Practices

For fruit trees the first fertilizer application is in the pit when the soil is being prepared for planting. After planting, fertilizers are applied in increasing quantities as the plant grows and the dose is stabilized after five to ten years. The fertilizer dose should

- meet soil and plant requirements,
- consider age of the plant,
- the rooting pattern, and
- orchard practices management level

In growing fruit plants fertilizers are generally applied in two or more splits during the year depending on factors such as stage of growth i.e. vegetative, flowering, fruit set and onset of .rains. It is also important to identify the active root (feeding) zone of fruit plants for placing fertilizer. Roots grow downward and sideward and as such feeding zone expands as the fruit trees grow. Proper studies need be conducted to collect information on the feeding zone of individual fruit plants and their varieties under specific soil and management conditions.

4.5.8. At planting stage

Mango plants are generally planted during February-March during spring and September-October during autumn. However, spring season is preferred as the plants establish themselves before the onset of frost in winter and can withstand it.

When the pits are dug for transplanting mango it is necessary that phosphorus and potash are applied and thoroughly mixed with the soil which will fill the pit. Pits of 1 x 1 x 1 meter are dug at proper spaces, keeping the 30 cm top soil at one side of the pit. After two weeks the pits are filled with top soil kept aside, and equal quantity of farmyard manure and silt (*bhal*) besides fertilizers and properly mixed outside the pit. The surplus sub soil obtained from the pit is spread in the field. After Irrigation when the pits are in proper conditions the plants ale planted. A general dose of 0.5 kg each of DAP and SOP/MOP is recommended for a pit of 1 meter deep.

4.5.9. Upto five year stage

Fertilizer application to non-bearings plants would vary depending on the fertility of soil and basal application to pits at planting time. Application of nitrogen along with appropriate phosphorus and potash combination is important for inducing vegetative growth in this critical phase of the plant. In case basal application of phosphorus and potash was done, the dose can be reduced in the non-bearing plants.

Upto five year age plants, each of nitrogen, phosphorus and potash application may be around 0.250 to 0.500 kg per plant (say 1.0 kg each of urea and MOP/SOP, and 0.5 kg DAP/TSP) besides 10 to 20 kg farmyard manure. Phosphorus and potash rates would vary from 0.250 to 0.500 kg each (0.5 to 1.0 kg each of TSP/DAP and SOP/MOP) per plant, depending on the requirements of the soil and plants.

Remember that young fruit trees require well balanced NPK recipe which should be applied in three to four splits in a year.

4.5.10. Five to ten year stage

For five to ten year plants, the above doses of fertilizers may be increased by 50-100 per cent depending on the health of plants and the soil requirements. When phosphorus is 'being applied annually its build-up should be monitored through soil and plant testing.

In general, it should be kept in mind that the amount of nitrogen applied depends on the varietal requirement of trees and their appearance and health. Less nitrogen should be applied if the trees put on too much vegetative growth. Conversely, more nitrogen needs to be applied to trees failing to produce sufficient new shoots as a result of a heavy fruit crop or for other reasons. The amount of nitrogen varies between 0.250 to 1.500 kg per tree or more in years of heavy fruit set.

4.5.11. Bearing plants of 10 years old and beyond

Studies show that a bearing mango tree generally requires about 1.5 to 2.0 kg nitrogen (3.0 to 4.0 kg urea), 0.5 kg P_2O_5 (1.0 kg DAP/TSP) and 0.5 to 1.0 kg K_2O (1.0 to 2.0 kg SOP/MOP). The quantity of urea may be decreased in consideration of nitrogen present in DAP. Besides fertilizers, about 80 to 120 kg farmyard manure should be applied. However, these doses can be suitably adjusted depending on the health of plants and the nutrient availability status of the soil. For bearing trees it is essential to maintain a proper balance between nitrogen, phosphate and potash so, that, in general, the amount of potash should be closer to nitrogen.

4.5.12. Time of application

For non-bearing plants fertilizers are applied in several splits during spring, summer and rainy seasons. This helps avoiding nutrient losses since the root system of young plants is not extensive to utilize the entire quantity of nutrients.

For bearing plants, the proper time of fertilizer application is related to the production of vegetative flush, flowering and fruit bud differentiation. Generally four timings are recognized:

1. Eight to ten weeks before flowering i.e. end December.
2. Two weeks before flowering i.e. end February.
3. At fruit set i.e. April.
4. After fruit harvest i.e. July-August.

Farmyard manure and phosphorus is generally applied in December-January i.e. two months before flowering. Fertilizer application during rainy season prior to full fruiting year helps to induce flushes which will give fruit next year, thus ensuring annual bearing.

Some studies also indicate advisability of applying full quantity of nitrogen fertilizer along with hair quantity each of phosphorus and potash just after harvesting the fruits. The remaining quantities of phosphorus and potash may be applied during December.

4.5.13. Method of application

A precise knowledge of rooting pattern is necessary for scientific application of fertilizers. Studies show that affective root system of a mature mango tree is confined to a depth of 1.2 meter and extends upto 1.8 meter from the trunk (1.2 to 2.4 meter could be the range). Most of the feeding roots are observed at 3 depths i.e. 30, 60 and 90 cm, the maximum density being within 30 cm. It decreases with depth and laterally from trunk to the drip line.

For young trees, more than one year in the field, fertilizer should be spread uniformly over the root area extending from near the trunk to 60 or 90 cm beyond the canopy of branches. To full grown trees fertilizer should be applied 30 to 100 cm away from the trunk in a basin, ring or trench. Fertilizer is uniformly spread on soil a little beyond the canopy spread of the tree, mixed well with soil upto 30 cm depth and followed by irrigation. Or it could be applied in 30 cm deep trench or 15 to 30 cm deep ring near drip of the tree and mixed with soil, followed by irrigation.

4.5.14. Micronutrients

Zinc deficiency has been reported in mangoes by some workers. The symptoms appear first on the terminal flushed in the upper part of the tree. The leaf blade in early stages fails to reach the normal size and veins of leaves may become yellowish with interveinal normal green colour. Sometimes, irregular yellow pockets appear between the veins, giving a mottled appearance to the leaf. The affected leaf is brittle, turgid and thickened. The internodes of growing branches become shortened. In severe cases the subsequent flushes of growth may fail to appear and symptoms of die back or twigs maybe noticed.

Zinc deficiency can be corrected by foliar application of2.25 kg zinc sulphate and 1.12 kg lime in 450 liters of water in spring and autumn. A spray of 0.75 per cent zinc sulphate or 0.20 per cent zinc oxide is also recommended. Remember

- Not to spray during hot, windy period and against the breeze, and
- Not when rain is imminent.
- Peation of solutions should be alkaline.

Soil application of 150 gm zinc sulphate per tree can also be done. Besides zinc, the associated copper and iron deficiencies could also occur.

Mature leaves should contain at least 20 ppm Zn; deficiency symptoms appear when it gets below 15 ppm.

4.5.15. Tissue Analysis

Since soil volume tapped by roots of growing trees is considerahle, soil testing is only of limited help in formulating fertilizer recommendations for fruit plants. Leaf analysis coupled with soil analysis is considered the best approach for applying nutrients in proper quantities and balance. However, leaf analysis requtres standardized leaf sampling methods and critical nutrients values for developing recommendations. Leaves including petioles are collected from 4-7 months old leaves from middle of the shoot (samples should be taken in November).

Nitrogen content in leaves of mango decline with age. For maximum fruit production N content should be maintained between 1.20 to 1.50 per cent. Below 1 per cert nitrogen content deficiency may be suspected. Below 0.60 severe deficiency occurs. For phosphorus (P) the level may be maintained between 0.09 to 0.15 per cent and below 0.08 deficiency is suspected. A severe deficiency occurs when P content is $<$ 0.03 per cent. For potash (K) the limit for normal plant growth should be maintained between 0.80 to 1.00 per cent and below 0.50 per cent deficiency is suspected. Severe deficiency occurs when K content is $<$ 0.25 per cent.

4.6. WATER MANAGEMENT FOR MANGO DURING DROUGHT CONDITIONS

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The water shortage in certain mystified the farmers generally and mango growers particularly as the water stress during one-year affects the mango crop for at least couple of years. The infliction of the mango growers due to water shortage is many folds, during the year of water shortage the fruit drop is severe followed by pitiable cropping next year. Out of the total annual water need 80% is desired in April, May and June, to trim down the mango fruit drop, to augment fruit growth and enlargement and to promote satisfactory vegetative growth to make safe the next year crop.

It is a fact that the scarcity of water is not a routine matter in Pakistan so most of the growers are not even aware how to deal with the situation. Although know- how/practice is at hand to tackle the problem to some extant to curtail or moderate the unpleasant effects of the drought, yet the unconsciousness is playing the major role for these fatalities. As a first step farmers which do have tubewells or can arrange tube well as secondary source of irrigation should assemble the subsequent scientific information regarding the nature/properties of the tube well water from the Soil and Water Testing Laboratory, available in each district. Either this water can be utilized for irrigation during tough times or not? If yes then:

1. How many irrigations (safe limits) can be applied during a year?
2. How the adverse effects (if any) of the said irrigation water can be eliminated?
3. What ratio is safe when applied in mixed form with canal water?

The growers having above information can effectively/sensibly utilize the secondary source of tube well water to irrigate their mango orchards without worsening the land, plants and plants output.

The limited resources demands most justified scientific and appropriate use of water. The growers should always strive to pull off the following objectives while irrigating the orchards not only during the drought periods but also during ordinary circumstances to exploit the resources most efficiently.

1. Irrigate the maximum area from the limitted quantity of water.
2. Maximise the irrigation interval.
3. Ensure the water availablity in the root zone at proper time according to the plant requirements. 1. irrigate the maximum area from the limitted quantity of water.

The desilting of canals and minors at the Government level is a splendid move; the growers must carry on the same up to their field to diminish the water loss. Cleaning of water channels and keeping them straight is a most important step at Farm level to uphold the water stream/speed, which eventually minimize the water losses.

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The irrigation of unleveled field involve, a lot more water than leveled field, further more, light irrigation may not be feasible on the unleveled field. Therefore, land, leveling is a prerequisite to knock the above objective. Precision land leveling can be achieved by utilizing the Laser Technology, which is available for the growers with Agriculture Engineering Department. Always apply light or medium irrigation instead of heavy irrigation, the latter may be observed during the period when sufficient water is available, especially to leach down the excessive soluble salt in the soil, having high pH level.

When the quantity of water is critical then application of water out of the root zone is the loss of resources. So, irrigation should' be restricted to the root zone only, and observe the improved methods of irrigation like Modified channel basin system and Bund system to achieve maximum benefits from the limited resources. Almost whole the root system is confined to the area under plant canopy and further the initial three feet circumference around the stem don't have any feeding roots. So, irrigation must be confined to the area having feeding roots.

4.6.1. Modified Channel Basin System

The water channel is located in between the each two rows or lines and feed the plants on both side. To irrigate .the whole root system, the boundary of the basin is maintained, which encircle the area under the tree canopy and Keep the water 3 feet away from the main stem; for this purpose either make the "watt" or maintain the slope around the stem. Before each irrigation, the channels may be cleaned. The method is slightly laborious and cumbersome but it can save lot of water, which is required for rest of the mango plants at the same farm. Moreover, it also minimizes the chance of spreading of soil born fungi (for example the fungus causing quick decline of mango plants) if present in the orchards, from one plant to next one.

4.6.2. "Nali" or Bund System

In this system, the trees are connected by channels, and water is given to the plants through them. Installment and maintenance of this system is little bit less laborious and needs minute knowledge and this system is useful in the orchards having large- medium to small sized plants. While irrigating the orchard by this system, it is necessary to keep the water at least two week .away from the stem (makes the watt or maintains the slope around the stem) otherwise It may carry the Infection from one tree trunk to the next one.

4.6.3. Maximize the Irrigation Interval

The plants utilize very little quantity of the irrigated water, which is absorbed through the roots, supplies nutrients, utilized in photosynthesis and transpires through the foliage to maintain the plant temperature. The total amount of soil moisture present in the soil is not as important as its availability. Before dealing the further detail, it is imperative to introduce certain scientific terms, which would help to understand the soil moisture nature and losses.

4.6.4. Gravitational water

The water, which freely drains through the soil. Field capacity/capillary water: the state of soil when all the soil moisture that is able to freely drain away has done so. The remaining moisture is held by the forces of surfaces tension around soil particles and in capillary pores.

4.6.5. Hygroscopic water and chemically combined water

The moisture left in the soil but unavailable to the plant is known as hygroscopic water and chemically combined water. The hygroscopic water is held tenaciously by the soil in "atomically" thin films. The amount of hygroscopic water varies with the surface area of the soil particles, and is therefore highest in clay and organic soils.

4.6.6. Permanent wilting point

The moisture contents at which irreversible wilting occur is known as the permanent wilting poil1t.

The available moisture is the difference between the permanent wilting point and field capacity; this water is often referred as capillary water. It is retained in the smaller soil pores, where the capillary forces prevent water drainage. The soils differ in their ability to hold moisture and this ability depends upon their texture, which can be improved by the addition of organic matter (farm yard manure or green manuring).

After irrigation, the field attains the field capacity, when gravitational water drained out below the root zone. The water held at field capacity does not move down below the root zone. This water is utilized by the plants. The only loss at this stage is evaporation loss from the soil surface through fine capillaries. 'The water moves up through the capillaries from the root zone and escape form the soil surface. This loss is the most painful and can be minimized by the following methods.

4.6.7. Hoeing

After irrigation when the soil attains the friable conditions "wattar", the capillaries on the soil surface can be broken down by the fine hoeing. In this way, these capillaries do not lead the water to the soil surface/atmosphere and soil moisture is preserved in the root zone and utilized by the plants. The success to decrease or minimize the evaporation losses depends upon soil texture and fineness of the hoeing.

4.6.8. Mulches

The soil under the plant having feeding roots is covered with grasses, straw, hay, dry leaves, wood shavings, weed scrapping and wood saw dust. Principally mulches are utilized in the orchards to conserve the soil moister; in addition, mulches also regulate temperatures, control weeds, improve the activities of the soil microorganisms, and ensure nutrients availability etc. The preserved water then utilized by the plants for longer period and in this way the irrigation interval is increased. The plastic sheet are also used for mulching under the tree canopy from September to March, to preserve the moisture in the root zone and method is quite successful, but during summer increase in soil temperature may damage the roots, so plastic sheet must be folded in mid April.

4.6.9. Ensure the water availability in the root zone according to the plant requirements.

During 365 days of the year mango plants pass through different critical stages e.g. flowering, fruit setting, fruit development, vegetative growth and bud differentiation. These stages are very important from plant production point of view and dependent on the moisture level present in the root zone to show their critical impact on the fruit production at some specific time. Different moisture levels are required in the root zone at different times (stage) during a year. Flowering, fruit setting needs moderate moisture, fruit development and vegetative growth require high moisture levels and on the other hand bud differentiation demands low moisture level in the soil. So, growers should know exactly when and how much water is required for the mango plants to harvest maximum benefits. Following are the requirements of the mango plants, around the year, which clearly indicate the irrigation requirements generally and after mulching.

Time Period	Details of water requirements	General water requirements	Water requirements after hoeing/mulching
Feb-March	Moderate level of moisture is required during flowering and fruit setting	Once in a month	One irrigation only
April-Aug.	Optimum moisture is required to. regulate the plant temperature, reduce fruit drop, and enhance fruit growth and development and to ensure the vegetative growth	Twice or thrice in a month.	One irrigation is sufficient for four to five weeks.
Sep-Oct.	For bud differentiation moisture stress is required to discourage the vegetative growth	One irrigation is required only	Nil
Nov-Jan	Irrigation is required to protect the plant form winter injuries	Irrigation after one month	Nil

4.7. CONTROL OF WEEDS IN MANGO ORCHARD

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Generally it is considered that mango tree is a deep-rooted tree and weed cannot .compete with mango roots for nutrients and water. Actually, 70% of the feeding roots are present in 25cm of upper soil layer while most of the feeder roots go up to 50 cm. Only the tap root may go up to 6 meter that is mainly for mechanical support and provide absorption of water from deep layers of the soil. ,.

Weeds compete, easily with mango plants for soil moisture light and carbon dioxide. It can also affect soil temperature and obstruct the lateral water

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distribution from micro-irrigation systems. Thus reducing the efficacy of irrigation. Weeds also provide place for insect's multiplication and act as host for several disease pathogens. Detail of the weeds commonly found in mango orchards is given in the following table, however the kind of weed infestation/weed population composition varies form location to location and in different ecological zones. The growers should choose the control measure according to the condition prevailing there. Some times in orchards more than one' weed grow and problem becomes complicated.

The mango orchard field can be divided in two, as far as general management practices are concerned. The one area is the so called "working row area" which is the area between the rows in which most of the traffic movement is taking place. The second area is the so called "drip area" which is the area under canopy of the trees. Where very little traffic movement is taking place. As far as weed control is concerned different strategies are being followed.

Table 4-1. Showing Detail of Weeds in Mango Orchards

Sr. No.	Botanical name	English name	Common Name
1.	Amaranthus	Slender amaranth	Jonli cholai
2.	Chenopdium album	Lambs quarter	Bathu
3.	Convolvulus arvensis	Field bindweed	Lehli
4.	Cuscuta species	Dodder	Amarbale
5.	Cynodob dactylon	Bermuda grass	Khabbal
6.	Cyperus rotudus	Purple nustsedge	Deela
7.	Digera arvensis	Digera	Tandla
8.	Fumaria indica	Fumitory	Shahtra
9.	Heliotropim indicum	Heliotrope	Oont chara
10.	Melilotus indica	Sweet clover	Zard senji, sufaid senji
11.	Phalaris minor	Bird's seed grass	Dumbi sittee
12.	Polypogen monspeliensis (L)	Desf, Foxtail Fescue	Dumb ghass
13.	Protulaca oleracea	Common purshane	Qulfa, loonak
14.	Rumex obtusifolius	Broad leaved dock	Jangli palak
15.	Solani, nigrum	Black night shade	Mako, peelak
16.	Sorghum helepense	Johnson grass	Baru
17.	Trianthema portulacastrum	Crpet weed	Itsit, Boodal
18.	Tribulus terrestris	Puncture clover	Bhakhra

4.7.1. Strategies for Weed Control

Mechanical methods

Mechanical weed control includes plowing with cultivator, Rotavator, rotary cutter, and hand tools hoeing. There should be light hoeing under the trees because shallow roots can be damaged with deep hoeing. Mechanical hoeing with disk plough is not recommended because of damage to the soil structure and tree roots. Implement traffic near the drip area must be avoided.

Table 4-2. Registered herbicides for use in mango orchards

Chemical	Trade name	Active ingredient (g)	Dose/ha	Time of application	Remarks
Cycloxydim	Focus ultra	10 g/liter Ec	0.8-4 liter	Post emergeoce	Annual and perennial grasses. Apply L as full cover spray. Dosage depends oo grass species and their growth stage
Diuron	Diurex 800 SC Diuron 800 SC Diurna-Flo	800g/liter SC 800g/kg WP	4 liter 4 kg	Pre emergeace	Mainly annual broad-leaved weeds. Use only in established orchards. Apply onto clean-cultivated moist soil during the growing season. Repeat the application after 2-3 months if required.
Fluazifop-p-butyl	Grasses fusillade	125g/liter EC	2-3 liter	Early post-emergence	Annual and perennial grasses
Glufosinate	Basta	200 g/liter SL	2-8 liter	Post emergence	Annual and perennial grasses broad-leaved weed and yellow and purple nutsedge. Prevent spray contact with leaves, green stems and fruit. Dosage de ends on the size of the weeds.
Glyphosate	Glifngarde Glyphngan 360 Glyphosate 360 Clear Out Mamba 360 Profit 360 Ridder W. Killer Roundu	360 g/liter SL	2-8 liter	Post emergence	Annual and perennial grasses, broad-leaved weeds and yellow and purple nutsedge. Prevent spray contact with leaves, green stems and fruit.
	Clear Out 180 Cobra 180 Wins 180 Glyphosate 180 Spuiker 180 Swift 180 Sting	180 g/liter SL	1-6 liter	Post emergence	Annual weeds. Apply to actively growing weeds. Prevent spray contact with leaves, green stems and fruit.
	Roundup (Small) Glyphosate Acid Sunup360 Tumbleweed	240g/liter SL	1.5-2.25 liter 2.25-3 liter 3.4-5 liter	Post Emergeace	Susceptible weeds. Moderately susceptible weeds. Moderately resistant weeds.
	Stirrup	144g/liter AL	5-7.5 liter	Post Emergence	Annual weeds. Dosage depends on the growth stage of the weeds. Prevent spray contact with leaves, green stems and fruit.
			5-22.5 liter		Perennial weeds. Depends oa weed species. Prevent spray contact with the leaves, green stems and fruit.
Paraquat	Agroquat Avi Paraquat Gramoxone Paragone paraquat	200g/liter SL	1.25-5 liter	Post Emergence	Annual grasses and broad-leaved weeds use higher dosage for spraying dense weed growth. Avoid spray contact with the green parts of the trees.
Glyphosate trimesiun	Touchdown	720 g/liter SL	0.33-6 liter	Post Emergence	Annual and perennial weeds. Dosage depends on weed species and their growth stage. Prevent spray contact with leaves, green stems and fruit.
Prnprop	Dalacide Dalspray Proprop	850 g/kg SP	3 kg	Post Emergence	Annual and perennial grasses. Use sufficient water to wet the grass foliage thoroughly with minimum of runoff. Avoid spraying the crop foliage and bare soil. Apply only to mater trees.

Cover Crops

Planting of cover crops is an effective method of weed control. There are several advantages of cover crops that make it worth while to consider. Some of these advantages include a reduction of mowing frequencies (thus a reduction in traffic movement), improvement of soil structure, an increase of water, penetration,- suppression of weeds, an increase in organic matter and biological activity and in the case of leguminous crops, an addition of conservation of nitrogen.

Chemical Weed Control

Chemical weed control has become an integral part of modem fruit culture. When using chemical, the growers should have a sound knowledge of weeds, the advantages and detrimental effects of the different chemicals and of the proper application method. The herbicides are classified in to two types.

Contact Herbicides

The herbicides which are applied after the plants have emerged and affect through contact with the leaves (Contact or scorch chemicals) e.g. paraquat are absorbed by leaves and toxic. No. translocation takes place and it has a fast action. It is non selective but only works on green tissue. A good coverage is required and the addition of a surfactant will improve the efficacy.

Systemic Herbicides

They are absorbed by leave and translocated to above/below ground parts where they disrupt physiological processes. They are slow working and plant must be actively: growing to ensure maximum up take and translocation. The herbicides can also be applied to the soil pre-emergence or as residual chemical.

4.8. PROBLEMS OF ALTERNATE BEARING IN MANGOES

Dr. Muhammad Hussain[*]

4.8.1. Abstract

Alternate bearing is a common and established observation in mango orchards. There are many factors which cause alternate bearing such as environmental factors, physiological factors and genetic factors. The environmental factors may be frost, rain, bailstorm, attack of mango hopper, etc. While the physiological factors such as shoot growth, intensity of blooming, age of tree, nitrogen/carbohydrate ratio.

To control the alternate bearing, proper cultural operation, control of pests, protection against frost, harvesting late in the "off year and early for the on year" and deblossming are important.

It is a common but established observation that a great majority of mango orchards do not bear uniform crops. In some years the crop may be comparatively less than the preceding or the following years. If the difference is not very wide and the variation fluctuates to the tune of 40 : 60 instead of 50 : 50 it does not bother the growers very much but once this gap widens to 20 : 80 or 10 : 90 then it becomes a real serious concern for the growers. As the fluctuations may not be of similar pattern in all orchards of the area and some orchards might bear heavy crop

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and others lighter crop in the same year, the overall situation in the market is not affected very much.

Alternate bearing, biennial bearing or periodicity in cropping is defined as the habit of bearing irregular crops by fruit plants. The rhythm may be a year of heavy crop followed by a year of lighter crop or a year of heavy crop followed by more than one year of lighter crops. The year in which a plant bears a heavy crop is termed as 'on year' and the one in which a plant bears lighter crop is defined as 'off year'.

The phenomenon of alternate bearing has been reported in fruits like apple, citrus and mango, etc. but in mango the problems sometimes becomes really serious. Biennial bearing rhythm has been a part of the mango growing history as it has been reported as early as 1590 in Aaien-Akberi. Even today irregular bearing is a problem of the mango growers and importance of this problem hardly needs any explanation. As the problem may originate due to many reasons/circumstances it is advisable to look into the literature before proceeding further. Selected literature to this problem is very briefly summarized below:

4.8.2. Nutritional Status

Avilan (1971) analyzed leaves of mango cv. Kent for NPK during a productive cycle and reported that NPK levels were the highest before flowering, fell during flowering and fruit formation and rose again during maturity, whereas Ca level was low before flowering rose during fruit formation and lowered subsequently. Singh (1976) sprayed Chaunsa mango variety with 2 to 5% of urea and P_2O_5 each during both the 'On' and 'Off' years and observed that the length of terminal shoots coupled with number of leaves. He found that the longest and heaviest terminal shoots and the maximum number of leaves were obtained in all cases when urea and phosphorus were sprayed at higher level. Mishra and Dhillon (1978) reported chemical composition of mango leaves cv. Langra at 10 days interval from 30th September to 15th December for two years and determined that the 'off' year was characterized by higher averages of N and P. Chandra (1984) found that in the mango cvs. Desi, Chaunsa and Bombay. The total shoot phosphorus content during the vegetative stage was higher during the 'On' than during the 'Off' years but in the cv. Dusehri no such difference was observed. He further remarked that during flowering, the total shoot phosphorus content was greater during the 'off' year in all cvs.

Thakur *et al* (1981) performed a trial on the nutrient level in fruiting and non-fruiting terminals after fruit harvest from 20 orchards of three mango (.vs., namely Dusehri, Chaunsa and Luknow Safeda, and summarized from their results that N, P and Ca contents were significantly higher in the leaves borne on fruiting terminal and reverse was true for K, Sand Zn contents while Mg and Mn contents were similar in three cvs., but K, Ca, Sand Zn in) two cvs. Dusehri and Luknow Safeda as compared to those from fruiting terminals. Whereas Mn and Fe contents in both kinds of terminals were more or less at par in all the three cvs. Mishra and Dhillon (1982) conducted a two years trial on leaf Zn levels in Langra mango and remarked that Zn level was higher during "Off' year ranging from 40 ppm in

September to 18 ppm in December, while for 'On' year the corresponding figure amounted to 16 and 19 ppm respectively.

Recent studies in the Philippines have revealed that polyembryonic cvs. were dramatically influenced by KNO_3 sprays. Bondad and Linsangan (1979) reported that flower formation occurred within four days and blossoms emerged within two weeks after 1 % KNO_3 spray. Anonymous (1987) found that alternate bearing could be controlled during 'Off' year in the mango cvs. Carabao, Pahuton and Pico by 1 % application of KNO_3.

Das and Sahoo (1981) applied GA_3 (50 ppm) and urea (1 percent) to the langra mango trees in the 'On' year and observed that vegetative shoot growth stimulated and increased the number and area of leaves. They also emphasized that these effects were considered promising for inducing fruit development in the following 'Off' year. Kachru *et. al.*, (1971) remarked that m flower formation in mango could be reduced in 'On' years by GA_3 application.

4.8.3. Carbohydrate/Nitrogen Ratio

Singh (1960) studied the seasonal cbange in C/N ratio and established that in Dusehri and Langra C/N ratio was found highest during flower-bud differentiation then it declined and remained lower in 'Off' year than in 'On' year. Singh (1978) summarized his results on seasonal variation in mango cv. Dusehri and remarked that the leaves 'N' contents were slightly higher in the 'Off' year attaining a peak in May and December. Leaf Carbohydrate contents in the 'Off' year were the highest from October to December and in the 'On' year from September to November while C/N ratio in the two years remained the highest in August and September, respectively. Scholefield *et al* (1985) studied the carbohydrate level in avocado and concluded that the initial level of carbohydrate decreased with flowering and fruit setting. They further observed that the carbohydrate reserve produced a bumper crop in 1977 but in 1978 there was poor bearing owing to the lack of carbohydrate accumulation the previous year.

4.8.4. Girdling and Flower Bud Initiation

Hussain (1964) reported than G/N ratio was higher in ringed branches than the control at fruit bud formation. Kumar and Ghhonkar (1974) studied the effect of branch ringing. They selected branches of mango cvs. Bombi, Zardalu, Hamsagar, Langra and subjected them to half and full girdling and observed that in all cvs. The ringing of branches in an 'On' year could increase the crop in the following 'Off' year. Maiti *et al* (1978) studied biennial bearing in mango cvs. Langra and Fazli and observed that shoots which ceased to grow in length in March but increased in diameter in June in an 'On' year and shoots which ceased to grow in length in March and in diameter in October in an 'Off' year generally produced greater number of flowers. They further noted that shoot growth in length beyond March and in diameter beyond October exerted an inhibiting effect on flowering. El-Nobwy *et al* (1983) concluded a trial on Langra and Ewis mangoes to study their floral induction and sex expression in relation to alternate bearing. They recorded that in the 'On' year flower-bud induction in both cvs., started in the second half of October whereas in the 'Off' year it started two weeks later. They further deduced that the percentage of perfect flowers in both cvs., in the 'On' year was markedly greater than in the 'Off' year.

Growth Regulators

Sen *et al* (1979) noted the effect of two growth retardant like B-nine and cycocel on growth and flowering of Langra and Baramasi mangoes in order to secure a regular crop. They found that both chemicals promoted flowering and the most effective range of cycocel was 4000 to 5000 ppm concentration.

Stino *et al* (1981) studied the physiology of biennial bearing of mango cvs, Langra and Evise. They applied Ethephon (250 ppm applied in October) combined with girdling (September) and TIBA (50 ppm in October) and concluded that Ethephon with girdling increased flowering in 'On' year trees in two cvs., whereas TIBA stimulating flowering 'Off' year trees. Hachru *et al* (1971) remarked that flower formation in mango could be reduced in 'On' year by GA_3 application.

Since irregular bearing is initiated due to more than one factors and its control depends upon eliminating the casual factor, knowledge and understanding of these factors is imperative for determining an effective solution to the problem. It is, therefore, pertinent to discuss here the probable casual factors and understanding how these factors can be manipulated to check alternate bearing. Various factors contributing to alternate bearing in mango may be classified into:

a) Environmental factors.
b) Physiological factors.
c) Genetic factors.

4.8.5. Environmental Factors

i) Heavy frost at bud opening in spring.
ii) Rain and high humidity at blossoming.
iii) Hail storm at fruit setting.
iv) Attack of anthracnose.
v) Attack of mango hopper and other pests.
vi) Attack of powdery mildew at flowering.

In case the damaging effect of .any single or a multiple of the above factors is severe enough to cause flower shedding or fruit shedding in the early stages of development it will lead to a poor harvest during the season thus the entire energy of the plant will be diverted to produce vigorous vegetative growth early in the season which in turn will provide very favourable conditions for fruit bud differentiation during that autumn and a very bumper crop during coming spring thereby leaving a few branches to put on vegetative growth and thus the cycle of alternate bearings sets in.

4.8.6. Physiological Factors

a) CarbohydratelNitrogen ratio.
b) Shoot growth.
c) Intensity of blossoming.
d) Age of the tree.

4.8.7. CHO/Nitrogen Ratio

One of the considered views about irregular bearing in mango is that it is associated with nutritional imbalance of the plant. It is also pointed out that the proportionate increase or decrease of nitrogen in tree and fluctuations in soil moisture may regulate the growth and flower formation. While studying the CHO/N ratio during fruit bud differentiation in mango varieties, following combinations have been established:

i.	Langra & Dusehri	High CHO/N ratio during 'On' year.
ii.	-do -	Low CHO/N ratio during 'Off' year.
iii.	Regular bearing varieties	High CHO/N ratio during both the years.

It is thus established that a high CHO/N ratio is favourable for crop production.

4.8.8. Shoot Growth

Mango shoot growth is not continuous but in flushes. Flushes appearing earlier in the season bear more fruit than later flushes as is given below:

Name of Flush	Number Flowering Shoots (%age)
April flush	36.7
May flush	29.4
June flush	19.8
July flush	11.0
August flush	7.0

It is thus most desirable that growth flushes are produced earlier in the season to guarantee good harvest for the following year.

4.8.9. Intensity of Blooming

Excessive blooming, particularly in case of irregular bearing varieties, check/retards vegetative growth early in the season and thus provides favourable conditions for alternate bearing cycle.

4.8.10. Age of the Tree

The age of the tree is an important factor governing the periodicity in cropping. Young trees bear a regular crop every year whereas older trees do not generally bear normal crop every year. This is because aging factor by itself reduces the vigour of the tree and such trees maintain a favourable balance between the vegetative growth and fruiting and the plants deteriorate in health and vigour. Old mango plants may bear a good crop after 3-4 years.

Genetic Factors

In addition to the environmental and physiological factors irregular bearing is considered to be controlled by the genetic make-up of the plants as well. Based on the response of various mango varieties to irregular bearing, these can be grouped into the following three categories:-

Varieties considered to be alternate bearing	Varieties considered to be less alternate bearing	Varieties considered to be regular bearing
Taimoria Langra Fajri Haidershah Wala Summar Bahisht Sanghlakhi	Tota Pari Romani Fazli Dusehri Amarpali Mallika Sensation	Neelum Benglora Mahmood Bahar Hybrid

4.8.11. Control of alternate Bearing

The problem of alternate originating due to environmental or physiological factor is characterized by :

i) Less spring growth during 'On' year which causes the failure of crop in the following year.

ii) More spring growth during 'Off' years responsible for bumper crop during next year.

If the tree is physiologically so normal, as to produce balanced vegetative growth alongwith fruiting during 'on year' then it is possible to regularize the crop every year. It may be possible to keep the tree in such a condition by following the recommended cultural and management practices:

1. Cultural operations (proper cultivation, balanced t nutrition, judicious irrigation and effective weed control).
2. Deblossoming.
3. Pest and disease control measures.
4. Protection against frost.
5. Harvesting late in the 'off year'.
6. Harvesting early in the 'on year'.
7. Evolution of regular bearing varieties.

4.8.12. Cultural Practices

By adopting better cultural operation such as cultivation/hoeing, fertilization and irrigation, the tree can be maintained in good healthy conditions and total failure of crop be averted. These operations would result in efficient absorption of mineral nutrition from the soil and vigorous vegetative growth. Application of ammonium sulphate alongwith phosphorus and potash early in the season and FYM during winter or early during 'on year' has great promoting effect. In the 'on year' good fertilization (double the usual application) of the tree would increase shoot growth and help the shoot to mature within short period of time so that they might bloom the next flowering season.

4.8.13. Deblossoming

Removal of excessive flower or fruits during 'on year' so as to induce the shoots to grow the same season and bear the next year helps checking the irregular bearing.

4.8.14. Pest and Disease Control Measures

Failure of mango crop due to attack of powdery mildew, anthracnose and mango hoppers, etc. should be checked by providing effective plant protection cover. This will also avert alternate bearing cycle.

4.8.15. Evolution of Regular Bearing Varieties

Prolific varieties free of irregular bearing menace should be developed through hybridization/selection. Such efforts were undertaken in India and as a result of mango breeding two hybrid (Mallika and Amarpala) have been evolved which are reported to be regular bearer.

4.9. TENDING ALTERNATE BEARING MANGO .TREES TO REGULAR BEARING. HABIT

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In the "on" year, the mango trees flower profusely and. fruit well. The trees get so exhausted in bearing the heavy crop that they-are not left with sufficient vitality to put on fresh vegetative growth. Hence, shoots capable of producing panicles (flowering shoots) in the following year are not produced.

On the other hand, in the "off" year, there is sparse flowering and fruit-setting. The trees have during the lean crop year, therefore, enough stored food material to put on vegetative growth early in summer; panicles are produced in the following year to flower abundantly and fruit heavily, unless the flowers and fruits are destroyed by natural calamities like diseases, pests, hailstorms, rains, hot winds, etc.

The habit of mango of bearing in alternate years can be controlled if the fertility of soil is maintained by regulating the cultural, manurial and irrigation practices in such a way as to keep the trees in perfect healthy condition to mature the crop well and to produce fresh vegetative growth every year for ensuring flower and fruit production the following year.

In the "off" Year

Just after picking the fruit in the "off" year (lean crop), apply well-rotted farm- yard or dung manure at the rate of 12 cartloads per acre by broadcasting near the trees, or at one maund per well grown tree.

Plough the orchard a number of times to break the soil well and to kill insects, weeds, wild grasses, etc., and leave it open to sun and air. At the close of the rainy season, plough the orchard again to give it a final touch and to kill the .remaining weeds, grasses and insects. After leveling the land, make water channels to irrigate the orchard occasionally in winter,

In the beginning of January, or about seven weeks before the new growth and flowers are expected, fertilize the trees, at the rate of five pounds of ammonium sulphate and two pounds of superphosphate per well grown tree, just under the outer hranches of the tree, about a foot deep or near the root zone, and mix it well with the soil by forking or ploughing.

Irrigate the orchard copiously at fort- nightly intervals, if there are no rains, with a view to inducing vegetative growth rather than flower production. The vegetative growth thus induced would help the tree put forth panicles in the following year for fruit production.

After the fruit has set and starts swelling irrigate the orchard well and repeat it as and when needed. It is the year for abundant flowering and fruiting.

In the "on " Year

After harvesting the crop during the "on" year, do not apply any manure, so as to discourage vegetative growth, but carryon ploughing and other cultural operations as usual to enable the trees to sustain the heavy crop. Do not irrigate the trees from October-April unless there is danger of damage from frost and severe cold in winter.

About a month before the new flushes and inflorescence are expected, fertilize the trees at the rate of four pounds of superphosphate, two pounds of potassium sulphate, five pounds of bonemeal and ten pounds of wood ash per well grown tree all well mixed and properly incorporated into the soil under the outer branches of the trees. Do not irrigate till the trees have flowered and the fruit has set and started swelling. This will enable the trees to produce more flowers than vegetative growth. This operation is to be repeated for about five years, or until the alternate-bearing trees have adapted themselves to produce new vegetative growth early in summer every year. After the treated trees have got into the habit of producing vegetative growth every year early in' the season, the orchard should be manured and fertilized every year as under.

For Regular bearers

Just after harvesting the mango crop, .manure the orchard at the rate of eight cartloads of farmyard manure or dung manure per acre and plough it repeatedly, at least six times, during the rains so as to break the soil, mix the manure well and kill the weeds, wild grasses and insects. A little before the close of the rains, give a final touch of ploughing to get rid of the remaining weeds, grasses and insects. Level the land "and make water channels for irrigation.

Grade designation	Minimum weight of each fruit in total	Definition of quality
(i) Fazli Mango		
I	80	The fruit shall be entirely free from damage, blemish or malformation.
II	70	
III	60	Each fruit shall be green in colour with trace of yellow at the time of package.
(ii) Langra Mango		
I.	20	The fruit shall be firm and entirely free from damage, blemish or malformation.
II.	15	
III.	10	Each fruit shall be green in colour without trace of yellow at the packets.

A month before the flushes and in florescence are expected, fertilize the trees with a mixture of two pounds of potassium sulphate, four pounds of superphosphate, five pounds of bonemeal and ten pounds of wood ash, well mixed to be applied per well grown tree. There should be no irrigation from October-April or I until the trees have flowered and the fruit has set and started swelling, unless there is danger of damage from frost and severe cold during the winter at 45°F for about 40 days, whereas with a bit more advanced maturity coat only sustain for a month.

4.10. MULCHING AND IRRIGATION EFFECTS ON GROWTH, CROPPING AND FRUIT QUALITY OF THE MANGO CV. SENSATION

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4.10.1. Abstract

Recently planted mango trees were drip irrigated by either of the three mean soil matric potentials. -27. -50 and -70 kPa. Half of them were mulched with sugar cane bagasse in a randomized, split block design. The duration of the experiment was six years. Residual effects were measured one year more under uniform mulching and irrigation.

Differences in water use between the dryest and wettest treatments varied between 15 and 40 % according to season. Mulcbing slightly increased trunk growth during the first three years and yield there- after. The wet treatment (-27 kPa) slightly increased trunk growth and yield over the dry one (-70 kPa). Tree efficiency, as yield/trunk area was considerably lower under the dry treatment. All treatments had fruit with a similar percentage of red skin and internal breakdown.

4.10.2. Introduction

Mangos are generally considered as one of the most drought tolerant fruit trees. Singh (1978) and Young and Sauls (1981) even cast doubts about the economic convenience of irrigation, when grown under tropical conditions with considerable rainfall over most of the growing season. However, increased fruit weight and/or number under irrigation have been reported for the Philippines. (Bondad, 1983), Republic of South Africa (Nel. 1984) and Florida (Larson and Schaffer, 1989).

Mulches increase the soil water content under intermittent rain or irrigation (Goode and Hyrycz, 1968i Lal, 1976). The purpose of this I work was to study the response of mango trees to mulching and irrigation at different soil matric potentials within the 0 to -70 kPa tensiometer range.

4.10.3. Material and methods

Environmental conditions

The experiment took place in Malaga. Spain from 1985 to 1991. Mean annual rainfall was 413 mm. most of it falling from November to March. Mean class A pan evaporation during the main growing period (1 June to 30 October) was 5.0 mm day^{-1}. It averaged 6.2 mm day^{-1} in the hottest month (August).

Soil

The 50 cm deep soil was a decomposed slate with 8 % clay. 17 % silt and 75 % sand and gravel. The subsoil was made of broken slate rock. Water quality was good, with 39 ppm Cl .

Planting and Irrigation

The container grown "Sensation" trees were planted in April 1985 at 4.5 x 3.5 m with one 3.3 l l.h. dripper' placed near the trunk. A second dripper was added in 1987 and a third one in 1988. They were placed in a triangle. 30 cm from the trunk. Soil matric potential was measured with mercury tensiometers 15 and 30 cm from the dripper and at 25. 50 and 100 cm depth. In the first two years readings were taken at 25 and 50 cm depth. In 1987 at 50 and 100 cm depth. From 1988 to 1991 the three depths were recorded. Two drippers per treatment were monitored.

Experimental design

Treatments were applied on a randomized block design with four tree plots and four replicates. Guard trees were used at the borders of the experiment but not between treatments. At the end of the experiment the between canopy distances were over 2 m between the row and over 1 m in the row. Border effects were therefore considered unlikely.

Irrigation water, enough to refill the profile was applied at the following water potentials from planting, 1985. to 1990.

Treatment	**Soil Ym**
Moist	-27 kPa
Medium	-50 kPa
Dry	-70 kPa

From spring 1986 tensiometer readings and irrigation were separately considered for the mulched and unmulched trees. Tensiometer readings were taken three times a week in summer and less frequently in winter. A reading of -100 kPa was assumed when the mercury column f broke with Ym (-80 kPa,

Soil Management

Sugar cane bagasse was applied to the mulched trees over a 2 m wide strip along the tree row. About 10 kg m^2 of bagasse with 50-60 '4 dry matter was applied in 1985. To keep the soil cover, a smaller amount was applied in 1987. Very little remained in place at the end of the experiment in 1991. The soil was kept weed free with herbicides.

Cultural operations

To prevent flower formation during the first three years, each winter the trees were sprayed to run-off, 3 to 4 times, with 100 ppm GA_3. Flower and fruit thinning were necessary in 1988, 89 and 91. Nitrogen, potassium and chelated iron were supplied through the irrigation system. Zinc was foliarly applied with the antioidium sprays. Copper oxycloride was used in winter against Pseudomonas syringae.

Records

Tree growth was assessed by measuring trunk cross sectional area 25 cm above ground. Picked fruits were softened at room temperature and evaluated for percentage red epidermis (0 -100 %), internal breakdown (0 -10), and stem end cavity (0 -10) (Wainwright and Burbage. 1989). Class 10 fruits did not show any difference in colour or flavour between different parts of the mesocarp. Class 5 fruits showed differences in colour and texture, but not in flavour. Class 0 fruits were almost completely decomposed. Fruits fallen to the ground, rotten or picked unripe were not evaluated. Except in 1988 and 1989, the fruit quality results correspond only to the fruits free of Mediterranean fruit fly (MFF). Leaves. 4 months old, from non fruiting shoots, were analyzed during the picking season in early October.

4.10.4. Results

Soil matric potential and water use

About 80 per cent of the irrigation water was used in the practically rainless period from 1 June to 31 October. This is when mean air temperatures are above 20°C and most growth takes place. Mean soil matric potentials in this period are shown in Table 4-3.

Table 4-3. Mean soil Ym (kPa) from 1 June – 31 October

	1987	1988	1989	1990	Mean
Moist	-22.5	-12.8	-20.8	-27.7	-20.9
Medium	-29.6	-23.5	-29.6	-35.5	-29.5
Dry	-46.2	-26.0	-34.4	-39.7	-36.6

In 1991 all trees were kept at a mean '(no of -20 kPa during the June to September period. Due to rain, the readings in October were -3.3 kPa.

The relative water use for the wettest and dryest years of the experiment is given in Table 4-4. Water use by the dry treatment without mulch was taken as base 100. Relative water use was always higher in the wetter treatments and clean soils.

Table 4-4. **Relative water use from 1 June – 31 October**

	Dry	Mulch Medium	Moist	Dry	Non-mulch Medium	Moist
1988	100	106	115	112	109	119
1990	100	111	119	115	121	141

4.10.5. Irrigation effects

Trunk growth

By the end of the third growing season (1987) the moist trees had grown slightly but not significantly better than the dry ones (table 4-5). During the three productive years (1987-1990) and the post experiment year (1990/91) trunk growth was similar for all irrigation treatments.

Table 4-5. **Recent increase in trunk growth**

	1985 to 1987	1987 to 1990	1990 to 1991
Moist	1010	262	11.8
Medium	925	266	9.3
Dry	835	258	10.4

Yield and productivity

Mean yield for the three crops under differential irrigation treatments was slightly but not significantly higher for the moist treatment (Table 4-6). To correct for tree size the productivity was alculated as yield .(g)/trunk cross sectional area (cm^2).

Table 4-6. **Yield and productivity**

	Yield kg $tree^{-1}$ $year^{-1}$ Mean 1988-89-90	Productivity g cm^{-2} $trunk^{-1}$ Mean 1988-89-90	Yield kg $tree^{-1}$ 1991	Productivity g cm^{-2} $trunk^{-1}$ 1991
Moist	10.6	190.8	20.1	198.8
Medium	9.0	194.5	18.2	194.1
Dry	9.4	160.5	19.4	181.6
% level of significance	n.s.	92	n.s	n.s

Productivity was significantly lower for the dry treatment from 1988 to 1990. Its slightly lower productivity in 1991 could be due to the after-effects of the drought applied up to the end of 1990.

Fruit sizes

Fruit sizes during the irrigation experiment (1988-89-90) were slightly but not significantly larger in the moist trees, under uniform irrigation (1991). All trees produced fruit of a similar size.

4.10.6. Mulching effects

Trunk growth

For the first two seasons (1985 and 1986) trunk growth was significantly larger for mulched trees (Table 5). These differences decreased markedly by the end of the third season (1985 to 1987).

During the three cropping years with differential irrigation treatments (1988 to 1990) trunk growth was slightly greater far the non-mulched trees (Table 4-7) but they had a lower yield (Table 4-8).

Table 4-7. **Trunk growth**

	% trunk growth 1985 and 1986	1985 to 1987	188 to 1990
Non-mulch	330	892	274
Mulch	379	954	248
% level of significance	99	n.s	n.s

Table 4-8. **Mean yield and productivity (1988/89/90/91)**

	Yield kg $tree^{-1}$ $year^{-1}$	Productivity g cm^{-2} $trunk^{-1}$
Non-mulch	11.1	177.5
Mulch 12.9	182.8	

Yield and productivity

The mulched trees had a slightly but not significantly higher yield and productivity than the clean trees (Table 6).

Mineral nutrition and fruit quality

Treatments did not affect leaf nutrient contents, that were generally within the Young and Sauls (1981) recommended ranges, with the following exceptions. In 1989 nitrogen levels were above normal (2.3 1.) due to excessive application and irrigation water contamination with nitrates. Calcium content (2 -2.5 %:) was always near the low end of the range, which may have contributed to the high incidence of internal breakdown and stem end cavity. Zinc levels remained low, despite foliar applications at blooming time.

The percentage red colour of the epidermis was similar for all treatments, with an overall mean of 66.5. No differences were either present for internal breakdown or stem end cavity with a mean value of 5.1 in both parameters.

Mediterranean fruit fly attack was similar for all treatments. Each year it .was bigger in the first half of the picking season, mean 16 %, compared with the second half, mean 5.3 %. Internal breakdown was worse in the first half of the picking season, on fruits with or without MFF larvae.

4.10.7. Discussion

Differences in soil Ym between the moist and dry treatments were well defined, while the medium one considerably overlapped with the other two. Regretfully soil water contents were not well stated in the studies of Bondad (1983). Nel (1984) and Larson and Schaffer (1989) previously mentioned.

The moist trees grew slightly but not significantly better than the dryer trees during the first three years. Every year fruit size was also slightly increased by the higher soil in. Larson and Schaffer (1989) reported similar differences comparing irrigation intervals and rates over one picking season.

The dry trees had a significantly lower mean productivity for the three crops with differential irrigation treatments. Those differences decreased in 1991 when all trees were under uniformly moist conditions. This supports the conclusion that they were caused by the irrigation treatments. The performance of the trees under uniformly high water potential in the coming years, will hopefully further clarify the sensitivity of the mango to low soil Ym.

Under lower evaporative demand in England. Apple trees also showed poorer growth and cropping when soil Ym was allowed to reach -60 kPa (Goode and Hyrycz. 1964). Similar results were reported by Richards *et al.* (1960) with avocados and Hilgemann and Sharp (1970) with citrus at soil Ym below -50 kPa.

In contrast, Richards and Warneke (1969) did not find any positive response to irrigation above -100 kPa in lemons grown in a cool constant environment

Wilting was never observed during the experiment, not even then, occasionally, the mean Ym under the dry trees approached -100 kPa and class A pan evaporation reached 9 -10 mm day^{-1}. This lack of visual symptoms and the small differences between the irrigation treatments may explain the contradictions found in the mango literature about its irrigation requirements.

Mulched trees grew significantly better during the first two years. Yield and productivity of mulched trees were slightly but not significantly, higher. Differences were larger with young avocados grown under similar conditions (Farre 1979, 1983). In spite of being larger, mulched mango trees had reduced water consumption. This is quite remarkable considering the small percentage of soil surface wetted by the drippers, about 2.5 %. The mulch may have acted as a rain trap reducing soil evaporation. This effect has also been reported under intermittent rain in temperate (Greenham, 1952) and tropical countries (Lal, 1976).

4.10.8. Acknowledgements

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4.10.9. References

Bondad, N., 1983. Past, present and suggested future research on mango, with an example of research and production in the Philippines. Int. Work. for Promoting Research on Tropical Fruits. Jakarta.

Farre, J.M., 1979. Water use and productivity of fruit trees: Effects of soil management and irrigation. Ph.D. Thesis. University of London.

Farre, J.M., 1983. Diez afios de ensajos sobre el cultivo del aguacate en la Estaci6n Experimental La Mayora. II Seminario del Aguacate. Junta de Andalucia. Sevilla.

Goode, J.E. and Hyrycz, K.J., 1964. The response of Laxton's Superb apple trees to different soil moisture conditions. J.Hort.Sci.39: 254-276.

Goode, J.E. and Hyrycz, K.J. 1968. The response of Malling Jewel and Malling Exploit raspberries to different soil moisture conditions and straw mulching. J.Hort.Sci. 45:379-391.

Greenham, D.W.P., 1952. Orchard soil management. PTOC. 13. Int. Hort. Congr., London 1:181-189.

Hilgeman, R.H. and Sharp, F.O., 1970. Response of Valencia orange trees to four soil water schedules, during 20 years. J.Am.Soc.hort. Sci. 95:739-745.

Lal, R., 1976. No-tillage effects on soil properties under different crops in western Nigeria. Proc. Soil Sci. Soc. Am. 40:762-768.

Larson, K. D. and Schaffer, B., 1989. Effect of irrigation on leaf water potential, growth and Yield of mango trees. Proc. Fla. State Hort. Soc. 102: 226-228.

Nel, D.J. 19J84. Soil requirements for mangos. Farming in South Africa. Leaflet 3.2. Department of Agriculture. Pretoria. Republic of South Africa.

Richards, S.J. Warneke, J. E., and Weeks, L. V., 1960. Irrigation of avocados. Ybk. Calif. Avocado soc. 44: 73-74.

Richards, S.J. Warneke, J. E., 1969. Sprinkler and furrow irrigation management for lemon trees under coastal climatic conditions. Proc. 1st. Citrus Symp. 1968. 3: 1749.

Sing, R. N., 1978. Mango. Indian Council of Agricultural Research. New Delhi.

Young, T. W. and Sauls, J. W., 1981. the mango industry in florida. Ext. Bul. 1989. University of Florida. IFAS.

4.11. YEAR-ROUND MANGO ORCHARD MANAGEMENT

4.11.1. JANUARY : Orchard Operation:

- Dig-out the soil around tree trunk to expose the eggs of mango mealybug to destroy them.
- Identify some reliable sources for the purchase of plants.
- Take measure against frost to minimize losses i.e., irrigate the field when there is danger of , frost, create smoke and cover the young plants.

4.11.2. FEBRUARY : Orchard Operation

- Kill the young mango mealybug nymphs with chemical spray when they are crawling around the stem.
- Start preparation of land for laying out of young orchard.
- Rotavate the berseem or the green manuring crops.
- At the end of month remove the frost coverings from plants.
- Apply gypsum in orchards, where need is established.
- Apply chemical fertilizer during the last week of February according to the age of plants and irrigate. Half doze of nitrogen should be applied with full doze of phosphorus and potash.
- Leaf analysis would be better for proper use of fertilizers.

Age of pant	Urea (kg)	S.S.P. (kg)	S.O.P.(kg)
2 years	¼	-	-
3 years	1/3	-	-
" 4 year	½	-	-
5 years	¾	-	-
6-8 years	1	1	¾
8-10 years	2	2½	1
10-14 years	3	6	2
More than 14 years	4	8	3

- Shift the seedlings into pots for inarching.
- Separate the plants form the mother plant, which were inarched during the previous season.

4.11.3. MARCH

4.11.4. Orchard Operation:

Start new plantation after 15th of March.

Complete the plantation upto the end of March.

Plants should be sprayed in the first week of March. against mealybugs, mango hopper, die back and powdery mildew before flower opening as given in the table.

Diseases	**Fungicides**
Powdery mildew	Afugan, Topas., Rubigan, Thiovit, Topsin-M.
Anthracnose	Bordeaux mixture, Antracol, Topsim-M

Insect	**Insecticides**
Mango hopper	Supracide, Diamicron, Methyl Parathion, Metasystox
Mango mealybug	Folidol, Diamicron, Metasystox

- Remove malformed Panicle with at least 1-1 ½ ft healthy branch.
- Repeat the spray of fungicide after 15 days interval of first spray against powdery mildew.
- Ploughing should be done to eradicate weeds.

Nursery Operation:

Start inarching and side grafting.

4.11.5. APRIL : Orchard Operation

- Apply the insecticidal treatment (Matesaystox, Diazinon), by stem injection method to kill mealybug, mango hoppers.
- Third spray of fungicide after 15 days of 2nd spray should be done.
- Start irrigation when fruit size is at pea stage and continue at fortnight interval.
- Apply the 2nd doze of chemical fertilizer i.e., remaining doze of nitrogenous fertilizer.
- Cultivate green manuring crops.
- Mound soil around trees stems to avoid water contact.
- White wash the stem with bordeaux paste with a ratio of3:3: 10.

4.11.6. Nursery Operation: Inarching and side grafting should continue.

4.11.7. MAY : Orchard Operation:

- Take measures to avoid injury from scorching sunlight.
- Irrigate orchard at 7-10 days interval.
- Install pheromone traps in the orchard to control the fruitfully.
- Collect adult mealybugs to destroy.
- White wash the stem with Bordeaux mixture if not done in April.
- Bum adult mango mealybugs gathered around the base of the stem.

4.11.8. JUNE : Orchard operation:

- Remove and bum the malformed and dried panicles to kill the eggs of hoppers.
- Irrigate the orchard at 7-10 days interval.
- Start harvesting of the early varieties like Malda.
- Rotavate the green manuring crops which were sown in April.

4.11.9. Nursery operation:

- Prepare the land for nursery sowing of stones

4.11.10. JULY : Orchard Operation

- Digging up of soil (contaminated with the eggs of mango mealybug) 2-6 inches deep and upto 5 feet around the stem and bury this soil in a deep pit outside the orchard.
- Harvesting of mid season varieties like Anwar Ratoul, Deshehri, Langra.
- Irrigate the orchard according to the intensity of rain.
- Prepare layout plan for the establishment of new orchard.
- Digging and refilling of pits.

4.11.11. Nursery Operation:

- Separate the in-orchard plants from mother plant.
- Sowing of mango stones should be dune for the raising of rootstock.

4.11.12. AUGUST : Orchard operation

- Harvest the late varieties like Samar Bahisht, Fajri and Sensation.
- The orchards having sever problem of mango hopper, a spray of insecticide should be done at the end of month and if mixed with fungicide. it is much better.
- Irrigate the orchard at 10 days interval. depending upon the rainfall.
- Plant new orchards

4.11.13. Nursery Operation:

- Rootstock plants which are already growing in the nursery should be side grafted or approach grafted.
- Carry on sowing of stones in the nursery for the raising of rootstock.

4.11.14. SEPTEMBER : Orchard Operation:

- Plantation of new orchard and missing plants should be done.
- To protect the plants from Anthracnose, spray the plants with proper fungicide e.g. Topsin-M or Antracol.
- Remove the diseased branches from the plant and destroy them.
- Better to not irrigate but if required then irrigate at 2-3 weeks interval (because late sprouting of shoots and younger leaves are affected by frost).

4.11.15. Nursery Operation

- Grafting operation should continue.

4.11.16. OCTOBER : Orchard Operation:

- For green manuring berseem or other leguminous crops should be sown.
- Ploughing of the orchard should be done.
- If plants are too young, cultivation of vegetable can be practiced.
- Irrigation stress should be given to the bearing orchard providing irrigation at 2-3 weeks interval.
- Pruning for aeration and good light penetration to all parts of the tree to avoid insect as welt as pathogenic attack.

4.11.17. NOVEMBER : Orchard Operation:

- Start exposing of mango mealybug eggs to the low temperature of November to destroy their viability.
- Cover the young plants with Sarkanda to protect them from frost damage.
- Only one irrigation is given during this month,

4.11.18. DECEMBER : Orchard Operation:

- Protection from frost should be provided.
- Destroy the eggs of mango mealybugs around the tree trunk by digging out soil and mixing BHC insecticide in the soil.
- Install sticky and slippery bands around the stem to control the mango mealybugs.
- Digging and refilling of pits by a mixture of F. Y.M., silt and top soil with ratio of 1:1:1 for new plantations add 3-4 kg of S.S.P. in this mixture that will be very helpful for root growth.
- F. Y.M. should be added in the field as suggested in the table followed by a light irrigation

Age of plant	**Farm yard manure (kg/plant)**
2vears	10-15
3 years	15-20
4 years	20-25
5 years	25-30
6-8 years	30-35
8-10	40
10-14 years	60
More than 14 years	80

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5. VARIETIES

5.1. CURRENT MANGO VARIETIES SITUATION AND FUTURE TRENDS IN INDIA

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Reputed as the fruit par excellence of India, mango has all along assumed a premier position among the commercial fruits of the country. Immense in the number of varieties and its *embarass de richesse* forms, the mango has had cosmopolitan appeal in its palatability as much as its adaptability to diverse environments. Its popularity with the producer as much as the consumer has had, therefore, never any challenge till recently. A search for new varieties has, however, assumed a new importance in recent times. This is partly due to an evident shift in consumer preference to the fruits like the apple, pear, peach, cherry and strawberry in the northern temperate regions of India and of the mangosteen, litchi and the like in the tropical South and East. This new development has compelled the mango growers to exert in their fresh efforts to retain the pre-eminent position their fruit occupied so far. Not only the hunt for new and novel varieties but the conlposition of improved production practices, the evolution of effective plant protection measures and the drive towards the popularization of preserved mango fruit products are all the evident signs of these concerted efforts.

In spite of these efforts, however, the mango still .presents problems of importance. Its varieties are innumerable, a vast majority of which have neither the quality nor the possibilities of economic utilization. Furthermore, they have yet to be identified and assessed so that the inferior ones may be weeded out. The newly discovered or evolved varieties have to be fitted into their appropriate climatic nexus. Their suitability for the can has yet to be judged. The erratic bearing habit to which the mango is so prone tells upon the dependability of its production in almost -all the areas where it is commercially grown and this constitutes a-most unreliable feature in the growers' enterprise towards building up assured markets for the consumer. And now there is the problem of malformation of the mango inflorescence which is not only steadily spreading but also assuming serous proportions.

The Indian mango still remains unrivalled in its fruit quality. The Dusehri, Langra and Chausa of the North, the Alphonso and Kalepad of the West, the Baneshan (Banganpalle), Himayuddin (Imampasand), Allumpur Baneshan and Cherukarasam of the South and South- East will together form a formidable array in any assembly of mango varieties displayed for their quality. Most of these varieties are of relatively recent origin. Between the time of their discovery and now, there is a significant gap so far as additions to the varietals list are concerned affording proof of the fact that the Indian commercial mango grower soon rested content with the few choice varieties he secured initially. It leaves, therefore, a rich" unexplored field for the future. Research on bringing the 'mango tree to some semblance of regularity in its cropping behaviour cannot be said to have solved the problem yet but undoubtedly has laid a good ground work for a sound future plan of investigation by disabusing many of the old mistaken notions: It is to be admitted that much headway has yet to be made in mango research. For creating variability in mango in the desired direction, hybridization of the controlled varieties is the positive need and requiring greater, exploitation. A procedure for controlling and regulating growth for fostering optimum: crop production through different aids such as orchard practices, hormonal treatments, plant protection and disease control measures has to be given a suitable new orientation.

The Indian Council'of Agricultural Research has initiated two projects; the first is the holding of All India Regional Fruit Shows, and: the other is the location and study of seedling mango trees superior merit, the latter being one of the simplest forms of breeding of variety improvement works. Both are, expected to unravel new, promising varietals wealth. Some of the most outstanding types which have already resulted from these projects are described in Table 5-1. (Gangolly, et al: 1957. Singh, D. 1960).

5.1.1. Hybridization

Hybridization as a means of varietal improvement was put under way as far back as 1913-15 by Burns and Prayag (1921). A planned breeding programme was possible, however, only with establishment of Fruit Research Station under the auspices of the Indian Council of agricultural Research in 1935. The tempo of research in this field has risen steadily during the last two decades or so.

The emergence of several promising hybrids have, been reported from the Fruit Research Station, Kodur by Naik (1948), Naik *et .al.* (1958) and. Bhujanga Rao and Ragacharlu (1958). and from Sabour by Roy *et al.* (1956); some initial results have also been .reported from Saharanpur by Singh and Sirigb, (1958). The Table 5-2 gives a list along with brief characteristics of the most promising hybrids.

5.1.2. Crop Regulation

In the sphere of crop regulation, regular off-season bearing trees and colonal strains have been spotted out and are under investigation. Scientific orchard efficiency analysis has brought to light varieties and unusual trees of merit worthy of multiplication and popularization. A positive correlation between certain growth features and fruit bud formation has been established. A recent development has been the formulation of a nation wide project by the Indian Council of agricultural Research to conduct pilot studies in selected private orchards to determine how far these crop regulation methods or other orchard practices like fertilization would foster and ensure optimum fruit production on an extended field scale.

Table 5-1. Outstanding variety

No.	Name of the variety	Description and Remarks
1.	Himsagar	Fruit medium, ovate to, ovate-oblique; skin medium thick, smooth, capucine yellow; flesh firm, fibreless, cadmium yellow; flavour delightful; taste very sweet; juice abundant; fruit and keeping, qualities excellent. It is a choice table variety from Bengal and deserves wider trials and perpetuation.
2.	Khasul-khas	Fruit medium to large; ovate to ovate-oblique; skin thick, smooth, inclined to be rough, empire yellow; flesh firm to soft, sparingly fibrous, apricot yellow; flavour pleasant to delightful; taste very sweet; juice moderately abundant; fruit quality very good and keeping quality medium. This fruit was declared the best fruit of the 2nd All India. Mango Show, held at Delhi in July, 1959.
3.	Rataul	Fruit medium, ovate; skin medium thick, smooth, primuline yellow; flesh firm, fibreless, cadmium yellow; flavour good; taste very 'sweet; juice moderate; fruit and keeping qualities good., This variety, of late, has been gaining more popularity with the growers in U.P.
4.	Badami (Model)	Fruit medium, ovate:-oblique; skin medium-thick, capucine yellow; flesh firm, fibreless; flavour delightful; taste very sweet, juice abundant; fruit quality best; keeping quality good. It is perhaps a strain of Alphonso.' It is an excellent quality fruit. which deserves wider dissemination. The fruit won prizes at the first All-India Mango Show held at Bombay, in May, 1955.
5.	Pottalma	Fruit medium, ovate-oblique; skin medium thick; flesh firm; almost fibreless with buttery pulp, very juicy; early to mid- bearing; fruit and keeping qualities very good. This is-a new find of the 2nd All India Mango Show, Madras, 1960, and deserves a large-scale trial due to its good qualities.
6.	Himayat Pasand	Fruit medium,' obliquely-oval; skin medium thick, smooth almost fibreless, flesh soft, yellow, delicious, juicy, early bearer with commendable qualities. This was spotted as 'a first grade quality fruit at the 2nd All-India Mango Show, Madras, 1960.
7.	Hamad	Fruit medium, ovate; skin thin to medium thick,. yellow colored, flesh fibreless, buttery to cut; taste sweet and delightful fruit quality very good. It is a early bearing type but has tendencies towards alternate bearing. It is a first grade selection of the second AU India Mango Show, Madras, 1960.
8.	Firangiludva	Fruit medium, ovate oblique; skin membranous, capucine yellow; flesh firm, cadmium yellow; moderately fibrous; flavour delightful; taste very sweet; juice fairly plentiful; fruit quality very good, keeping quality medium. An excellent juicy type from Andhra Pradesh and deserves greater popularization.
9.	Kesar	Description not ,available. It is a medium size fruit with good taste and flavour, and has gained wide popularity in the Saurashtra region due to its excellent table quality fruit.
10.	Dil-Khush	Description not available. This fruit was declared as the second best fruit at the second All-India Mango Show, Calcutta, 1959.

Table 5-2. Brief characteristics of the most promising hybrids

No.	Name of the hybrid	Parent	Description and Remarks
1.	Himayuddin x Neelum (7/5)	Himayuddin-staminate; choice fruiting but shy bearing. Neelum-female, regular bearing.	Fruit medium to large; oblong to oblong oval, skin medium-thick, leathery, "cadmium yellow; flesh firm, fibreless, apricot yellow; juice moderately abundant; flavour delightful; taste very sweet, fruit and keeping qualities very good.
2.	Jehangir x Suvarnarekha (11/13)	Jehangir-staminate, choice and shy-bearing; Suvarnarekha-female, prolific and regular bearing	Fruit large, ovate-oblong, skin thick, tough and inclined to be rough; apricot yellow; flesh soft. Maize yellow; fibreless; juice abundant; flavour pleasant; taste sweet, fruit quality good and keeping quality medium to poor.
3.	Chinna Suvarnarekha x Himayuddin (4/6)	------	Fruit medium, cordate, skin thin and peels off easily, flesh fibreless, firm, moderate; flavour pleasant and very sweet; fruit and keeping qualities good.
4.	Neelum x Allumpur Baneshan (7/5)	------	Fruit medium, flesh firm, tender and melting, sligbtly fibrous; flavour delightful, taste very sweet; juice moderate; fruit quality very good.
5.	Mahmud Bahar	Bombai x Kalapady	Fruit medium, base slightly flat, apex rounded, shoulders rising slightly; sinusnil; skin slightly rough, canary yellow, texture soft; fiber slight; flesh melting, apricot, sweet and aromatic, juicy; fruit quality good and keeping quality very good; a regular bearer.
6.	Probhashankar	Bombai x Kalapady	Fruit medium, base rounded and symmetrical, shoulders not prominent and ridged; sinus marked; apex rounded; skin smooth, raw sienna, texture fine; flesh crisp, amber yellow, fiber very little, quite juicy; fruit quality good and keeping quality poor.

A finding of no less importance in Bihar is that the choice of varieties such as *Kalepad* characterized by the production of mixed panicles which tend to foster a regular bearing pattern in the grove and can also be utilized as a useful parent in breeding for imparting this tendency.

5.1.3. Conslusions

The story of mango research particularly in relation to the evolution of new mango varieties in the past quarter of a century has been a fascinating chapter in the history of the Indian mango industry. Much remains to be accomplished, however, to further the solution of the many-sided problems that face the culture and marketing of this fruit. Hundreds of varieties already established in India have laid the groundwork for systematized variety improvement work. A planned breeding programme with controlled varieties and probably the utilization of irradiation and radioisotope techniques would further the objectives of building up the nation's varietal wealth, suitable for various aspects. The development of modern refined methods of analysis by paper chromatography would lead to a more reliable and critical analysis of auxins and their movements in relation to mango flowering. Under the second and third National Plan Schemes, intensification of research on these aspects is expected to be taken up in order to make the mango industry a sound horticultural enterprise on which a commercial grower could depend for his living.

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5.1.5. References

Bhujanga Rao, C. and V. S. Rangacharlu, 1958. Breeding new mango varieties in South India. Indian Jour. Hort. 15 (3 & 4); 173-183. *Special Symposium number on Origin, Cytogenetics and Breeding of Tropical Fruits.*

Burns, W. and S. H. Prayag, 1921. The book of. the mango. Dept. Agr. Bombay, Bull. No. 103.

Gangolly, S. R., Ranjit Singh, S. L. Katyal and Daljit Singh. 1957. The mango, I.C.A.R., New Delhi.

Naik, K. C., 1948. Improvement of the mango. *Mangifera indica* L. by selection and hybridization. Indian Jour. Agr. Sci., I8. (Part I): 35-41, March.

Naik, K. C., C. Bhujanga Rao and V. S. Raman, 1958. Problems in crop improvement mango. Indian Jour. Hort., 15 (3 & 4): 159-167; Special Symposium Number.

Roy, R. S., P. C. Malik and R. P. Sinha, 1956. Mango breeding in Bihar, India. Proc. Amer. Soc. Hort. Sci., 68: 259-264; Dec.

Singh, Daljit, 1960. New promising mango varieties at the second all I India mango $how, Madras, May, 1960. Under print in Indian .Hort., 4 (4): July-Sept.

Singh, L. B. and Singh, R. N., 1958. Variability in the mango and. its significance to the production of new varieties. Indian Jour. Hort., 15 (3 & 4); 168-172; Special Symposium Number.

5.2. COMMERCIAL FLORIDA MANGO CULTIVARS

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5.2.1. Abstract

Florida is the source of numerous mango *(Mangifera indica* L.) cultivars, many of which have become important commercial export mangos throughout the world. Morphological descriptions, strengths and weaknesses, shipping and handling characteristics and other outstanding attributes that influence the commercial possibilities of Florida mangos are discussed. The cultivars discussed are broken into five groups roughly based on the volume of production presently in Florida. Group 1 includes the cultivars produced in the largest volume; 'Tommy Atkins', 'Keitt', and 'Van Dyke'. Group 2 contains 'Palmer' and 'Irwin', which are still produced in substantial volumes, followed closely by 'Kent' and 'Golden Nuggets', which constitute Group 3. Group 4 is composed of 'Haden', which is produced in appreciable volume in Florida due to existing older orchards. Group 5 includes the minor commercial cultivars !3rooks', 'Davis-Haden', 'Edward', 'Glenn', 'Fascell', 'Lippens', 'Parvin', 'Sensation', 'Smith', arid 'Zill'.

5.2.2. Introduction

In Florida the mango has had a relatively short history, spanning about the last 140 years. Yet, during this limited time significant advances have been achieved in the selection of new cultivars within Florida as a result of a concentrated effort of germplasm introduction and selection on the part of professional institutions and private individuals within the state. The product of this intense effort is a group of superior mango cultivars collectively known as the "Florida Mangos" (Campbell, 1992; Crane and Campbell, 1991; Lynch and Mustard, 1950; Ruehle and Ledin, 1956; Young and Sauls, 1979).

Commercial mango production in Florida began with polyembryonic cultivars (e.g. 'Turpentine', 'Number 11') that were brought to Florida from the Caribbean (Campbell, 1992). These trees were grown from seed and due to their polyembryonic nature there was little chance of cultivar improvement by selection of new cultivars. However, in the late 1800's the United States Department of Agriculture began a mango germplasm introduction program in Florida. These introductions, or more specifically the progeny of these introductions, were to dramatically change mango production in Florida. In 1912, one of these progeny, the 'Haden' mango, was selected. 'Haden' was an instant commercial success, and it dominated commercial mango production In Florida for over 40 years. Gradually, other cultivars were selected which offered advantages over 'Haden'. For example, 'Brooks' was selected in the 1920's because of its late harvest season in Florida. It was in the 1940's and 1950's, however, when the most dramatic proliferation of new cultivars occurred. During those two decades dozens of cultivars were selected, many of which have commercial promise.

The objective of this paper is to present descriptive information and outstanding strengths and weaknesses of Florida mangos, which have contributed to their success as commercial mangos throughout the world. The cultivars discussed in this paper represent the current commercial cultivars of Florida separated into 5 groups based roughly on the present volume of production in Florida.

5.2.3. Group 1

'Tommy Atkins' is the most important commercial mango in Florida and throughout Tropical America. 'Tommy Atkins' has been described in detail by Campbell (1973). The fruit arc oval to oblong with a broadly rounded base and a rounded apex. Fruit nature from June to July and average from 450 to 750 g. The fruit are exceptionally attractive, with an orange yellow ground and a crimson or dark red blush. The skin is thick and tough and highly resistant to handling damage. The flesh is deep yellow, firm and moderately juicy with a sweet and mild flavor. Eating quality is generally considered fair to good and there is abundant fine fiber in the flesh. 'Tommy Atkins' is a consistent, heavy producer in Florida and throughout Tropical America. The fruit have significant resistance to anthracnose' *(Colletotrichum gloeosporioides)* and are tolerant of rough handling and hot-water quarantine treatments (C.A Campbell. personal communication). 'Tommy Atkins' responds favorably to bloom induction by means of drought stress, girdling, and/or applied chemicals (R.J. Campbell, personal observation). One outstanding weaknesses is the often severe occurrence of internal breakdown, particularly on early-season fruit.

'Keitt' is the most popular late-season cultivar produced in Florida, maturing from August to early October. Fruit arc oval with a rounded base and apex. Fruit are large, averaging from 510 to 2000 g. Fruit color is typically poor in Florida, with a greenish-yellow ground color and a pink blush. In arid climates, the color may be significantly better. The skin is thick and tough, fu and tolerant of handling damage. The flesh is yellow, firm and juicy with a mild and sweet

flavor. Eating quality is considered good to excellent. 'Keitt' is a precocious, heavy producer in Florida, with significant anthracnose resistance. The poor color is a significant drawback for this cultivar. The tree has a "leggy;' growth pattern, making pruning an important part of an overall management program.

'Van Dyke' is a more recent addition to commercial production in Florida, and has been described in detail by Campbell *et al.* (1990). 'Van Dyke' fruit arc oval with a rounded base and a bluntly pointed apex. Fruit mature from July to August and arc small, averaging from 250 to SUO g. Fruit are colorful, with a bright yellow ground color and a crimson nr red blush. The skin is thick and tough. The flesh is orange-yellow, firm, juicy and melting with a spicy and sweet flavor. There is little fiber in the flesh. Eating quality is considered good to excellent. 'Van Dyke' is a consistent, heavy producer in Florida with exceptional color development. Fruit have good resistance to anthracnose and good storage and handling characteristics due to the firmness of the flesh. Internal breakdown is a serious limitation of this cultivar. The small size has also been considered a hindrance to marketing in some locations.

5.2.4. Group 2

The second group of mangos includes 'Palmer' and 'Irwin'. These cultivars are still produced" in considerable volume in older orchards in Florida, but few new plantings are being made.

'Palmer' fruit are oblong with a rounded base and apex. Fruit mature from July to early September and average from 510 to 850 g. Ground color is yellow-orange with a dark red to crimson blush. The skin is thick, tough, and adherent. The flesh is orange-yellow, firm and melting with an aromatic and mild flavor. Eating quality is good with lit tic fiber in the flesh. 'Palmer' fruit arc sometimes harvested while still immature because the fruit are usually highly colored before acceptable commercial maturity is achieved. The elongated shape of the fruit is considered less desirable by packers and handlers, who prefer fruit with an ovoid shape.

'Irwin' fruit are ovate with a rounded or slightly flattened base and a bluntly pointed apex. Fruit mature from June to early July and average from 340 lo 450 g. Fruit color is outstanding, with a bright yellow ground color and a crimson or dark red blush. The skin is medium thick, tender and adherent, and susceptible to handling damage. The flesh is lemon-yellow, soft, melting and juicy with a sweet and mild flavor. Eating quality is good with no fiber in the llesh. 'Irwin' is a consistent, heavy producer in Florida with good consumer appeal. Fruit typically have no internal breakdown, but they are soft and generally have a short post-harvest life. There is a tendency in this cultivar for the production of small, seedless fruits in some years.

5.2.5. Group 3

This group consists of 'Kent' and 'Golden Nuggets', both produced in appreciable, yet smaller volumes than group 2.

'Kent' has been grown in Florida for many years, but is not widely planted at the present time. The fruit are oval with a rounded base and apex. The fruit mature from July to August and average from 600 to 750 g. The color is usually outstanding with a greenish-yellow ground color and a crimson or red blush. The skin is thick, tough and adherent. The flesh is deep-yellow, tender, melting and juicy with a rich and sweet flavor. Eating quality is excellent with little fiber in the flesh. 'Kent' is considered among the finest flavored mangos in Florida. 'Kent' has been grown throughout Tropical America for about the last 20 years; in some areas it has performed quite well, and in others it has performed poorly. 'Kent' has mediocre handling and storage characteristics, and internal breakdown is sometimes a problem.

'Golden Nuggets' is a recent addition to the Florida mango industry (patented in 1990) and is still in the evaluation stage. The fruit are oval with an irregularly rounded base and apex. Fruit mature from late July to August and average from 340 to 550 g. The fruit have a yellow- orange ground color with a pink blush. The skin is medium thick, lender and adherent. The flesh is lemon-yellow, firm and meliing with a mild and sweet flavor. Eating quality is good to excellent with medium, fine fiber in the flesh. 'Golden Nuggets' has been a consistent, heavy producer in Florida and has shown excellent harvesting and handling characteristics. The fruit are sometimes damaged by hot-water quarantine treatments.

5.2.6. Group 4

This group consists of the single cultivar 'Haden'. 'Haden' is put into a separate group because it is still harvested routinely in Florida from older orchards. It is not being planted in Florida at the present time.

'Haden' fruit arc oval with a rounded base and apex. The fruit mature from June to mid-July and average from 510 to 680 g. The fruit are quite attractive with a bright yellow ground color and a crimson or red blush, sometimes with additional highlights of green. The flesh is deep yellow, firm and juicy with a sweet and rich flavor. Eating quality is gond to excellent with ahundant fine fiher in the flesh. In Florida, 'Haden' is an inconsistent producer and is severely damaged by anthracnose. Internal breakdown is common in this cultivar and there is a tendency tn produce seedless fruits in some years. 'Haden' is widely grown in Tropical America, where it produces good crops and responds well to bloom induction (R.J. Campbell, personal ohservation).

5.2.7. Group 5

This group consists of minor commercial cultivars from Florida. Many of these cultivars hold promise for other areas.

'Brooks' was the dominant late-season cultivar in Florida until it was replaced by 'Keitt'. Its major drawback has heen the lack of color. The fruit arc oblong with a rounded base and a bluntly-pointed apex. The fruit mature from August to early October and average from 480 to 830 g. Fruit have poor colnr with a greenish-yellow ground color and-no blush. The skin is thick, medium tnugh and adherent. The flesh is deep yellow, firm. and juicy with a mild and sweet flavor. Eating quality is fair with medium fiber in the flesh.

'Davis-Haden' has heen grown commercially to a limited extent in Florida. The fruit are large and highly susceptihle to anthracnose infection. Fruit are oval to ovate with a rounded base and apex. Fruit mature from mid-July to August and average from 680 to 900 g. Fruit have a greenish-yellow ground color with a purplish or red blush. The skin is medium thick, tender and adhesive. The flesh is orange, firm and juicy with a rich, spicy and sweet flavor. Eating quality is good with lit tic fiber in the flesh.

'Edward' has been grown commercially to only a limited extent due to its inconsistent, light production and only fair color, but the eating quality is excellent. 'Edward' is presently grown in some areas of Tropical America on a limited commercial scale. The fruit arc oval to oblong with a rounded basic and a bluntly pointed and rounded apex. Fruit mature from June to July and average from 450 to

620 g. The color is generally poor with a greenish-yellow ground color and a pink blush. The skin is medium thick, tender and adherent. The flesh is orange, tender, melting and juicy with a rich and spicy flavor. Eating quality is excellent with no fiber in the flesh.

'Fascell' was the first patented mango selected in Florida. Maturity is sometimes difficult to determine on this cultivar due to its flattened shape and coloring habit. The: fruit are nearly fiberless, which adds to their soft nature and short postharvest life. The fruit are oval to ovate with a somewhat flattened base and a rounded apex. Fruit mature from late June to July and average from 300 to 450 g. Fruit have a bright yellow ground color with a pink to crimson blush. The skin is thin, tough and adherent. The flesh is yellow, tender and juicy with a mild and sweet flavor. Eating quality is good with no fiber in the flesh.

'Glenn' has received limited commercial attention in Florida, but is produced on a small commercial scale in Tropical America. The major disadvantage of 'Glenn' is its softness and generally poor handling and storage characteristics. The fruit are oval to ohlong with a rounded base and a bluntly pointed apex. Fruit mature from June to July and average from 400 to 620 g. They have a bright yellow ground color with a orange-red blush. The flesh is yellow, soft and juicy with a rich and spicy flavor. Eating quality is excellent with no fiber in the flesh.

'Lippens' is a heavy producer in dry climates, however, in Florida it is inconsistent due to its great susceptibility to anthracnose. The fruit are ovate to oblong with a rounded to slightly flattened base and a rounded apex. Fruit mature from late June to July and average from 350 to 520 g. Fruit have a yellow ground colour with a pink or crimson blush. The skin is medium thick, tough and adherent. The flesh is deep yellow, firm, melting and juicy with a mild, sweet, aromatic flavor. Eating quality is good to excellent with no fiber in the flesh.

'Parvin' has been described in detail by Campbell and Campbell (1991). It has been grown commercially in Florida and Puerto Rico for many years and is now attracting attention in Tropical America. In Florida, commercial production has been discouraged hy the tendency to produce seedless fruits. 'Parvin' has exceptional storage characteristics with an exceptionally long postharvest life. It is reported to respond well to Dower induction. The fruit are oval to oblong with a rounded base and apex. The fruit mature from July to August and average from 450 to 690 g. The ground color is greenish-yellow with a dark red blush. The skin is thick, tough and easily separating. The flesh is yellow, firm and juicy with a mild and sweet flavor. Eating quality is good to excellent with moderate fine fiber in the flesh.

'Sensation' is a consistent, heavy producer In Florida, but the fruit are small and highly susceptible to anthracnose. It has performed well in dry climates, and has substantial resistance to bacterial black spot. 'Sensation' fruit are oval with a rounded base and apex. The fruit mature from mid-July to September and average from 280 to 340 g. The ground color is dark yellow with a prominent red to purple hlush. The skin is medium thick, tough. and easily separating. The flesh is deep yellow, firm and moderately juicy with a mild, sweet flavor. Eating quality is fair to good with no fiber in the flesh.

'Smith' is a consistent, heavy producer in Florida. Its commercial production has been limited due to its susceptibility to anthracnose and only fair eating quality. The fruit are oblong with a rounded base and apex. The fruit mature from July to August and average from 580 to 950 g. The ground color is yellow-orange with a dull crimson blush. The skin is thin, tough and adherent. The flesh is deep yellow, firm and moderately juicy with a mild sweet flavor. Eating quality is fair to good with medium fiber in the flesh.

'Zill' is a consistent, heavy producer in Florida, but its small size, softness, and anthracnose susceptibility have limited its commercial success. There is increased interest in this cultivar in Tropical America due to its good flesh quality and brilliant color. The fruit are oval to ovate with a slightly flattened base and a bluntly pointed or rounded apex. The fruit mature from June to early July and average from 230 to 370 g. The fruit are attractive with a yellow ground color and a bright red blush. The skin is thin, tender and adherent. The flesh is pale yellow, soft and juicy with a mild and sweet flavor. Eating quality is good to excellent with no fiber in the flesh.

The mango cultivars discussed in this paper will continue to strongly influence commercial mango production throughout Tropical America in terms of both domestic consumption and export markets. Characteristics that have limited the commercial use of a particular cultivar in Florida may be of no consequence in other areas due to differences in rainfall patterns, temperature, and/or humidity. Thus, each of these cultivars could hold promise well beyond that attained thus far in Florida. Additionally, the:-e are many other cultivars which are grown in home gardens or in germplasm collections throughout the state which have not been grown on a commercial scale. Detailed descriptions of many of these other cultivars have recently been! published (Campbell, 1992). These cultivars constitute not only a potential for future commercial development, but also a valuable source of germplasm for the mango industry of the world.

5.2.8. References

Campbell, C. W. 1973. The 'Tommy Atkins' mango. Proc. Florida State Hort. Soc. 86:348-350.

Campbell, C. W., C.A. Campbell, and K. Mitchell. 1990. The 'Van Dyke' mango. Proc. Florida State Hort. Soc. 103:298-299.

Campbell, R.J. (ed.). 1992. *A Guide to Mangos in Florida.* Fairchild Tropical Garden, Miami, Fl.

Campbell, R.J. and C. W. Campbell. 1991. The 'Parvin' mango. Proc. Florida State Hort. Soc. 104:47-48.

Crane, J.H. and C. W. Campbell. 1991. The mango. Fla. Coop. Ext. Serv., Fruit Crops Fact Sheet FC-2, revised.

Lynch, S.J. and M.J. Mustard. 1950. Mangos in Florida. Fla. Dept. of Agr. Bul. 20.

Ruehle, G.D. and R.B. Ledin. 1956. Mango growing in Florida. Fla. Agr. Exp. Sta. Bul. 574.

Young, T. W. and J. W. Sauls. 1979. The mango industry in Florida. Fla. Coop. Ext. Servo Bul. 189.

5.3. WORLD COMMERCIAL MANGO VARIETIES

By R. J. Knight, Jr. Homestead, Florida

The following are some of the mango varieties being grown in countries other than Indo-Pak, sub-continent. Commercial varieties of India and Pakistan have been described separately.

5.3.1. Bombay green (India)

Also called 'Bhojpuri', 'Bomhai', 'Hiralal Bomhai', 'Kali Homhai', 'Laile Alipur', 'Malda', 'Sarauli' and 'Sheeri-Ohan', The tree is tall and erect, the fruit is apple green with yellow ochre blush at the base and on some exposed parts, dots abundant, with brown specks in the middle, ovate with beak almost missing, medium-sized, with tough, thick, non-adhering smooth skin; the flesh is cadmium-orange, firm and juicy with scanty fibre just under the skin, very sweet with pleasant aroma, of very good quality; seed monoembryonic in full, thick, medium-sized stone. Season early, A medium bearer. 'Bombay yellow' is said to be practically identical with this cultivar but for a slight deterrence in fruit colour. The present 'Bombay green' is considered to be a degenerate form of the original one (Singh, 1960) (Bombay green' has long been grown in Jamaica, but introductions from there to Florida have not been successful, and have fruited poorly. In Jamaica it is sometimes called 'Peter', which suggests a confusion with 'Pairi', but the Jamaican 'Peter' is without the bright red blush normal to 'Pairi'.

5.3.2. Bourbon (Brazil)

The tree is of medium size with a dense canopy; the fruit is greenish-yellow, ovate-cordiform with rounded base, of medium size averaging 300 g in weight, the skin is smooth, thick and easily separating; flesh with long, diffuse fibers, juicy, yellow, taste agreeable, subacid and resinous, quality considered for fresh consumption; stone medium-sized, oblong and quite fibrous, enclosing polyembryonic seed. Ripens over a long season, through most of the year (Sampaio, 1980; A,C, Pinto, personal communication, 1996; L,C: Donadio, personal communication, 1996).

5.3.3. Cambodiana (Vietnam)

Also known as 'Xoai Voi', The tree is moderately vigorous, with a dense, rounded canopy; the fruit is greenish-yellow, unblushed with a few small white dots, oblong to ovate, 9-11,5 cm long by 6,5-7.5 cm broad by 6-6.5 cm thick, weighing 220-340 g; the skin is thin, tender and adherent; the flesh contains little fibre, is tender and melting, lemon yellow, sweet and mildly subacid with a pleasant aroma; the seed polyembryonic in thick, woody stone. Season early. Brought to Florida in 1902, gave rise to the ,'Saigon' landrace there (Campbell, 1992).

5.3.4. Carabao (Philippines)

The tree is vigorous, forming a large and canopy; fruit greenish to bright yellow, blushed with few small green dots, long and slender, with base rounded to slightly flattened, 11-13 cm long by 6.5-7 cm broad by 6-6,5 cm thick, weighing 270-440 g; the skin is thin, medium-tough and easily separated; the flesh is without fibre, tender and melting, lemon yellow, spicy and sweet with mild aroma, of good to excellent quality; seed polyemoryonic in thin, papery stone. Season early (Campoell, 1992). A heavy hearer that may alternate; however, it can be induced to fruit by potassium nitrate treatment in the tropics (Bondad and Linsangan, 1979). Highly resistant to bacterial black spot (*Xanthamonas campestris pv. Mangiferaeindicae*) in Queensland (Mayer *et al.*, 1988). Introduced to Florida in 1909, 'Carabao' is important in commerce between the Philippines and Japan

5.3.5. Coracao de Boi (Brazil)

The tree is vigorous, precocious and productive; the fruit is greenish-yellow and intense red on the side exposed to the sun, cordiform, medium-sized, pulp yellow and fibrous. Seed polyembryonic. Two seasons in Sao Paulo, January-February and September-December. One of the best brown commercial cultivars in Sao Paulo state (Sampaio, 1980; A. C. Pinto, personal communication, 1996; L. C. Donadio, personal communication, 1966).

5.3.6. Espada (Brazil)

The tree is tall and developing rapidly, with a dense canopy, very productive, the fruit is intense green or greenish yellow, oblong-elongate with concave base, medium-sized, with smooth, thick skin; the flesh has much fibre, is egg yellow, with a strong aroma of turpentine, quality considered good for fresh consumption. polyembryonic seed in oblong stone, covered with soft fibres and many nerves. Two seasons per year in Sao Paulo, January-February and November- December (Sampaio, 1980; A.C. Pinto, personal communication, 1990; Donadio, personal communication, 1996).

5.3.7. Extrema (Brazil)

The tree is upright, vigorous and productive; the fruit is yellow with greenish areas, ovate-reniform, weighing 350-400 g, with skin smooth and thin, flesh yellow, watery, with almost no fibre, with moderately resinous, agreeahle taste, quality considered good for fresh consumption and processing. Polyembryonic seed in large, fibrous stone. Season early (Sampaio, 1980; A,C. Pinto, personal complication, 1996).

5.3.8. Golek (Indonesia)

The tree is moderately vigorous with upright, open canopy; the fruit is greenish-yellow with an orange overlay and prominent white dot, oblong with rounded base, 9.5-12.5 cm long by 6-8 cm broad by 5.5-6.5 cm thick, weighing 200- 365 g; the skin is thin, tough and easily separated, flesh soft and juicy with abundant fibre (not objectionable), deep yellow, sweet, insipid with mild aroma, of poor to fair quality, seed polyembryonic in large, woody stone with abundant fine fibre. Midseason (R. J. Knight, Jr. personal communication, 1995),

5.3.9. Hindi' (Egypt)

Also known as 'Hindi Be Sennar', The tree is vigorous, tall and upright, the fruit is greenish -yellow; with an orange-yellow blush and a few large, hellow-shite dots, long and slender with rounded base, 1012 cm long by 6.5-7.5 cm broad by 5-6 cm thick, weighting 250-300 g, the skin is thin and tough, easily separating the flesh is soft, tender, melting and juicy with no fibre, deep yellow, rich, very sweet and spicy with a mild, pleasant aroma, of good quality; seed polyembryonic in thick, woody stone with a moderate amount of medium-long fibre. Light crop. Midseason (C.W. Campbell, personal communication, 1995). (NB. This cultivar approximates in size, appearance and quality many popular Egyptian kinds, of which the following are examples: Awis, Sebda, Taimour, Miska and Succary. Although its name suggests and Indian origin, Hindi does not closely resemble any well-known Indian cultivar.

5.3.10. Itamaraca (Brazil)

The tree is small, with a dense canopy; the fruit is greenish yellow, oval (similar to a tomato in shape) with a flat base having a small cavity, small, with a smooth skin and juicy golden yellow fibreless flesh of an agreeable taste with little turpentine aroma, of very good quality; seed polyembryonic in a small stone. Early to midseason, highly productive, Originated on the island of the same name in Pernambuco state (Sampaio, 1980; A.C, Pinto, personal communication, 1996; L.C, Donadio, personal communication, 1996).

5.3.11. Julie (West Indies)

Also called 'St Julienne'. The tree is compact (quite dwarf in Florida), with a dense canopy; the fruit is greenish-yellow with a light pink to maroon blush and numerous small white dots, rounded with flattened apex, pronouncedly compressed laterally, 7-9,5 cm long by 4-7.5 cm broad by 2-5.5 cm thick, weighing 300-325 g with a thin, tender skin and soft, melting juicy orange flesh with scanty fibre, of a ricb, spicy flavour with a strong, pleasant aroma, of good quality; and seed monoembryonic in a thin, papery stone. Midseason, regular producer of small crops. The fruit is often severely infected with anthracnose disease, but its unique taste is preferred by many West Indians, and it is exported to the London market (C,W, Campbell, personal communication, 1996).

5.3.12. Kensington (Australia)

Also known as 'Kensington Pride' and 'Bowen'. 'Kensington' has a large, vigorous tree with spreading canopy; the fruit is yellow with an orange red blush on the shoulder, round ovate with flattened base; with a slight beak, 10.5-13 cm long by 8.5-9.6 cm broad by 7.5-8.5 cm thick, weighting 350-750 g; the skin is thick, tender and adherent; the flesh is soft and juicy, with moderate to little fibre, yellow, sweet with a characteristic flavour that makes it the most popular cultivar in Australian markets, of excellent quality; seed polyembryonic in moderately thick, woody stone. Midseason, bears well. Unusually susceptible locally in Florida, to damage by red-banded thrips [*Selenothrips mhricinculs* (Giaru)] and may be killed by this pest wlthout adequate counter measures (R.J. Campbell, personal communication, 1994; R.J. Knight, Jr, personal communications, 1995). Moderately susceptible to anthracnose and bacterial spot (Mayers *et. al.*, 1988).

5.3.13. Kent (Florida)

The tree is large, vigorous, with dense, upright canopy; the fruit is greenish-yellow with red or crimson blush, numerous small yellow dots, oval, with rounded base, 11-13 cm long by 9.5-11 cm broad by 9-9.5 cm thick, weighing 600-750 g; the skin is thick; tough and adherent; the flesh is firm, tender, melting and juicy with little fibre, deep yellow to orange yellow, sweet with a rich flavour and pleasant aroma, of excellent quality; the seed is monoembryonic in thick woody stone. Late midseason to late; may alternate. Seedling of 'Brooks', which is a seedling of 'Totapuri' ('Sandersha'). 'Kent' is not commonly commercial ill Florida because there it is prone to storage disease, but a successful commercial cultivar in drier parts of Mexico, Central America and West Africa (Campbell, 1992). Highly susceptible to bacterial black spot in Queensland (Mayers *et. al.*, 1988).

5.3.14. Kyo Savoy' (Thailand)

The tree is large, vigorous, with open canopy made up of long hranches: the fruit is green when harvested (before ripening process begins), turning to greenish-yellow, oblong, 11.5-12.5 cm long by 5.5-6,5 cm broad by 5-6 cm thick, weighing 230-340 g; the skin is thin, tender and adherent; the flesh is medium firm, tender and not very juicy with no fibre, pale yellow, very sweet with insipid taste and mild, pleasant aroma, affair to good quality, seed highly polyemhryonic in medium-thin stone. Regular producer (C. W. Campbell, personal communication, 1995). (Fruit often consumed green, as is `Nuwun Chan'.)

5.3.15. Mabrouka (Egypt)

The tree is strong and sturdy, with a dense .canopy; the fruit is a beautiful deep orange colour, medium to large, elongated with a pronounced beak: the flesh is free of fibre with a pleasant aroma, seed monoembryonic, quality good. High yielding, considered to be an introduced cultivar from India whose original identity was lost (Singh, 1960).

5.3.16. Madame Francis' (Haiti) !

The tree is moderately vigorous, medium-sized, forming an open canopy; the fruit is greenish to bright yellow, with no blush and a few large russet dots. oblong, sigmoid with rounded base, 15-17 cm long by 8.5-1I cm broad by 5.5-7.5 cm thick, weighing 370-520 g; the skin is thin, tender and adherent; the flesh is soft and juicy with medium fibre, orange, rich, spicy and sweet with pleasant aroma, of fair to good quality; seed polycmbryonic in a thin, papery stone. Early to midseason, hears well. Early fruit is shipped to North America in markets from Haiti before any fruit ripens on the USA mainland (Campbell, 1992).

5.3.17. Madu (Indonesia)

Also spelled 'Madoe'. The tree is moderately vigorous with dense, rounded canopy; the fruit is light greenish yellow, oblong with rounded base, of moderate size, weighing 240-385 g, the flesh is soft, tender and juicy, with much fibre, yellow, weakly aromatic and sweet, of poor to fair quality; seed polyembryonic in a large, woody stone. Midseason, alternates. The name means `honey' (R.J. Knight, Jr, personal communication, 1995).

5.3.18. Manila (Mexico)

The tree is large, vigorous with upright, open canopy; the fruit is bright yelk)w, sometimes with light pink blush, a few small reddish dots, long and slender with rounded base and bluntly pointed apex sometimes with a small beak, 12.5-14 cm long by 5.5-6 cm broad by 5-5.5 cm thick, weighing 180-260 g; the skin is thin, medium tough and easily separating; flesh medium firm and juicy, with little to abundant fibre, deep yellow, sweet, rich and spicy in taste with a pleasant aroma of good to very good quality; seed polyembryonic in medium thick and woody stone. Early midseason, crops fairly dependably. For a long time, 'Manila' 1las been the most popular mango in Mexico. 'Ataulfo' is a selection commonly grown in Chiapas state and now, in the Canary Islands (Campbell, 1992),

Manzanillo-Nunez (Mexico)

The tree is large, of medium vigour with uprighı canopy; the fruit is yellowish-orange with 75% of surface blushed an intense dark red with numerous dots, oval with moderately flattened base, averaging 12 cm long by 10 cm broad by 7.5 cm thick and 660 g weight, flesh low in fibre, slightly subacid and very palatable, quality high; seed monoembryonic in relatively small stone, Season early but spread over a 60-day harvest period. Bears heavily without pronounced alternational; fruit stores and ships well (Nunez-Elisea, 1984).

5.3.19. Maya (Israel)

A cultivar of unknown parentage selected in Israel by Professor Chanan Oppenheimer. The tree is vigorous, making a tall dense canopy; the fruit is yellow with a red blush, small to medium-sized, 250-350 g, of high eating quality and in demand in local markets, Seed monoembryonic, Season is one of the earliest. Often suffering from internal breakdown, 'Maya' is no longer recommended for commercial planting (Eli Tomer, personal communication, 1995; S, Gazit, personal communication, 1996).

Mulgoa (India, to Florida)

Also spelled 'Mulgoba' and 'Mulgova' The tree is large, vigorous with open, spreading canopy, the fruit is bright yellow with pink blush and numerous large white dots, oval to ovate with flattened has~ H. 5-1.0. 5 cm long by 6.5-7.5 cm broad by 5-6 cm thick, weighing 340-450 g; the skin is thick, medium tough and adherent, flesh soft, tender, melting and juicy, with little fibre, lemon yellow, rich, spicy and sweet with strong pleasant aroma, of good to excellent quality; seed monoemhryonic in thick, woody stone. Midseason to late, a shy, irregular hearer, Introduced to Florida in 1989 and there called 'Mulgoha', this is the seed parent of 'Haden', first of a series of cultivars known as the Florida group, A question exists whether the cultivar known as 'Mulgoha' in Florida is identical with the Indian cultivar or is a seedling rootstock that survived after the scion was killed by cold. In either case its superior quality ensured .its retention and propagation (Camphell, 1.992). Literature serves to compound the nomenclatural confusion; as illustrated by Gangolly et at. (1957), 'Mulgoa' fruit, yellow overall and roundish-oblique with a deeply depressed stem insertion, does not resemble the cultivar introduced to Florida. Singh (1960), on the other hand, portrays a rounded, lightly blushed greenish yellow fruit that closely resembles the Florida mango, Furthermore, vegetative propagation of selected chance seedlings has resulted in a variety of clonal types carried under this name in India (Ratnam and Chellapa, no date).

5.3.20. Nam Doc Mai (Thailand)

The tree is vigorous, medium-sized, with upright, dense canopy; the fruit is greenish to hright yellow with slight pink blush and numerous small green dots, long and slender, sigmoid in shape with a rounded base, 17-19 cm long by 7.5-8.5 cm broad by 6.5-7.5 cm thick, weighing 340-580 g; skin medium thick, tender and easily separated from flesh which is soft, tender and juicy with no fibre, lemon yellow, rich, spicy and very sweet with a pleasant aroma, of excellent quality; seed polyemhryonic in thin, papery stone. Early midseason, fruits regularly, may have multiple crops in one season (Campbell, 1992). Highly resistant to foliar infection, and resistant to fruit infection by bacterial black spot in Queensland (Mayers *et. al.*, 1988).

5.3.21. Naomi (Israel)

The tree is medium-sized and fairly erect; the fruit is an attractive red, oblong, of uniform size, weighing an average of 450 g, skin smooth and thin; the flesh is tender, juicy and nearly fibreless, yellow, mild and moderately sweet, with a weak pleasant aroma, of good quality; seed monoemhryonic. Midseason. 'Naomi' is a seedling of 'Palmer' open-pollinated, and is patented (Tomer *et al.*, 1993).

Nuwun Chan' (Thailand)

The tree is moderately vigorous, small, upright with dense canopy; the fruit is ' greenish-yellow with pink to red blush, numerous small green dots, long and slender with flattened base, 16-18 cm long by 7-8 cm broad by 6-6.5 cm thick, weighing 340-500 g; the skin is thick, tough and easily separated; the flesh is soft, melting, juicy with little fibre, pale yellow, mild and sweet with faint, pleasant aroma, of good eating quality; seed polyembryonic in thick; woody stone, Early. regular bearer. Often eaten green, as is 'Kyo Savoy' (Campbell, 1992).

5.3.22. Okrung (Thailand)

The tree is moderately vigorous, medium-sized and upright forming a dense canopy; the fruit is green to greenish yellow with no blush and numerous small white dots, oblong and sigmoid with rounded base, 11-13 cm long by 5-6 cm broad by 4.5-5.5 cm thick, weighing 160-240 g; the skin is thick, tough and medium adherent; the flesh is soft and juicy with abundant fibre, yellow or greenish, mild, somewhat insipid and very sweet with a pleasant aroma, of good quality; seed polyembryonic in a thick, woody stone. Midseason; heavy producer, sometimes more than one crop per year (Campbell, 1992).'

5.3.23. R2E2 (Australia)

The tree is upright and slightly spreading, extremely vigorous until it begins cropping 4-5 years after planting; the fruit is yellow with strong orange-red blush over sun-exposed parts of the fruit, ovate shaped, weighing 800 g on. average; the flesh is firm but low in fibre, sweet and mild-flavoured with good shelf life, highly regarded and competes well in domestic and export markets; seed predominately polyembryonic. Mid to late season. This open-pollinated seedling of 'Kent' was selected by I. Bally and R. Wright at Bowemn 1982 and was released to the industry in 1991; 100,000 trees were planted in northern Queensland by 1994. It is not expected to replace volume sales of smaller fruit in the 400-600 g range (Anonymous, 1991; Chacko *et al.*, 1996)."R2E2' is moderately susceptible to anthracnose and bacterial black spot (A. W. Whiley, Queensland, personal communication, 1996).

5.3.24. Rosa (Brazil)

The tree is medium-sized, of slow growth with rounded canopy; the fruit is yellow to rose-red on the side exposed to sun, oblong-cordiform and medium-sized; the skin is thick and smooth; the flesh is finl1 an(i moderately juicy, fibrous, golden yellow, moderately sweet with turpentine aroma, of ordinary quality susceptible to anthracnose disease; polyembryqnic seed in small, oblong stone. Midseason to late. One of the most important commercial cultivars in the Federal District, used for juice as well as fresh consumption; one of the most well-known cultivars in Brazil (Sampaio, 1980; A. Pinto, personal communication, 1996; L.C. Donadio, personal communication, 1996).

5.3.25. Sabina (Brazil)

The tree is moderately vigorous, upright with dense canopy; the fruit is green, rounded and medium-sized; the flesh is firm and yellow, pleasantly sweet with a mild aroma, of fair to good quality; susceptible to anthracnose disease although generally; disease resistant in Brazil (Sampalo, 1980), seed polyembryonic in medium-sized woody stone, .Early, fruits irregularly (R. J. Knight, Jr. personal communication, 1995).

5.3.26. Sensation (Florida)

The tree is vigorous, with moderately open, symmetrical canopy; the fruit is dark yellow with prominent dark red to purple hlush that covers most of its surface, oval with rounded base and rounded apex, 9-11,5 cm long by 7-8 cm broad by 6.5-7 cm thick, weighing 280-340 g; the skin is medium thick, tough and easily separating; the flesh is firm and medium juicy, fibreless, deep yellow, mild and sweet with a weak, pleasant aroma, of fair to good quality; seed monoembryonic in a thick, woody stone, Midseason to late (Campbell, 1992). Alternates severly, and in 'on' years fruit may be clustered so heavily that it becomes diseased before maturity, thus 'Sensation' is not of commercial importance. Highly resistant to bacterial black spot in Queensland (Mayers *et al.*, 1988), blat often has severe internal breakdown (A. W, Whiley, Queensland, personal communications, 1996)

5.3.27. Suvarnarekha (India)

Also called 'Swarnarekha' and 'Sundri', The tree is moderately vigorous and tall, with rounded, dense, spreading canopy; the fruit is light cadmium yellow with blush of jasper red and abundant small, light-coloured dots, ovate oblong with base slightly flattened, of medium size, 11 cm long by 8.2 cm broad, weighing 400 g; the skin is medium thick, easily separated, flesh soft, fibreless, primrose yellow with pleasant aroma, sweet taste and abundant juice, of medium to good quality;

seed monoembryonic in an oblong-oval stone covered with soft, short fibre. Season early, heavy bearing (Gangoll *et al*, 1957).

Tahar (Israel)

The tree is vigorous, medium-sized, with an upright, dense canopy; the fruit is bright yellow with dark red blush and numerous small white dots, ovate with flattened base, 11.5-13 cm long by 8.9-9.5 cm broad by 7.5-8 cm thick, weighing 360-520 g; the skin is thick; tough and easily separating; the flesh is soft and juicy with little fibre, deep yellow, mild, aromatic and slightly insipid with a strong odour not appreciated by many, of fair to good quality; seed monoembryonic in a medium-thick woody stone. Late midseason; bears well in Israel (Campbell, 1992).

5.3.28. Tommy Atkins (Florida)

The tree is vigorous, with dense, rounded canopy; the fruit is orange-yellow, with crimson or dark red blush and numerous small white dots, oval to oblong, with broadly rounded base, 12-14.5 cm long by 10-13 cm broad by 8.5-10 cm thick, weighing 450-700 g; the skin is thick, tough and adherent; the flesh is firm and medium juicy, with medium amount of fibre, lemon to deep yellow, mild and sweet with a strong pleasant aroma, of fair to good quality; seed monoembryonic in thick, woody stone. Early to midseason. 'Haden.; seedling. 'Tommy Atkins' is the most important commercial cultivar in Florida, and now grown in numerous countries; it is highly resistant to anthracnose disease and handling and shipping stress, and a consistent, heavy producer (Campbell, 1992). 'Jelly seed' (internal breakdown) is a serious problem in the moist subtropics and tropics outside Florida, where the mango is grown on calcareous, well-drained soil (A.W Whiley, personal communication, 1996).

5.3.29. Van Dyke (Florida)

The tree is moderately vigorous, with large, open canopy; the fruit is bright yellow with bright red or crimson blush, oval with rounded base, 9-11.5 cm long, by 7.5-9.5 broad by 7-8 cm thick, weighing 250-520 g; the skin is thick, tough and easily separating, flesh quite firnl, melting and juicy with little fibre, orange- yellow, rich, spicy and sweet with a strong, pleasant aroma, of good to excellent quality; susceptible to internal breakdown seed monoembryonic in a medium- thick, woody stone, Late midseason; regular, heavy producer (Campbell, 1992).

5.3.30. Vallenato (Colombia)

The tree is vigorous, with upright, dense canopy; the fruit is bright yellow, with crimson blush, oblong with flattened base, 8-9 cm long by 7-8 cm broad by 6-7 cm thick, weighing 195-340 g; the skin is thin, tough and adherent, flesh firm, juicy with abundant fine fibre (not objectionahle), pale yellow, mild and sweet with a strong, pleasant aroma, of good to excellent quality, seed monoembryonic. Early midseason (R.J. Campbell, personal communication, 1995). '

5.3.31. Zill (Florida)

The tree is vigorous and tall with an open, spreading canopy; the fruit is greenish-yellow to yellow with intense red or crimson blush, oval to ovate with base slightly flattened, apex rounded to bluntly flattened with a small beak, 8.5-10 cm long by 7.5-8.5 cm broad by 6-7 cm thick, weighing 230-370 g; the skin is thin, tender and adherent; the flesh is pale yellow, soft and juicy without fibre, mild and sweet with a strong, pleasant aroma, of good to excellent quality. Seed monoembryonic in thick, woody stone. Early midseason, a regular producer. `Zill' does not withstand storage and shipping stresses well, and thus is not favoured for commerce (Camphell, 1992).

5.4. SENSATION: A MANGO VARIETY FOR EXPORT

***Dr. Saeed Ahmed*[3]**

Introduction of mango varieties from India more than a century mango laid down the foundation of mango industry in Florida, the only state which produces some quantity of mango on the main land U.S.A. None of the varieties introduced form India however did well under Florida's soil, climate and biotic conditions. Sexual progeny of Mulgoa variety, which was erroneously introduced into Florida as Mulgoba, gave some promising chance seedling. Among these one seedling later named as 'Haden' generated keen interest in mango cultivation on commercial scale. Haden did exceedingly well under Florida conditions and held its own for long time. However continued search for more promising chance seedling; replaced this variety with more regular and heavy bearing cultivars such as Kent, Keitt, sensation, Irwin and Tommy Atkins.

In early sixties the writer who was Fruit-specialist at that time introduced five mango varieties from Florida and three from Hawaii at Ayub Agricultural Research Institute, Faisalabad, for testing and acclimatization. Kent, Keitt, Zill, early gold and sensation Mango varieties from Florida did well but could not be commercially exploited since except for one, namely sensation, the others ripened at about the time when the locally well ,established and highly prized varieties also mature and come in the market. Consumer's preference for local, well flavoured and aromatic varieties did not favour the cultivation of those varieties, with good size, well developed shoulders and red, pinkish tint on surface.

Sensation, however, ripened very late in the season and hanged well on trees even in September, and provided an opportunity to extend the period of mango harvest and availability of fresh fruit by month or two. The variety has the following morphological and internal characteristics.

The tree is heavy cropper. The fruit is medium small to medium in size. The fruit weighs from 300 grams to 350 grams, but larger fruit weighs as much as 600 grams or so, length 9 cms width 7.5 cms, thickness 6.75 cms, base flattened. The left shoulder more developed and slightly raised, the right shoulder sloping, the stem slightly elevated obliquely inserted in grooved cavity, apex rounded to bluntly pointed, beak lateral, often inconspicuous about 2cms above apex, surface

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smooth to somewhat undulating, the peel, thin, adhering firmly, however separating easily, ground colour bright yellow to yellow orange, the blush dark plum red, with numerous lenticels, pulp firm, pale yellow mild slightly sweet with distinctive agreeable flavour and aroma fibre scanty, quality good.

At Ayub Argi. Research Institute, Faisalabad the trees show the tendency to put forth major bloom in spring months, with several subsequent light blooms during early summer months, with the result that fruit matures late August and September, when the leading local varieties have already been harvested. The fruit at maturity attains beautiful pinkish plum red blush.

The trees of sensation variety first fruited in the year 1968-69. Opinion of panel of experts and consumers response led to the commercial exploitation of this variety which fully adapted itself to local environs and .warranted the possibilities of the extension of mango season by one to two months. Punjab government should have keen interest in the variety and advised its multiplication and distrihution of plants. Plants supplied at that time and during latter years, are now in full bearing in may mango orchards. However, area under the variety and production is relatively still small. It has largely been due to non-availability of grafted plants of the variety in any large number.

In European markets, greater emphasis is laid on eye appeal and consumer in those countries prefer to buy red checked mangoes, It is because of the fact that supplies of mango to those markets so far came from Florida, Venezuela, Mexico and Brazil and consisted of red blushed mangoes.

Sensation from Pakistan possesses all those traits and can therefore be exported to those markets successfully. Edge should be in favour of Pakistan, since sensation ripens here at a time when the supplies from other sources cease. Along with this strong promotional measures must be taken to introduce and boost the sale of our own varieties which quality wise remain world's best.

In view of the prospects and possibilities the variety offers in extending the mango season and bright prospects of export the situation demands that the variety should be multiplied in large quantity to exploit the potentials and derive economic benefits to the fullest extent.

5.5. FLORIDA'S COMMERCIAL MANGO VARIETIES

Geo D. Ruehle and r. Bruce Ledin, Sub-Tropical Experiment Station Homestead, Florida

For many years Haden was the only variety planted commercially. But because of its irregular bearing in commercial planting, it has lost favour and is being replaced by some of the newer varieties that have shown promise of bearing crops nearly every year. Thirty-nine varieties originating in Florida have so far been named, but of these only it few appear to have the characteristics desirable in commercial varieties. Some have not been, grown long enough to determine their commercial possibilities; others, though they may bear well, either do not have quality or eye appeal or do not ship well not ship well.

In judging a mango for its commercial possibilities, the following should be considered:

1. Under favourable conditions, it should bear good crops every year.
2. A high percentage of flowers should be perfect and there should be little tendency to produce embryoless fruit.
3. The fruit should be attractively coloured.
4. The fruit should hold well when shipped and ripen with good quality as much as 10-14 days after harvest.
5. The variety should be sufficiently resistant to anthracnose so that commercial control is practicable.
6. The flavour should be satisfactory with flesh free of objectionable fibers and the stone should be 10 per cent or less of the weight of the whole fruit.

Varieties that seem to meet most of these requirements., especially in bearing good crops, and that are being planted commercially include Zill, 'Irwin, Kent, Palmer, and Keitt: These, listed according to time of maturity from early to late are briefly described here.

Zill: Fruit small to medium-small, to 4 inches long, averaging 8-12 ounces in weight; shape ovate; ground colour yellowish with a light tn dark crimsnn blush and a lavender bloom, lenticels many, small and yellow. Flesh is juicy, fiberless with flavour rich and sweet and quality good to very good. Stone makes up about 18 per cent of the weight of the fruit. Season early, sometimes as early as May 15 and extending through June and sometimes into early July. Packs well and holds up well in shipping, and can be picked at mature-green state and will ripen satisfactorily with good quality. Tree becomes fairly large but relatively open with leaves yellow-green in colour.

Irwin: Fruit medium size, to 5 inches long, weighiilg up to 16 ounces; averaging about 12; shape is rather elongate or narrow-ovate; ground colour orange-yellow with a bright red blush, lenticels small and white. Flesh fiberless with mild flavour and quality good to very gnod. Stone relatively small. Season June and July. Fruit holds up well in shipping. Tree somewhat dwarf; fruits produced in clusters.

Kent: Fruit large, becoming 5 inches or more in length, averaging about 24 ounces in weight; shape ovate and rather thick and plump; ground colour greenish-yellow with a dark red blush and gray bloom; lenticels numerous, small and yellow. Flesh juicy and fiberless, rich and sweet and quality very good to excellent. Stone makes up 9 per cent of the weight of the fruit. Season is July and 'August and sometimes early September. Fruit hnlds up well in shipping and is one of the better late mangoes. Growth habit is upright with ascending branches.

Palmer: fruit large, to 6 inches long and to 2 pounds in weight, averaging about 25 ounces; shape elongated but full; ground colour orange-yellow with a red blush and pale bloom, lenticels large and, numerous. Flesh firm and with only a small amount of fiber, quality fair to good. Stone long and of medium size. Season July and August. Tree of moderate vigour and open in growth.

Keitt: Fruit large, to $4^3/_4$ inches long and to 24, ounces in weight; shape oval, plump and thick; ground colour yellow with a light pink hlush and with a lavender bloom, lenticels numerous small and yellow to red in colour. Flesh juicy, fiberless except near the seed, flavour rich and sweet, and quality very good. Stone small, 7 to 8.5 per cent of the weight of the fruit. Season is August and September. Fruit ships well and is considered the best of the very late mangoes. Tree has a very peculiar habit of growth, producing long arching branches and a scraggly open appearance.

Other varieties that are being planted commercially but on a smaller scale, include Davis-Haden, Fascell, Lippens, Haden, Smith, Springfels, and Brooks, although the last named four are not being planted as extensively as in previous years.

Davis-Haden: Fruit large to 6 inches long and 2 pounds in weight; shape ovate and full; ground colour orange-yellow with a dark red to purple-red plush, lenticels large, white. Flesh with only a few fine fihers; quality considered fair to good. Season July and August.

Fascell: Fruit medium size, to 4½ inches long and to 16 ounces in weight; shape ovate and some what flattened; ground colour pale yellow .with a pink red or old rose blush, lenticels large, white to yellow. Flesh nearly fiberless, with flavour tart to sub-acid and quality rated as fair to good. Season middle of June through July. Tree of moderate vigour with a rather open growth.

Lippens: Fruit medium size, to 4½ inches long and 16 ounces in weight; shape ovate-oblong; ground colour deep yellow with a bright crimson hlush and lavender bloom speckled with, rose; lenticels many, small and yellow. Flesh juicy, fiberless, with flavour rich and sweet and very good quality. Season is June and July. Tree of moderate vigour with compact growth.

Haden: Fruit large, to 5½ inches long and to 24 ounces in weight; shape oval and plump; ground colour yellow with a crimson blush and with numerous white lenticels and a heavy bloom, producing an attractive variegated appearance. Flesh juicy, nearly fiberless with sub-acid flavour and good quality. Season June and early July. Tree becomes quite large and spreading. Formerly much planted in commercial groves and door yards.

Smith: Fruit large, to 6 inches long and to 2 pounds in weight; shape elongated and full; ground colour orange-yellow with a deep maroon to scarlet blush, lenticels large and white. Flesh nearly fiberless, quality rated as fair to good. Season July and Aug4st. Tree is upright and open and rather asymmetrical in growth.

Springfels: Fruit large, to 9 inches long and to 3 pounds in weight; shape oblong; ground colour orange-yellow with a deep maroon blush, lenticels numerous, white. Flesh contains only a. small amount of fibers. Quality rated as fair to good. Season is July and August. Tree tends to remain dwarf.

Brooks: Fruit medium-large, to 6 inches long and to 24 ounces in weight; shape oval to oblong and plump; colour greenish-yellow, sometimes with a pale red blush; lenticels large and white. Flesh moderately free of fibers, quality fair to good. Season August and September and sometimes, early Octoher. Somewhat dwarf and open in growth. Valued as a late variety but becomes of the lack of eye appeal, has lost favour as a commercial variety.

Several new varieties have been under test at the Subtropical Experiment Station for a number of years. Their commercial possibilities have not been thoroughly tested, but they seem desirable either because of their early season (Early gold) or because of their small fruit (Adams, Ruby, Sensation, Sunset).

Adams: Fruit small, to 3¼ inches long and to 10 ounces in weight; shape oval to oblong; ground colour bright yellow with a crimson blush, lenticels small and yellow. Flesh juicy, rich, sweet, fiberless; quality very good. Tree of moderate vigour, upright and only slightly spreading. Season June and July.

Earlygold: Fruit medium size to 5¼ inches long, and to 12 ounces in weight; shape oblong; ground colour orange-yellow with an orange-red or orange-pink blush, lenticels small, yellow to white. Flesh juicy, sweet, and fiberless; quality very good to excellent. Stone often contains aborted seeds but the fruit matures to its full size. Tree upright and of moderate vigour. Season is May and June.

Eldom: Fruit medium size to 4¼ inches long, and to 18 ounces in weight; shape oval; ground colour pale yellow with a bright tomato-red blush, lenticels medium large, yellow in colour. Flesh juicy, sweet, and fiberless; quality very good to very good. Tree of moderate vigour, upright and with a dense crown. Season is July and early August.

Ruby: Fruit small to 5 inches long, and to 8 ounces in weight; shape long and slender; ground colour yellow- orange with an dark-red to crimson blush, lenticels yellow and numerous. Flesh sweet and fiberless; quality is good to very good. Fruit often produced in clusters. Tree is of moderate vigour, upright and somewhat open. Season is July and early August.

Sensation: Fruit medium-small to 4¼ inches long, and averaging 10-12 ounces in weight; but individual fruit weights to 10 ounces; shape oval; ground colour bright-yellow to yellow-orange with a dark plum-red blush, lenticels numerous, small and pale yellow. Flesh slightly sweet and a distinctive mild flavour and with scanty fibers; quality good. Tree vigorous, moderately open. And symmetrical in growth. Season August and September.

Sunset: Fruit medium-small to 4¼ inches long, and to 12 ounces in weight; shape oval to oblong; ground colour yellow-orange with a bright orange-red blush, lenticels small and yellow. Flesh is juicy, fiberless; sweet to somewhat acidulous; quality good to very good; .Tree vigorous, grower, upright and somewhat spreading. Season June and July:

5.5.1. Varieties for Home Planting

All of the commercial varieties mentioned above are satisfactory for home planting, In addition, a number of other varieties that produce fruit of very good to excellent quality are recommended for dooryard, planting. They are not commercial varieties because they are either low yielding or produce fruit that lacks eye appeal. Some of these are the following:

Carrie: Fruit medium size, to 4 inches long and 12 ounces in weight; shape oblong; colour greenish-yellow, lenticels small and white. Flesh very juicy, very rich, aromatic and fiberless; quality excellent. Tree somewhat dwarf with a very dense crown, making this variety a very attractive one for dooryard planting. Season June and July.

Edward: Fruit medium-large, to 6 inches long and 16-20 ounces in weight; shape oval to oblong, usually, thick and plump; ground colour yellow-orange with a pink or bright red blush lenticels pale green. Flesh firm, fiberless, moderately juicy; flavour rich and. melting; quality excellent. Stone small and sometimes contains aborted seeds. Season June and July. Tree somewhat dwarf with a very dense crown, making a hand-some tree: Edward is highly recommended for dooryard planting.

Florigon: Fruit medium size, to 5 inches long and to 16 ounces in weight; shape ovate and plump; colour is greenish-yellow to deep yellow, lenticels numerous, small and yellow. Flesh juicy, fiberless; flavour rich and sweet; quality very good to excellent. Season June and July, sometimes late May. It is highly recommended for home planting.

Jacquelin: Fruit large, to 5½ inches long and to 22 ounces in weight; shape round to reniform, thick and plump and rather asymmetrical; ground colour greenish-yellow to yellow-orange,: with a dark red blush and usually when mature variegated with several pastel shades; lenticels numerous, large and yellow to oblong; ground colour bright yellow with a crimson blush, lenticels small and yellow. Flesh juicy, rich, sweet, fiberless; quality very good. Tree of moderate vigour, upright and only slightly spreading. Season June and July.

5.5.2. Classification of Varieties According to Season

The time of fruit maturity varies in different years; in some years the crop may be early with the early varieties beginning to ripen in May and the late varieties in august or even earlier. In other years the season may be late with no variety maturing fruit until June and the late varieties in September and even October. Some varieties, like Edward, will ripen over a period of four to eight weeks and the longer the fruit is left on the tree, the larger it becomes. Some-times fruit matures from two separate blooms and these results in variations in the mango season. The following chart will aid the mango grower and the home owner to choose a number of varieties of mangoes in order to have fruit maturing through the season.

5.5.3. Early Varieties

Earlygold	June, sometimes May
Cambodiana	June and early July, sometimes May.
Florigon	June and July, sometimes May.
Haden	June and early July, sometimes May.
Zill	June and early July, sometimes May.
Irwin	June and early July.

5.5.4. Early Midseason Varieties

Carrie	June and July.
Jacquelin	June and July.
Edward	June and 'July.
Lippens	Late June and July.
Fascell	Late June and July.
Sunset	Late. June and July.
Adams	Late June an9 July, sometimes August

5.5.5. Midseason Varieties

Davis-Haden	July arid August
Eldon	July arid August
Ruby	July arid August
Springfels	July arid August
Smith	July arid August

5.5.6. Late Midseason Varieties

Kept	July and August sometimes September
Palmer	July and August, sometimes September.

5.5.7. Late Varieties

Sensation	August and September
Keitt	August and September.
Brookc	August and September, sometimes October

5.5.8. Development of New Varieties

It would be desirable to develop new varieties, of mangoes by hand-crossing two parents with several desirable qualities with the purpose of incorporating the desired characters of each parent in the offspring. However, in actual practice hand-crossing is very difficult. Because of the inherent nature of the mango, thousands of pollinations must be made to obtain only a few fruit. Young made 12, 703 hand crosses and obtained only 45 fruit. Fourteen years later 43 of these "hybrids" were studied and not one was found that was worthwhile. Similar results have been reported from India. A few good varieties, such as Edward, have been obtained by purposeful breeding. However, the labour involved and the small number of fruit obtained makes this method of producing new varieties hardly feasible,.

Most mango varieties have come into being as chance seedlings. This method is essentially one of planting seeds of choice fruits and allowing the seedlings to bear fruit. Only a very small portion of such seedlings will produce acceptable mangoes. The Experiment Station, commercial nurseries, growers, and interested individuals plant many seeds each year but the chances of finding a superior mango are very small. If a superior mango is found it can be described and propagated as a new variety.

INDO-PAK VARIETIES

STATELY MANGO TREE

AMAN DUSEHRI

LANGRA

Mango Ready to be Served

SINDHRI

GULAB KHASA

SALEH BHAI

AL-PHANSO

ANWAR RATOL

LANGRA

SAMAR BEHISHTCHAUNSA
IN FOREIGN
MARKETS, PEOPLE
WAIT FOR CHAUNSA

ANWAR RATOL

MALDA (SAROLI)

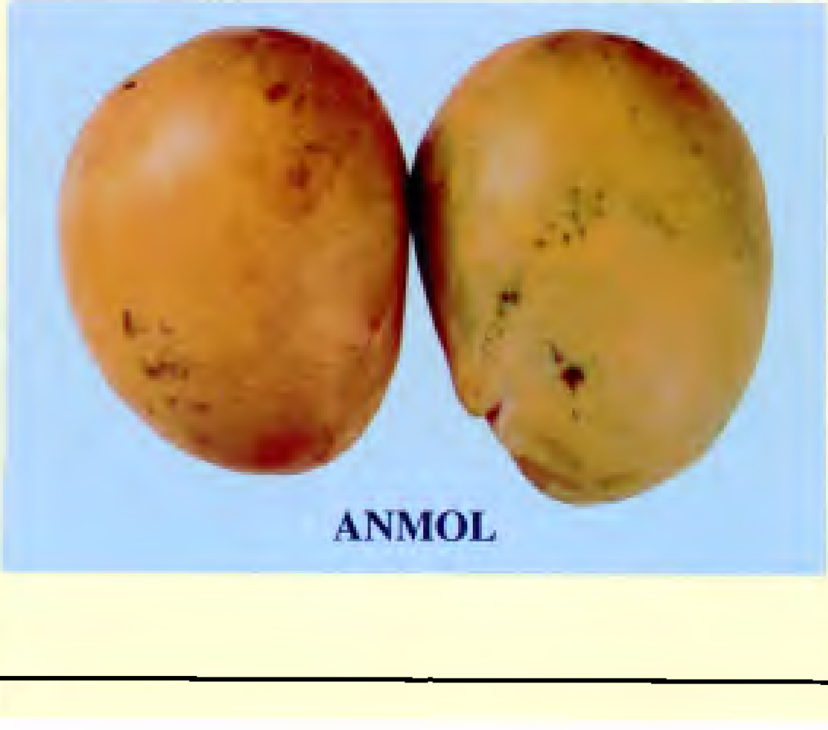
SINDHRI LEADING
EXPORT VARIETY

NEELUM

LATE VARIETY FROM SINDH

YAKTA

LAB-E-MASHOQ



ANMOL

DUSEHRI

MID SEASON VARIETY IN PUNJAB

SHAH PASAND

ALMAS

SUFAIDA

LANGRA

IMPORTANT VARIETY IN INDIA AND PAKISTAN

GHAFOORAY WALA

SAROOLY

IMPORTANT VARIETY IN INDIA AND PAKISTAN

ZARD ALU

NEELM X DUSEHRI

GHULAB KHAS

TOTA PARI

S.S.II

PAN

COLLECTOR

SINDHRI

EARLY VARIETY FROM SINDH FOR EXPORT

ZAFRAN

ZILL

INTRODUCED SUCCESSFULLY IN PAKISTAN

S.S.I

COLLECTOR

S.S.III

BAGAN PALI

WHITE FLESHED, A VERY GOOD QUALITY VARIETY FROM SINDH

MAYA

BURMA SURKHA

HIDER SHAH WALA

SANGLAKHI

VARIETIES FROM FLORIDA

SENSATION

LATE RITENING VARIETY FROM FLORIDA

KEFTT

HADEN

LAID THE FOUNDATION OF MANGO INDUSTRY IN FLORIDA

SPRING FELLS

TOMMY ATKIN

LEADING VARIETY IN FLORIDA

VARIETIES FROM OTHER COUNTRIES

MOMI-K

VARIETY FROM HAWAII

POPE

VARIETY FROM HAWAII

KEINSINGTON

IMPORTANT VARIETY IN AUSTRALIA

JOWELECH

VARIETY FROM HAWAII

MAYA

VARIETY FROM ISRAEL

6. MANGO CULTURE FAR AND NEAR

K. L. Chadha and R. N. Pol

6.1. THE CURRENT STATUS OF THE MANGO INDUSTRY IN ASIA

6.1.1. Introduction

Mango is one of the most important fruits of the tropical and sub-tropical regions of the world. It is native to the Indo-Burma region where it has been under cultivation for more than 4000 years. Mango production in Asia covers an area of 1.002 million ha and total production is about 12.42 million tonnes. Among Asian countries, mango is extensively grown in India, Pakistan, Cambodia, Indonesia, Philippines, Thailand, Bangladesh, Sri Lanka, Malaysia and Israel. India accounts for 60.5 percent of the world production. Of the other countries, Pakistan, Thailand, Indonesia and the Philippines are important mango growing countries with a combined production of 13.4 percent of the total world production. In India, the major mango growing states are Uttar Pradesh, Bihar, Andhra Pradesh, Orissa, Kerala and Tamil Nadu.

6.1.2. Cultivars

There are two types of mango varieties grown in different parts of Asia, monoembryonic and polyembryonic. In the monoembryonic group, seedlings are variable and consistent reproduction of any particular cultivar has to be accomplished by asexual methods. In the polyembryonic group, plants may be raised from seeds. Most Indian cultivars are monoembryonic. The major commercial cultivars in Indonesia, Philippines and Thailand are the polyembryonic type while in Malaysia and Singapore, a mixture of polyembryonic and monoembryonic cultivars are grown.

There are about 1000 cultivars of mango grown throughout Asia. However, only 25-30 cultivars are grown on a commercial scale. In India, commercial cultivars are Alphonso, Bangalora, Banganpalli, Bombai, Bombay Green, Dashehari, Fajri, Fernandin, Himsagar, Kesar, Kishan Bhog, Langra, Mankurad, Mulgoa, Neelum, Chausa, Suvarn-rekha, Vanraj and Zardalu. Of these, Alphonso, Dashehari, Bangalora, Banganpalli, Langra and Chausa are very important. Three new promising hybrids, Amrapalli, Mallika and Ratna, have been developed and released for commercial cultivation. The details of these varieties are as follows.

i) Mallika: A cross between Neelum x Dashehari and an improvement over both of its parents. It possesses many good characteristics of an ideal variety of mango. Fruit quality is good. It is, however, susceptible to bacterial canker in Northern India. It is released from IARI, New Delhi.

ii) Amrarpalli: A cross between Dashehari x Neelum, regular bearer, late and rich in vitamin A content. Very dwarf, 1600 plants can be accommodated per ha with a yield of 22 t/ha. This has been released from JARJ, New Delhi.

iii) Rglilll: A cross between Neelum x Alphonso and released from the Fruit Research Station, Vengurla. This variety is an improvement over parent Alphonso and is free from the malady of spongy tissue.

Recently, the following promising hybrids have also been released by the Indian Institute of Horticultural Research (Iyer, 1991);

i) Arka Aruna (Banganpalli x Alphonso)

ii) ii) Arka Puneet (Alphonso x Banganpalli)

The above hybrids are superior in quality, free from spongy tissue and similar to Alphonso.

iii) Arka Anmol (Alphonso x Janardan Pasand): Very attractive fruit, free from spongy tissue and suitable for export.

The principal commercial cultivars of Pakistan are Anwar Ratole, Chausa, Dashehari, Gulab Khas, Langra, Siroli, Sindhri, Swamrekha and Zabran. The leading varieties of Bangladesh are Fazlee, Langra, Gopal Bhog, Himsagar, Kishan Bhog and Bombai (Hossain, 1989). In Indonesia, Arumanis, Dodol, Gedong, Golek, Madhu and Manalagi are important, while in Malaysia, Tok Boon, Arumanis, Kwala Selangor, Golek, Maha-65, Apple mango and Mulgoa are grown. The two most important cultivars grown commercially in the Philippines are Carabao and Pico. However, some less important cultivars such as Pahutan, Dudual, Senova and Binoboy are also grown in some parts of the country. The leading cultivars of Thailand are Okrong, Nam Dorkmai, Tongdum, Nang Klamgwim, Rad Keaw, Pimsen Mun and Sample. In Singapore, plantations are very limited.

6.1.3. Propagation

The polyembryonic varieties are easily propagated by seed. However, monoembryonic varieties do not come true to type from seed and therefore must be raised through asexual means (Majumdar, 1989). Several techniques that are used for the multiplication of plants are described below:

Inarching or Approach Grafting

Inarching is an ancient method of vegetative propagation that is still practiced in India, Pakistan and Bangladesh. Although this is a very cumbersome and laborious method, it is still used by the majority of nurserymen because of its simplicity and very good success.

6.1.4. Veneer Grafting

Veneer grafting has gained importance because of its many advantages over inarching. This method has become very popular and is in commercial use. This technique has been standardized under different climatic conditions of India, Pakistan and Bangladesh. Side grafting, a modified form of veneer grafting has also been successful in some regions of India, Bangladesh and Pakistan (Khan, 1989).

6.1.5. Epicotyl or Stone or Embryo Grafting

This technique has been standardized relatively recently (Majumdar and Rathore, 1970) and holds great promise especially in humid regions, for multiplying plants in larger numbers and in less time. This has become a very popular commercial method of propagation in Maharashtra and Madhya Pradesh. It has many advantages over other methods, as the nursery life is shortened by a year and the grafts are small in size, and can therefore easily be transported without damage.

6.1.6. Soft Wood Grafting

This is a new technique standardized by Amin (1974) under Gujarat conditions. In this method, a wedge shaped scion is inserted on the terminal growth (usually with copper coloured leaves) of one-year-old seedling rootstock. The scion unites quickly and growth commences within a fortnight. Amin (1978) and Patel and Amin (1981) have also recommended this method for in-situ grafting.

6.1.7. Rootstocks

Not much work has been done in India regarding the use of rootstocks in mango. In general, seedlings are used as rootstock depending on availability of stones. Work done at Lucknow has shown that there was no significant difference in growth of the Dashehari cultivar on different polyembryonic and monoembryonic rootstocks. Samaddar and' Chakrabarti (1989) reported Olour as a dwarfing and productive rootstock for the Himsagar and Langra varieties under West Bengal conditions. Vellaikulumban imparted dwarfing to Alphonso scions but fruit yields were very low compared to other rootstocks. Olour had the maximum growth, fruit yield and leaf nutrient content of the rootstocks tested (Kohli *et al.*, 1989). Thakur *et al.* (1989) reported, that leaf nutrient contents wer,e significantly influenced by different rootstocks. Rumanni rootstock resulted in higher leaf N content and ST -9 rootstock in higher P and K contents. An interstock trial conducted at Lucknow indicated differences in growth parameters at later stages of plant growth. The use of polyembryonic varieties as rootstocks is recommended.

6.1.8. Nutrient Requirements

According to Prasad and Saran (1969-71), a dose of 0.8 kg N was optimum for Dashehari mango trees for more than 10 years of age, while Samra *et al.* (1978) observed the highest yields in mature mango trees of Dashehari when 1 kg N per tree was applied. Foliar application of urea and double super phosphate increased fruit yield when sprayed at full blossom (Samra *et al.*, 1977). Chadha et at. (1984) reported a depletion of N, P, K, Ca, Mg and S contents in the leaves of mango cvs. Dashehari, Chausa and Lucknow Safeda at the postharvest stage as compared to the flowering stage. This major drain of nutrients might be due to translocation of these nutrients to the developing fruits. Thus, there is a need to supplement this loss through soil or foliar application during the postharvest stage.

6.1.9. Leaf Nutrient Standards

Leaf analysis has been used as a guide for determining the nutritional need of mango trees. Most nutrient standards have been established by sand culture experiments and nutritional surveys. Samra *et al.* (1976) analyzed the leaf nutrient status of 30 orchards around Malihabad and concluded that nutrient content of mango leaves varied from orchard to orchard which may be due to rootstock effects. The ideal tissue for analysis was found to be the whole leaf along with the petiole, 4-5 months old and borne on non-fruiting shoots.

6.1.10. Salt Tolerance

Salinity and sodicity are soil conditions that occur mainly in arid and semi-arid regions of India. The area where mangoes are produced in the Pubjab State in India is fast declining due to an increase in soluble salts in the soil. Bhambota *et al.* (1963) reported in Langra mango that high concentrations of all of the three sodium salts viz: chloride, sulfate and carbonate, had injurious effects on the plants. Jindal *et al.* (1975) screened mango seedlings for salt tolerance. Salt injury was low in the vigorous seedlings and high in the weak seedlings. Nutritional studies of mango have also been conducted in other countries. Different timing of fertilizer applications have heen recommended in various countries, depending on environmental factors and growth and developmental stages of mango.

6.1.11. Irrigation

Water management in mango orchards is important but little scientific information is availahle on this suhject. It may play an important role not only in the production of new flushes, but also in retention of fruits, therehy affecting yield. The cultivar, Rumani produced the highest yield (25-95 kg/tree) when irrigated at 10 day intervals between February and May (Purshottam and Navsinha, 1981).

The planting of mango in the Konkan region of India is confined mainly to the lateritic soil which is characterized by highly percolative soil and scarce water resources in the post-monsoon season. In such situations, mango requires irrigation for the initial period of 2-3 years. Successful efforts have been made at Konkan Krishi Vidyapeeth, Depoli to develop a drip irrigation system to irrigate individual grafted trees during the period of establishment.

6.1.12. Intercropping

Not much research has been conducted on this important aspect. Cereals, pulses, vegetables and certain oilseeds grown as intercrops in young mango orchards showed no adverse effect on the growth and yield of mango and gave good monetary returns (Rajput *et al.*, 1986). Intercrop rotation of cowpea-wheat, blackgram-wheat, green gram-wheat was found profitahle. Income from mono-cropping of mango was Rs. 295 per ha/year, whereas it varied from Rs. 3326 to Rs. 4159 per ha/year from the intercropping system (Rajput *et al.*, 1989). Dashehari and Mallika can be grown as fillers in the Dashehari orchard for a few years as a high density planting (Rajput et al., 1986).

6.1.13. High Density Planting

High density planting of mango is not commonly practicetl. However, Majumdar and Sharma (1989) reported an approach which has resulted in achieving a plant density as high as 1600 plants/ha with the new variety Amrapali that has helped in attaining a yield of 11.5 t/ha in the fourth year. The yield increased regularly to about 22 t/ha in the ninth year, which was previously unattainable in mango. The national average is only 8.67 t/ha under the traditional system.

A comparative study of high density orchards with a planting distance of 3.0 x 2.5 m (1333 trees/ha) against the normal spacing of 12 x 12 m (69 trees/ha) was made for grafted Dashehari mango (Ram and Sirohi, 1991). Although per tree yield was greater for the low density than for the high density orchard, the total yield was about 14 times greater for the high density orchard. During the eleventh and twelfth years, height and spread of the trees in the high density orchard was reduced by the same ratio. However, the total yield from trees in the high density planting was about 10 times more that from those planted at a normal density during this period, wrlen trees in the high density were pruned. Thus, high density plantations of Dashehari produced more fruit (10-14 times) than those planted at low density.

6.1.14. Physiological Disorders

Mango suffers from several physiological disorders such as malformation, alternate bearing, spongy tissue, black-tip, internal necrosis, fruit drop and embryo abortion. Some of these disorders are very complex and seem to be caused by several factors. In many cases, the identity of the causal has not been clearly established.

6.1.15. Biennial Bearing

Biennial bearing is a serious problem in mango growing countries. Most of the commercial varieties of mango flower in alternate years. There are two distinct groups of mango varieties with regards to flowering behavior. Varieties grown in North India such as Langra, Dashehari, Chausa and Bombay Green flower in alternate years while those of South India such as Totapuri Red Small, Neelum and Bangalora flower and fruit every year.

There are many factors that affect flowering and fruit of mango, e.g. growth pattern, C/N ratio, crop load, phosphorous qontent, environmental factors and levels of endogenous plant growth regulators (Chadha and Pal, 1986). Work done on levels of endogenous growth substances has shown that shoot tips of Dashehari in 'on' years contained about 35 times more auxin than those in 'off' years (Lal and Ram, 1977). The level of gibberellic acid was found to be higher in 'off' years than in 'on' years. Further, exogenous application of gibberellic acid had resulted in inhibition of flowering (Kachru *et al.*, 1971). Cytokinins, ethylene and inhibitors were found to be in higher concentrations in fruit 'on' years (Agrawal *et al.*, 1980). Kaushik and Ram (1991) isolated 15 steroid-like factors from emerging panicles and their levels were found to be higher during 'on' years.

Work done at the Fruit Research Station, Sangareddy (Kulkarni, 1989) has shown that defoliated shoots of cvs. Alphonso, Da.shehari and Totapuri could be induced to flower within four weeks during the off-season by veneer grafting them onto leafy shoots of the off-season flowering cultivar, Royal Special during the non-flowering season.

Various control measures have been tried for the control of biennial brearing, e.g. dis-blossoming and thinning of fruits, pruning, smudging, potassium nitrate, use of plant growth regulators and other chemicals and adoption of regular bearing varieties. Findings for some of these control measures are described below:

6.1.16. Smudging

Smudging or smoking mango trees to induce out of season flowering and fruiting is a unique feature of mango growing in the Philippines (Gonzales, 1923; Valmayor, 1972; Obligado, 1986). A mango tree is ready for smudging if it has an appearance of suspended growth. At this stage, the leaves are dull green or greenish brown in colour and are brittle when crushed in the hand. The terminal buds should be dormant but well formed. The smudging operation consists of building a smoky fire below the tree canopy and directing the smoke to pass through the foliage. Smudging is often done in December and early January to advance flowering and fruiting by a few weeks. However, it is also done at any time of the year whenever a tree becomes' ready for smudging. Under Indian conditions, smudging has not been found to be effective in inducing flowering in mango.

6.1.17. Use of Potassium Nitrate

Studies in the Philippines have shown that polyembryonic cultivars are dramatically influenced by KNO_3 sprays (Astudil10 and Bondad 1978). Potassium nitrate at 10-40 g/liter induced flowering in 4.5- to 8.5-month-old Carabao mango shoots. The oldest shoots (8.5 months) required only 10 g KNO_3 per liter to produce the best response, whereas younger (4.5 to 7.5 months) shoots were most responsive to 20 g/liter. Pal *et al.* (1984) observed that potassium nitrate, calcium nitrate and magnesium nitrate sprayed at 10 g/liter each on Dashehari cultivars continuously for 5 years, one month before flowering failed to induce more flowering as compared to the control. The differences may be due to the fact that growth under Philippine conditions is continuous unlike the growth pattern under Indian conditions. The commercial cultivars in the Philippines are polyembryonic, whereas the Indian cultivars are monoembryonic.

6.1.18. Use of Plant Growth Regulators

Various plant growth regulators were tried for induction of Flowering. Ethephon was found to induce flowering in mango but results were not consistent. In the last 5-6 years, the effects of paclobutrazol (cultar, a gibberellin biosynthesis inhibitor) on mango growth and development has been studied extensively. It has been demonstrated to induce flowering in a number of commercially important mango cultivars (Tongumpai et al., 1991; Burondkar and Gunjate, 1991). The product is being developed in Thailand, Malaysia, Indonesia, Taiwan, Pakistan and other countries for mango cropping manipulation. The manipulation possible with cultar ranged from entirely off-season or early season cropping to increased yield in season. The extent to which mango cropping can be manipulated varied with local climate, cultivars and occurrence of pests and diseases. There is usually a yield increase associated with cultar treatments.

Burondkar and Gunjate (1991) studied the effect of paclobutrazol as foliar sprays (500, 1000 and 2000 ppm) and as soil applications (5 and 10 g ai/tree) in Alphonso mango. All of the concentrations of paclobutrazol suppressed vegetative growth but induced profuse early flowering and fruiting in both the cropping years. Soil application was more effective than foliar sprays. The maximum average yield was reported for the 5 g ai/tree treatment. Soil application of paclobutrazol 10 g ai/tree promoted flowering in bearing Banganapalli mango (Kulkarni, 1988). Foliar sprays of paclobutrazol have not proved very effective. Kulkarni (1988) reported that a postharvest soil application of paclobutrazol at the rate of 5 to 7.5 g/tree induced profuse early flowering and early fruit maturity in Alphonso, Banganapalli and Dashehari cultivars.

6.1.19. Malformation

Mango malformation is a very serious disorder of mango and is a limiting factor in its economic cultivation. The malady has been reported from several mango growing countries including India and Pakistan (Chadha *et al.*, 1979). The incidence of mango malformation in India was found to be highest in North India. The floral malformation is more important than vegetative malformation because it affects yield as unformed panicles are unproductive. The complex nature of the malady is obvious from the diverse claims made by different workers about its causes, 'e.g. physiological, mites, virus, fungus, nutritional and cultural practices.

Spongy Tissue

Occurrence of spongy tissue, a ripening disorder of mango fruit in Alphonso is a .serious problem in India. There are no external symptoms of the malady on the fruit either at the time of picking or at the ripe stage. Affected tissue is visible only when , the ripe fruit is cut. The affected flesh or tissue is differentiated from healthy tissue by its pale yellow colour, soft or spongy nature with or without air pockets, accompanied by off flavour. Losses due to this disorder may be as high as 30 percent but it varies with the weight and size of the fruit, time of harvest, postharvest handling location and orchard condition. This ripening disorder occurs because of the inhibition of ripening in certain portions of the pulp caused by inactivation of ripening enzymes due to factors such as high temperature, convective heat, and postharvest exposure to sun light.

6.1.20. Black Tip

The black-tip disorder of mango fruit in which the tissues at the distal end die during the early .stages of development in most commercial cultivars of mango, is a very serious problem in orchards located in the vicinity of brick-kilns (Pal and Chadha, 1980). The disorder has also been known as mango necrosis or chimney disease of mango fruits. The affected fruits become unmarketable. The malady is observed only in north India where modern brick-kilns are in operation.

The first external noticeable symptom is the appearance of a small etiolated (yellowing) area. at the distal end of the fruit (Das Gupta and Verma, 1939). The etiolated area gradually increases in size and intensity and covers the entire tip. Simultaneously, isolated grayish spots of indefinite outline make their appearance. As the malady progresses, the spots become dark brown, increase in size and finally coalesce to form a continuous necrotic area. Due to decay of the tissues, the necrotic portion collapses. Subsequently, there is a complete disintegration of the pericarp and mesocarp of the necrotic area exposing the flesh which shows a dark brown colour.

Investigations have shown that brick-kiln fumes are responsible for black-tip malady (Sen, 1941, 1942, 1943; Das Gupta and Verma, 1939; Ranjan and Jha 1940; Prasad and Singh, 1965; Pal and Chadha, 1980). Of the coal fume gases, sulphur dioxide, ethylene and carbon monoxide are especially toxic to the plants and of these, sulphur dioxide causes the most damage (Ranjan and Jha, 1940).

There appears to be a difference in varietal susceptibility to black tip disorder. Dashehari suffered the most, with 100 percent damage in affected orchards while other varieties, namely Gola Mohanbhog, Khajri, Bombay, Safeda, Mallihabad, Kesari, Kalapahar and Taimuria showed less damage. Pracer and Chahal (1963) reported that the variety Champa Kelwa showed resistance to the effects of toxic gases.

6.1.21. Internal Necrosis

Internal necrosis is a physiological disorder of developing mango fruits and caused severe losses (Ram 1976). The disorder was found in immature fruits while on the tree and the affected fruits dropped before attaining maturity. The disorder is characteristically different from black tip, soft nose and spongy tissue formation in mango. The first noticeable symptom in the cv. Dashehari was the appearance of dark green color in the lower half of the fruit. Soon after, it was accompanied by browning of seed and mesocarpic tissue in small areas of indefinite outline in the second and third weeks of May, the period of endocarp hardening (Ram *et al.*, 1978). The brown tissues then turned into brownish black necrotic lesions which later extended towards the epicarp. This was evidenced by the appearance of water soaked isolated areas exuding gummy substances on the fruit surface below the green tip. These brown areas developed into dark brown gummy cavities in the mesocarp surrounded hy tissue. At the advanced stage of the disorder, the affected tissue of the entire lower half of the fruit turned necrotic and collapsed which resulted in longitudinal fruit cracking, exposing the seed through the necrotic region.

The cultivar, Dashehari was found to be more susceptible to internal necrosis than Lucknow Safeda, Bombay Green, Fajri and Chausa. However, Langra was found to be free from this disorder.

Based on effective control of the disorder by soil application of boron or by an injection technique resulting in an increase in foliar boron, it is postulated that internal necrosis is due to boron deficiency.

6.1.22. Ripening

After harvest, mango fruits are stored under ambient conditions for ripening, In Northern India, varieties such as Dashehari, Langra, and Chausa ripen in about 6 days (32-37°C) while in South India, Alphonso, Totapari and Banganpalli may take about 12 days (25°C). Moreover, mango fruits have erratic ripening behavior. Postharvest hot water treatment or an ethrel in a hot water dip produced uniform ripening.

6.1.23. Packaging

The common packages used in the commercial practices in different countries are wooden boxes, wire bound boxes, bamboo or mulberry stick baskets of different shapes and sizes. The corrugated fibre board boxes of different sizes (5-10 kg) are mainly used for packaging for export purposes. Materials such as green leaves, straw, wood saw dust and paper are used for cushioning. However, tissue paper or newspaper wrapping keeps the fruits in good condition with less spoilage and a better appearance.

6.1.24. Transportation

After harvest and packaging, fruits are transported manually or by carts, trucks or rail to consumption center. The latter two modes are mainly used for long distance transport and air-transport is exclusively for the export market. During transport losses of fruit may range from 10-15 percent due to heat burns, bruising, microbial" spoilage, etc. A number of methods such as ventilation, cushioning, and wrapping can reduce transportation losses.

6.1.25. Storage

There is negligible commercial storage of mango fruits in Asian countries. Tremendous efforts are being made to enhance storage life of mango through various treatments but there has not been much success so far. Previously, there were claims for low temperature storage of mango fruits but no information is available for extension of life for more than two weeks storage. Dashehari fruits (mature unripe) stored for a month at 10°C developed chilling injury with blackening of pulp fibres.

The extension of storage life with wax emulsion coating of fruit was only 2-4 days in North Indian cultivars (Kalra *et al.*, 1988). Similarly, Langra and Dashehari mangoes, when stored in perforated polyethylene bags (25.9-33.8°C), had improved quality and shelf life of fruits.

6.1.26. Processing

Mango fruit are used for product preparation at every stage of development. At the early stages of development, raw mango peeled slices are sun dried and .powdered. This powder is used as a souring agent during curry preparation. At a later stage (about 70 days after anthesis) mango slices, peeled and unpeeled, are used for pickling. As a base material for pickles, chutney, etc., raw mango slices are preserved and traded domestically and in the export market. After harvest, mango fruits are generally ripened under ambient conditions without any pre-treatments. Mango slices are also canned in sugar syrup. Homogenized mango pulp is preserved through heat processing, chemical preservation and to a limited extent, by freezing. With the application of aseptic technology, the production of fruit-based drinks made from mango has shown an upsurge. Mango sheet leather is also prepared by dehydration of mango puree. Other commercial products such as mango jam, squashes, etc. are also prepared.

6.1.27. Waste Utilization

The processing waste from the mango industry my have many uses, particularly the kernel, which is rich in starch and fat. However, the mango processing industry is still in a nascent stage using only 0.5 percent of the total mango produce. Hence it generates an insignificant amount of waste. The bulk of the mango crop is consumed fresh and there is no established systen-1 to collect the waste material. Moreover, the waste consisting of kernel and peel is easily spoiled and needs stabilization.

6.1.28. Pests

Mango suffers a colossal loss due to about 188 insect pests. In India, hoppers, mealy bugs, shoot gall psyllas, stone weevils and fruit flies are of major importance and infestation of fruit flies and stone weevils has hampered the export of mango. Important pests in Bangladesh include: hoppers, shoot gall psyllas, fruit flies, mealy bugs, fruit weevils and stem borers. Important pests in Pakistan are hoppers, mealy bugs, shoot borers and fruit flies. In the Philippines important pests include: hoppers, fruit flies, stone weevils, tip borers and twig borers. Hoppers and fruit flies are important pests in Malaysia and Thailand.

6.1.29. Diseases

There are about 70 diseases that affect mango, but only a few are important economically. The major diseases in India are powdery mildew, anthracnose, phoma blight, die-back, bacterial canker, stem end rot, black rot and soft rot. In Pakistan, the major diseases are powdery mildew, anthracnose, stem end rot, bacterial blight and die-back. Important diseases in Thailand are anthracnose and Aspergillus rot. Anthracnose and bacterial leaf spot are important diseases of mango in Malaysia. In the Philippines, anthracnose, powdery mildew, stem end rot, scab, sooty mould and Aspergillus rot are important diseases.

6.1.30. World Production

India accounts for over 60 percent of the world mango production but its share in world exports is not commensurate with its production. For example, 45 percent of the North American demand for fresh mangoes is met within the region, with the balance (40 percent) coming from South America. Only 10 percent comes from Asia and 5 percent is from Africa. However, 90 percent of the mango demand of the Middle East is met from Asia, with 10 percent from Africa.

Traditionally, the major market for Indian mangoes has been West Asia. Some small quantities are also exported to the United Kingdom, Canada, Singapore and ,. Australia. Indian mangoes have not been able to penetrate markets of EEC and t South East Asian Countries. India is not able to export to the large markets of the U.S.A. and Japan due to quarantine restrictions.

Other Asian countries exporting mangoes are: the Philippines to Hongkong, Japan and Singapore; Thailand to Singapore and Malaysia; Indonesia to Hongkong and Singapore; c.nd Pakistan to the Middle East.

India dominates the world trade of processed mango products. Andhra Pradesh is the leading Indian State in production of mango products, followed by

Mahaashtra, U.P., Karnataka, Tamil Nadu and Gujarat. Mango pulp is the main mango product followed by beverages.

Mango pulp is the main mango product exported from India followed by mango chutney, mango pickles, canned mango slices in syrup and mango slices in brine. Importing countries are Bahrain, Bangladesh, France, Norway, Oman, Qatar, South Arabia, the United Arab Emirates and the United Kingdom.

6.1.31. References

Agarwal, A., Ram, S. and Garg, G.K. 1990. Endogenous cytokinins of mango shoot tips and their significance in flowering. Indian J. Expt. BioI. 18(5):504-509.

Amin, R.S. 1978. Soft wood grafting of mango in situ. Indian J. Hort. 35: 105-108.

Astudillo, E.O. and Bondad, N.D. 1978. Po::assium nitrate induced flowering of 'Carabao' mango shoots at different stages of maturity. Philip. J. Crop. Sci. 3:147-152.

Bhambota, J .R., Singh, R.P. and Gupta, M.R. 1963. Studies on salt tolerance of mango plant. Punjab Hort. J. 3:164-170.

Burondkar, M.M. and Gunjate, R.T. 1991. Regulation of shoot growth and flowering in Alphonso mango with paclobutrazol. Acta. Hort. 291 :79-84.

Chadha, K.L., Pal, R.N., Prakash, O. Tandon, P.L., Singh, H., Singh, N.P., Rao, M.R.K. and Lal, B. 1979. Studies on mango malformation -its causes and control. Indian J. Hort. 36:359-368.

Chadha, K.L., Thakur, R.S., Rajput, M.S. and Samra, J.S. 1984. Leaf nutrient status of three mango cultivars at flowering and post-harvest stages. Indian J. Hort. 42:43-84.

Chadha, K.L., and Pal, R.N. 1986. Mango flowering. In: Handbook of Flowering. 211-230. A.H. Halevy (ed.). CRC Press, Boca Raton, Florida.

Das Gupta, S.N. and Verma, G.S. 1939. Studies in the diseases of Mangijera indica Linn. I -Preliminary observations on the necrosis of the mango fruit with special reference to the external symptoms of the disease. Proc. Indian Acad. Sci.,89:13-28.

Gonzales, L. G., 1923. The smudging of mango trees and its effects. Philipp. Agric. 12:15-17.

Hossain, A.K.M.A. 1989. Manual on mango cultivation"in Bangladesh. Bangladesh Agric. Res. Inst., loudebpur, Bangladesh, 86 pp.

Iyer, C.P.A. 1991. Recent advances in varietal improvement in mango. Acta Hort. 291:109-132.

Jindal, P.C., Singh, 1.P. and Gupta, G.P. 1975. Screening of mango seedlings for salt tolerance. Haryana 1. Hort. Sci. 4: 112-115.

Kachru, R.B., Singh, R.N. and Chacko, E.K. 1971. Inhibition of flowering in mango (Mangifera indica L.) by gibberellic acid. Hort. Science 6:140-141.

Kalra, S.K., Tandon, D.K: and Lohani, H.C. 1988. Ripening of wax coated Dashehari mango during storage. Indian Food Packer 42:7-11.

Kaushik, V. and Ram, S. 1989. Endogenous steroids of mango shoot-tip and their significance in flowering. Acta Hort. 291:32-42.

Khan, D.H. 1989. Fruit industry of Pakistan. FAG Regional Expert Consultation on Fruits. Bangkok

Khader, S.E.S.A. 1989. A Short note on clustering in mango -an new disorder. Haryana 1. Hort. Sci. 18:233-234.

Kohli, R.R. and Reddy, Y. T.N. 1989. Influence of rootstocks on growth, yield and leaf nutrient composition of Alphonso mango. Acta Hort. 231 :225-231.

Kulkarni, V.I. 1988. Chemical control of tree vigour and promotion of flowering and fruiting in mango using paclobutrazol. 1. Hort. Sci. 63:557-566.

Kulkarni, V.I. 1989. Physiology of flowering in mango studied by grafting. Acta Hort. 231 :96-105.

Lal, K. and Ram, S. 1977. Auxins of mango shoot tip and their significance in flowering. Pantnagar 1. Res. 2(1):31-35.

Majumdar, P.K. and Rathore, D.S. 1970. Epicotyl grafting in Mango. Curro Sci. 29: 142.

Majumdar, P.K. 1989. Recent advances in propagation and rootstocks in mango- world situation. Acta Hort. 231:157-163.

Majumdar, P.K. and Sharma, D.K. 1989. A new concept of or char ding in mango. Acta Hort. 231:335-338.

Obligado, A. 1986. Plant Industry Production Guide -Mango. No. 62, Bureau of Plant Industry, Philippines, 141 pp.

Pal, R.N. and Chadha, K.L. 1980. Black tip disorder of mango -A review. Punjab Hort. 1. 20:112-121.

Pal, R.N., Chadha, K.L. and Rao, M.R.K. 1984. Effect of different plant growth regulators and other chemicals on flowering behaviour of mango. Indian 1. Hort.41:8-15.

Patel, B.M. and Amin, R.S. 1981. Investigation into the best period for soft wood grafting of mango in situ. South Indian Hort. 29:90-94.

Prasad! A. and Singh, M.P. 1965. A short note on the control of mango necrosis. c ScI.andCult.31:251.

Prasad, A. and Saran, M.D. 1969-71. Optimum requirements of N, P and Kat different ages for maximum growth and fruiting of mango. Hort. Adv. 13:22-26.

Pracer, C.S. and Chahal, D.S. 1963. Common diseases of mango. Punjab Hort. J. 3:221-225.

Puroshotham, K. and Narasimham, B. 198i. Depletion of soil moisture by young mango trees with and without irrigation. South Indian Hort. 29:68-69.

Ram, S. 1976. Internal necrosis in fruit. Indian Farmers Digest 2(3):37-40.

Ram, S., Bist, L.D. and Dwivedi, T.S. 1978. Internal fruit necrosis: A new physiological disorder in mango. Pantnagar J. Res. 3: 196-203.

Ram, S. and Sirohi, S.C. 1991. Feasibility of high density orcharding in.!Dashehari mango. Acta Hort. 291 :207-212.

Ranjan, S. and Jha, V.R. 1940. The effect of ethylene and sulphur dioxide on the fruits of Mangifera indica L. Proc. Indian Acad. Sci. Sect. B. 12:267-288.

Rajput, M.S., Srivastava, K.C., Joshi, O.P. and Biswas, P.P. 1986. Effect of intel-planting fruit crops on mango. Indian J. Hort. 43:216-220.

Rajput, M.S., Biswas, P.P., Joshi, O.P. and Srivastava, K.C. 1989. Mango based cereal pulse cropping system. Indian J. Agric. Sci. 59: 149-153.

Samra, J.S., Thakur, R.S. and Chadha, K.L. 1976. A survey of nutritional status of mango orchards in U.P. Fruit Research Wksp., Hyderabad, May 1976.

Samra, J.S., Thakur, R.S. and Chadha, K.L. 1977. Effect of foliar application of urea on yield and yield parameter of mango. Indian J. Hort. 34:26-29.

Samra, J.S., Thakur, R.S. and Chadha, K.L. 1978. Evaluation of existing critical limits of leaf nutrient standards in mango. Scientia Hort. 8:349-355.

Samaddar, H.N. and Chakrabarti, V. 1989. Effects of different rootstocks on Himsagar and Langra. Acta Hort. 231:220-224.

Sen, P .K. 1941. Black-tip of the mango. Sci. and Cult. 7:56. Sen, P .K. 1942. Further studies on black-tip of the mango. Sci. and Cult. 8:91-92. Sen, P .K. 1943. Studies on black-tip damage of the mango. Sci. and Cult. 9:343-345.

Subramanyam, H., Krishnamurthy, S., Subhadra, N.V., Dalal, V.B., Randhawa, G.S. and Chacko,.E.K. 1981. Studies on internal breakdown -a physiological ripening disorder In Alphonso mango. Trop. Sci. 13:203-210.

Tongumpai, P.K., Jutamanee, K. and Subhadrabandhu, S. 1991. Effect of paclobutrazol on flowering of mango cv. Khiew Sawoey. Acta. Hort. 291 :67-70.

Thakur, R.S., Srivastava, R.P., Chadha, K.L. and Singh, N.P. 1989. Effect of rootstocks on mineral composition of mango leaves. Acta Hort. 231 :232-238.

Valmayor, R. V. I ?72. The Philippine mango industry -its problems and progress. Acta Hort. 24.19-23.

6.2. THE FLORIDA MANGO INDUSTRY

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It is believed that Florida has the largest mango industry outside of India and Pakistan, although the total equivalent of about 7500 acres in Florida is very small in comparison with the 2 million or more acres devoted to mango in its homeland. There are some 300,000 mango trees in Florida, about half of them in orchard plantings and the other half in gardens or yards. At least half of all these mango trees are in Dade County, which includes the city of Miami and is the southern most county on the Florida mainland. Winter minimum temperature is the chief limiting factor to mango culture in Florida, and as minima are higher near the coast than in the interior, and higher the farther south one goes, it is not surprising that mangoes are grown almost entirely in coastal areas of the southern half of the state.

Mango harvest begins usually in May, reaches a peak in June, and declines steadily during July and August. The total crop in an average year is about 3 million pounds, of which 2 million are shipped out of the state to northern markets. The mango is still very little known in the United States, where probably only one person in ten has ever eaten one. No other state than Florida is able to produce this fruit, although another 1 million pounds comes into the country from Cuba, Mexico, Puerto Rico, and Jamaica. Even with 3 million pounds sold in the United States outside of Florida, this would provide annually only one mango fruit per 20 adults on the average.

There have been mango trees in Florida for over a century, brought over from nearby Cuba whither the Spanish had introduced them in the 18th century from Asia. But the mango industry may be said to have begun with the fruiting of a .single tree from India in 1898. There had been several attempts to introduce mangoes of good quality from India to oaf Florida, where only fibrous seedlings were -known, in 1885, 1887 and 1889. Winter freezes had killed all of these imports except for a single tree of Mulgoba which survived and finally fruited in 1898. The delicious flavor and complete lack of fiber of this fruit revived flagging interest and during the next ten years there were many large shipments of mango trees from India to Florida nurseries. Also timely was the development by George Cellon, in 1900, of a method of budding mangoes, making available a much easier technique of propagation than the cumbersome approach-grafting then used exclusively in India.

Now the Mulgoba is a mystery fruit. No variety corresponding to its description has ever been listed in India, so far as I can find, and the name is unknown there. What is more mystifying is that the description sent with the original Mulgoba tree from Bombay does not at all fit the Mulgoba fruit which developed on that tree, although it fits rather well the Mulgoa variety. Apparently it was intended to send a grafted tree of Mulgoa, though the spelling was slightly garbled, but what was actually sent was a tree with fruit of quality and appearance even better than Mulgoa. Since no Mulgoba variety is known in India, there is no confusion caused by using this name for the Florida variety, but one would very much like to know how it came to be sent from Bombay.

None of the 60 or 70 varieties imported from India ever proved well adapted to Florida, so far as fruitfulness was concerned) and the 111ango industry might well have died in infancy were it not for Haden. In 1901, Captain J. J. Haden obtained a few of the still very rare Mulgoba fruits .and planted the seeds. One of the seedlings fruited In 1910 and immediately attracted attention by its magnificent color and its apparently good bearing character. Soon it was being planted commercially in increasing numbers, and the Florida mango industry was an unquestioned reality. For 30 years hardly any mango was planted other than Haden, and several hundred acres were set of it in orchard form.

By 1935, however, it had become only too evident that while Haden had 1.mex- celled eye appeal, good size, a tough skin that endured shipment well, and fairly good flavour, it suffered the serious defect of bearing light and irregular crops. It was also evident that it was unlikely that varieties introduced from other countries would prove satisfactory here. An intensive search was made, therefore, for other seedling trees which, like Haden, had come from seeds of fine grafted types. Between 1940 and 1950, a number of such seedling trees were brought forward which seemed equally as acceptable to the market as Haden and better than Haden in productiveness. Today Haden is little propagated, though probably half of the crop is still of this variety because of the large size of trees of older plantings, and the newer varieties, such as Zill, Irwin, Kent, Palmer, and Keith, constitute most of the younger orchards. With these better varieties, plantings have increased greatly since 1940.

Propagation of the mango in Florida has mostly been either by veneer-grafting or by shield-budding. With the latter method the seedlings are grown in containers and budded when the stocks are about 9 months old, i.e., in the spring following the summer when seeds were planted. For stocks grown in field nurseries, veneer grafting in the second spring has been more successful. The field-grown trees are larger at setting in the orchard than budded trees a come into bearing sooner, but also must be sold at .1 higher prices. There has been no interest in Florida in growing seedlings in the permanent orchard location and .budding or grafting them in place, since there is no difficulty in transplanting nursery trees to the orchard. Recently a method of propagation has been developed, and has had limited usage, by which trees can be made ready for field planting in a. single season. Vigorous -seedlings only 2 to 3 weeks old and still. very succulent, with leaves and bark still red, are side-cleft grafted, using a large shield bud as scion. The stocks are in containers, and the grafted plants can be set out. in the orchard the next spring, when they are only 10 or 12 inches high. Naturally these can be sold cheaply in comparison with trees which the nursery- man cares for much longer.

There is little trouble in getting trees to bloom, such as is often reported from India in off-bearing years. The problem in Florida is to obtain a good set of fruit from the heavy bloom, and this problem is still unsolved. The antl1racnose fungus, *Colletotrichum gloeosporioides,* may blight the bloom, but copper sprays are effective in control and it is not the cause of poor crops. Research has shown the importance of assuring a supply of pollinating insects, notably the honey bee, if a good crop is to be obtained. Low temperatures often destroy much of the flowers or young fruit, but even in years of mild winters there may be little crop set. Research has shown that in Florida, as in India and Pakistan, there arc large differences between varieties in the percent- age of flowers which are perfect, and for a given variety this figure varies from year to year. While there seems to be some correlation between percentage of perfect flowers and fruit setting, as has been reported from India, there seems to be as good or better correlation between setting and polyembryony. Unfortunately none of the polyembryonic varieties has good market quality, and we have no good market varieties which consistently set good crops.

Flower-hud differentiation takes place in the autumn in Florida as in the Punjah, and theft: is no evidence of any problem in this connection. The combination of low rainfall and low temperature at this season even in the warmest section of the state, seems to provide proper conditions for initiating this process. The fertilization programme, therefore, does not need to be directed toward creating favour table conditions for flower-bud differentiation. Of more importance is a good at supply of readily available nitrogen in the soil at the time of blooming. Deficiencies of such micronutrient elements as zinc and copper are well understood and are taken care- of by spray applications.

Shipping of immature fruit to market continues to he a problem, although there is no excuse for such shipments, which demoralize the market. No grower can plead ignorance of how to be sure his fruits are properly mature, since it has been shown that as soon as some fruits have ripened naturally on the tree, all other fruits from the same bloom will ripen satisfactorily on picking. Eventually maturity standards will be developed and enforced, but thus far it has not been possible to set up any standard which can easily be enforced, such as the ratio of solids to acid in oranges.

There is no satisfactory way to utilize mangoes other than as fresh fruit. Neither canning nor freezing has given a very appetizing product. Development of some processing technique would be very helpful in decreasing the prohlem of having nearly all the crop maturing within less than two month.

6.3. THE SOUTH AFRICAN MANGO INDUSTRY

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6.3.1. Abstract

As early as the 17th century mangoes were introduced to South Africa. Over the years processing has become a very important part of production and 60% of the crop is processed to achar (45%) and juice (14%). Exports amount to ahout 10% and local fresh fruit sales to 31% of the total. The total crop for the 1991/92 season amounted to 42 thousand tons. Mangoes are grown in the eastern lowveld regions of the Northern Transvaal Province with rainfall varying between 400 and 1,000 mm annually. Cold spells during winter often result in poor fruit set. New developments are mostly done under irrigation. Although the fibrous cultivars Peach and Sahre still play an important part in the processing and local market sales, the planting of fihreless cultivars increased sharply during the past few years. The cultivars Zill, Tommy Atkins, Sensation, Kent and Keitt are the most important. Powdery mildew, blossom malformation, blossom blight and hacterial blackspot are important pre-harvest diseases with anthracnose and soft brown rot causing most of the post-harvest problems. Important insect prohlems are mango weevil and mango scale. The South African Mango Growers' Association (SAMGA) is a voluntary organization with an estimated 90% of mango growers as members. The association co-ordinates and funds mango research, extension and more recently the feedback from overseas concerning our export fruit. The funds

for meeting the commitments of the association are gathered as a voluntary levy contribution.

6.3.2. Introduction

It is on record that the first mangoes in South Africa were produced before the 17th century. Modern mango production started in 1920 in the Lowveld regions of the Transvaal Province with larger plantings only since 1962 with the introduction of fibreless cultivars. At this stage there are an estimated 10 000 ha of mangoes planted of which more than 50% are of the fibrous cultivars like Peach and Sabre. Important fibreless cultivars include Zill, Tommy Atkins, Sensation, Kent and Keitt.

More than 60% of the mangoes are cultivated under dry land conditions. Large scale plantings are taking place of which most are of the fibreless cultivars planted under irrigation. Better management is also resulting in higher yield and quality. Of the more than 600 mango farms, the top 50 farms produce more than 75% of the total crop.

6.3.3. Production

Mango production figures for the past five seasons are shown in Table 6-1. For this period the total crop nearly doubled from 23 thousand to 42 thousand tons.

Table 6-1. Estimated sale of mangoes

Year	Achar	Juice	Local		Export		Total	
	Ton	Ton	Ton	Cartons	Ton	Cartons	Ton	Cartons
87/88	9,980	1,290	10,972	2,743,000	1,533	383,000	23,775	3,126
88/89	12,000	1,500	12,500	3,134,106	2,400	600,000	28,400	3,734
89/90	12,000	3,000	14,500	3,600,000	3,000	670,000	32,500	4,270
90/91	16,000	4,000	14,400	3,205,000	2,700	612,000	37,100	3,817
91/92	19,000	6,000	13,000	2,888,000	4,400	1,100,000	42,400	3,988

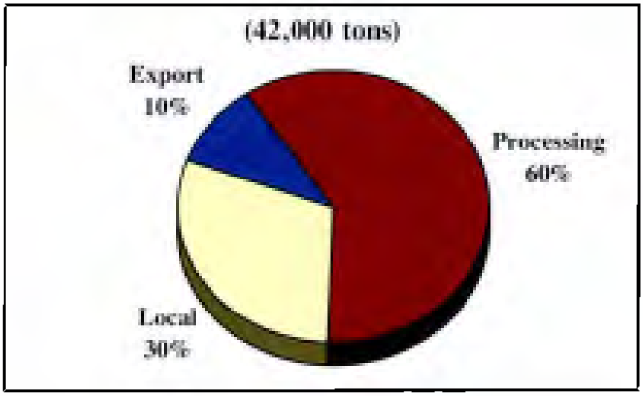
More than 50% of the crop is processed to achar, a green pickled mango product, highly sought after by the black population in South Africa.' Another 10% is processed to mango puree for different mango juices and blends. A smaller percentage is dehydrated and packed as dried mangoes.

Fresh fruit in South Africa accunts for 30% of the total crop and sold on 15 national fresh produce markets from where it can be distributed to retailers, chain stores or other informal sectors. Smaller quantities are sold directly on the farm to chain stores or the hawker trade.

Mango exports increased from about 400 000 cartons five years ago to more than 1,1 million cartons during the past season. A large proportion of fruit is exported to Europe from the middle of December to the middle of April. More than 80% of the export crop is exported by sea in container vessels.

The fruit is packed at various packinghouses in the production areas from where it is transported to Cape Town harbour over a distance of 2 000 km by refrigerated trucks (Figure 6-1). At the harbour modern facilities are available where pallets are containerized and loaded onto the vessels. Fruit arrives in Europe after a voyage of approximately 16 days. Various export agents in South Africa and import agents in Europe are involved.

Figure 6-1. S. A. Mango Production (42,000 tons)



6.3.4. Industry Problems

Climate

Mangoes are produced under sub-tropical conditions. Although trees usually flower profusely, cold spells during this period can result in poor fruit set. Windy conditions during the early part of the season also causes fruit drop and bruises. Rainy wet weather increases disease problems by preventing proper spraying.

Diseases and Pests

The more important mango pre- and post-harvest diseases are:

- Powdery mildew
- Blossom blight
- Blossom malformation
- Bacterial black spot
- Anthracnose
- Soft brown rot.

Insect problems consist mostly of:

- Mango weevil
- Mango scale.

Export related problems

- Fruit size
- Deciding on harvest maturity
- Temperature management from packinghouse to Europe
- Post harvest disease control.

6.3.5. Mango Research

The South African Mango Growers' Association, together with different researchers and research institutions evaluate the industry's problems annually to determine research priorities. Depending on the priorities various research institutions (Governmental, Private and Universities) are fully or partially funded to carry out contract research projects. Feedback and results are presented at the annual research symposium organized by the Association. These symposia are well attended by researchers as well as our grower members.

Some of the more important and interesting projects are discussed briefly:

- Due to our climatic conditions mango flowering within an orchard, even a single tree, can take place over a period of up to three months particularly for the cultivar Sensation.
- Cold spells early in the season can also cause poor fruit set and fruit drop.
- Mechanical and chemical deblossoming to manipulate flowering for Sensation have shown promising results (Oosthuyse 1992).
- Some mango cultivars retain less than one fruit per panicle in spite of adequate measures to control blossom diseases and sufficient irrigation and fertilization. It appears that under local conditions these cultivars do not produce optimally (Oosthuyse 1992). A study was initiated to evaluate foliar spray applications of KNO_3, low biuret urea, GA_3 (glibberellin), CCPU (synthetic cytokinin) and NNA (synthetic auxin). Applications were made during the flowering period. The KNO_3 spray resulted in a noticeable increase in number of fruit retained as well as an increase in average fruit size.
- The objective of manipulating tree size to improve yields by reducing the time from planting until young trees can produce their first crop depends on the degree of peripheral branching of bearing trees and is attainable by pruning. Initial pruning trials with young trees show very promising results. There are unanswered questions about the effect of pruning on productivity because it is a function of both quantity and quality of fruit produced. It is also essential that the benefit of pruning must warrant the additional cost incurred (Oosthuyse 1992). Planting density is also being emphasised. Old orchards were spaced in meters 5 x 5, 8 x 8, 10 x 10 and 12 x 12. The latest spacing tend to be closer for example 7 x 2m with some experimental 3 x 3,5m plantings.
- Some research is also directed at certain ecophysiological aspects of the mango yield problem. Although national yields are as low as 4 to 9 tons/ha, calculations suggest a realistic yield of about 10 to 45 tons/ha. The key to improved fruiting in mango appears to be related to physiological events before and after pollination particularly during the fruit drop period. Excessive flowering results in a marked \ increase in transpiration and subsequent depletion of: carbohydrates cause to severe fruit drop. Researchers believe nutrient and water relations to be the major constraints in existing cultivars. Fruit set appears to be dependant on stored rather than current photosynthate (Wolstenholme and Robert 1991). Research currently underway aims to establish phenological cycles and carbohydrate trends for mango trees.
- Research on mango diseases include the following projects:
- Latent infections affecting post-harvest diseases.

- critical infection periods for anthracnose and soft brown rot
- Pre-harvest chemical control of post-harvest diseases
- screening of post-harvest chemicals for registration
- Ultra-violet and infra-red treatment, and radurisation are other alternatives looked at for controlling post-harvest diseases
- *Xanthomonas campestris* pv *mangiferaeindicae* is the cause of bacterial hlackspot of mango. Fruit isolates of X. c. pv *mangiferaeindicae* which differed in terms of virulence were used to produce monoclonal antibodies. Differences in virulence were confirmed using plant inoculation studies. These antibodies cross react with all the virulence groups, and it is most useful for field detection of latent and existing infections. A selective medium was also developed which might be used by nurserymen together with antibodies to determine infection in the field. This work is of great importance to ourseries and the technique can be used by prospective buyers of plants to determine whether they are free of bacterial blackspot (Sanders, Korsten, van Rooyen, Verschoor & Kotze, 1992).
- *Bacillus licheniformis* and *B. subtilis* on its own or integrated with copper oxychloride pre-harvest sprays effectively cootrolled anthacnose for the third consecutive year. Optimized pre-harvest biocontrol sprays could also reduce powdery mildew and bacterial black spot of mango. The antagonists were also evaluated in semi-commercial experiments in the pack house over a five year period. Warm water antagonist dip applications on its own or integrated with benomyl controlled anthracnose post-harvestly. Integrated control requiring less fungicidal sprays as well as biocontrol treatments could provide an alternative disease control measure for the S A mango industry, providing such biocontrol agents can be registered for commercial use (Korsteo, 1993).
- Irrigation and fertilization 'trials.
- Research on maturity and post-harvest storage is covered by the report about the South African export experience.
- The role and effect of bees and 'other insects on pollination.
- In total more than 38 different research projects are currently being conducted.

South African Mango Growers' Association

The South African Mango Growers' Association (SAMGA) is a voluntary organisation with an estimated 90% of all mango growers as memhers.

The main function of the associatioo is co-ordination of:

- Research
- Extension
- Promotions and advertising.

Research

- Determine research priorities for the industry in consultation with reseachers and research institutions.

- Financing or partial financing of research projects through Universities, Government research organisations as well as private institutions.
- Annual research symposia.
- Annual research reports and yearbooks which place all members in touch with new developments.
- Feedback from Europe by a member of our staff on fruit quality and export trials.
- Plant Improvement and certification Scheme with the aim of improving planting material and distributing new cultivars to the industry.

Extension

- Various study groups where emphasis is put on increased yield and better quality.
- Demonstrations and farmer days
- Annual Harvest and Marketing day to prepare farmers and agents for the corning season.

Promotion and advertising

- Due to the expected increase in production over the next five to ten years the Association's involvement in promotion and advertising is increasing in South Africa and also in Europe.

Funding

- Funds for the Association are accumulated as a voluntary levy paid by all members on all mangoes sold. Agents are very helpful in deducting the levy and paying it over to the Association.

6.3.6. References

Korsten, L. (1993). Personal communication.

Oosthuyse, S. A. (1992). Options to syncronize and delay flowering of Sensation mango. *Internal research* report, *Merensky Technological Services.*

Oosthuyse, S. A. (1992). Effect of foliar applications of KNO_3, urea and growth regulations on yield of Tommy Atkins mango. *Internal research* report, *Merensky Technological Services.*

Oosthuyse, S. A. (1992). Ideas on pruning of mango trees. *Internal research* report, *Merensky Technological* Services.

Sanders, G. M., Korsten, L , van Rooyen, E., Verschoor, J. A. & Kotze J. M. (1992). Production of monoclonal antibodies against different strains of *Xanthomonas campestris pvmagiferaeindicae* can detection methods. S A Mango Growers' Association Yearbook 12. Wolstenholme, B. N. and Robert, J. P. (1991) .Some horticultural aspects of the mango yield problem and opportunities for research. S A Mango Growers' Association Yearbook 11:11-16

6.4. MANGO *(MANGIFERA INDICA* L.) INTRODUCTION AND EVALUATION IN FLORIDA AND ITS IMPACT ON THE WORLD INDUSTRY

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6.4.1. Abstract

The first surviving introductions of mango *(Mangifera indica* L.) germplasm entered Florida from the West Indies, beginning in 1861, when a polyembryonic clone, 'No. 11,' was brought from Cuba. Later, in the 1880s, Pliny Reasoner spent four weeks in Cuba collecting additional material which' was established at the Royal Palm Nursery near Bradenton. The first improved Indian cultivar grown here was 'Mulgoba,' introduced by the United States Department of Agriculture in 1889. Subsequently many additional cultivars were brought to Florida from India and fewer from Vietnam, the Philippines, and more recently Thailand and Israel. The mango's breeding system favors outcrossing, thus the proximity of numerous genotypes of disparate geographic origin has made Flnrida a secondary center of diversity for this crop. 'Haden,' a seedling of 'Mulgoba' that probably arose from cross-pollination with 'Turpentine,' was introduced in 1912 and gave impetus to the establishnlent of a commercial mango industry here. 'Haden' was exported to Hawaii, Mexico, Central America, Brazil, Venezuela and Israel, among other places, where it has been commercially important. Since 1945 'Haden' has become superseded in trade by the more reliably productive 'Tommy Atkins' (a 'Haden' seedling) and other cultivars. Evaluation and improvement efforts continue in Florida and elsewhere.

6.4.2. Mango Introduction and Evaluation in Florida

Although the mango has long been known and esteemed in India and Southeast Asia, it is a relatively new crop in the United States. Interest in growing the mango and other tropical fruits in Florida was engendered in the last century by the successful sale of fruit imported from the Caribbean area in Key West and other cities along the Gulf coast and Atlantic Seaboard of this country (Wolfe, 1962). The first mangos grown in Florida Were polyembryonic criollo types brought from Cuba, all of which were seed-propagated. The first recorded successful introduction of mango germplasm into the state was made in the Miami area in 1861, when seeds of 'No. 11' from Cuba were planted near the Miami River. Seven years later, seeds of 'Peach' were planted in Snapper Creek Hammock, south of Miami. On Florida's west coast, a seedling of 'No. 11' brought from Cuba was planted at Bradenton in 1872, and in 1877 seeds of 'No. 11' were planted at Point Pinellas, near the present site of St. Petersburg (Wolfe, 1962). Because 'No. 11' and 'Peach' are both polyembryonic, seedling populations of these cultivars show a high degree of uniformity. When the 'No. 11' trees at Point Pinellas entered production, the fruit was marketed with success, and by 1887 1,000 young mango trees had been planted at that site, plus nearly as many at Bradenton and Ft. Myers (Wolfe, 1962). In the 1880s, Pliny Reasoner, a nurseryman, spent four weeks in Cuba collecting mangos which he then established at Manatee, near Bradenton (Royal Palm Nurseries, 1887).

In addition to 'No. 11,' mango plants offered for sale in 1887 included one called the 'Common,' better known as 'Turpentine' because of the small, fibrous fruit's strongly resinous flavor (Royal Palm Nurseries, 1887). 'Turpentine's' origin is obscure, but it appears to have been brought from east Africa to the western hemisphere by the Portuguese, nearly 500 years ago. A number of kinds of mango evidently were brought to east Africa from Asia by Arab traders who regularly visited the area before the Portuguese ventured into that 'part of the world (Wheatley, 1956). 'Turpentine' appears to be identical to a mango brought from Kenya to Israel, where it is known as '4-9' (Gazit, pers. comm.).

India was a center of cultivation of mangos and named cultivars of recognized, superior quality had long been known there. The Mogul Emperor Akbar's orchard at Darbhanga was certainly the best-publicized early collection of improved mangos, and it appears to have had an important influence on mango culture, first in India and later throughout the world, thanks to superior germplasm exported and used subsequently as raw material for combining with germplasm from other sources (Popenoe, 1920). This is a continuing process whose ultimate result is yet to be realized, but early results of the effort in Florida had far-reaching consequences.

The horticultural and commercial success of Turpentine' and other polyembryonic mangos in Florida in the last quarter of the 19th century increased the public interest in this fruit, and in 1889 the united Sates Department of Agriculture (USDA) imported six grafted cultivars from India. These six grafted plants were placed by USDA with a cooperator at West Palm Beach, Florida, Professor Elbridge Gale. Severe freezing weather during the winter of 1894-95 killed five of the six outright, with only one, 'Mulgoba,' surviving. It was severely damaged, however, and doubt has been expressed that the surviving tissue was anything other than the seedling rootstock (Fairchild, 1931). Whatever its identity, fruit of the surviving tree when it first appeared in the spring of 1898 was so obviously superior to any mango previously grown in Florida that it kindled new enthusiasm for the cultivation of this crop. A technique for mango propagation by budding was developed, much prefe1'able to the traditional but cumbersome approach-grafting or inarching previously employed. Production of young budded trees in quantity now made it possible to plant sizeable orchards of 'Mulgoba' (Wolfe, 1962).

As the 'Mulgoba' orchards matured, it became evident that this cultivar does not yield dependably under Florida conditions, which was unfortunate because its fruit is of excellent quality. In the ten years after 'Mulgoba' first fruited, more than 60: Indian cultivars were imported and many came into bearing. About this time it became evident that many of high quality such as 'Paheri', 'Borsha' and 'Alfonso' were going to be unproductive in Florida. In the spring of 1910, an event occurred that eclipsed 'Mulgoba' and 'the other Imported cultivars, instantly. A seedling of' 'Mulgoba' entered production, and when the first fruit, matured it became evident that new epoch had opened in Florida mango culture. This new cultivar was named `Haden' by the widow of the man who earlier had planted 'Mulgoba' seed obtained from Professor Gale (Fairchild, 1951).

The appearance of 'Haden' constitutes a watershed event in pomology that has had subsequent, continuing impact in Florida and in many other subtropical and tropical areas. Some facts were obvious when the first 'Haden' fruit appeared: it was more beautiful than any imported cultivar, having a golden ground color and a glorious red blush. It was also larger than fruit of any of the high-quality imports, and at that time appeared to fruit prolifically (Wolfe, 1962). What later became evident from its performance at many sites was that 'Haden' has a much broader genetic base than most Indian imports. In many cases these are superior to 'Haden' in fruit quality but each is so finely attuned to a specific set of environmental conditions that it fails to fruit well when planted far from its site by 'origin. A perfect example is set by 'Alfonso,' which grows well in southern Florida but does not fruit dependably here. 'Haden,' in contrast, has been taken to disparate ecological communities in Mexico, Honduras, Brazil, Hawaii and Israel, where it has performed well as a commercial cultivar.

There has been some question as to the identity of 'Haden's' pollen parent. Because most of the mango trees growing in Florida in 1900 were of the common 'Turpentine' cultivar, speculation has held that 'Haden' resulted from he pollination of 'Mulgoba' by 'Turpentine.' A lot of circumstantial evidence suggests this to be true: 'Haden's' fruit is more fibrous than that of 'Mulgoba,' and its bright crimson blush repeats the similar but less brilliant blush normal on 'Turpentine' fruit. 'Haden's' flavor too is reminiscent of that of 'Turpentine,' although less pungent. Furthermore, the breeding system of the mango encourages out-crossing (Singh, 1969), and 'Haden's' vigor hardly suggests it to be the product of inbreeding.

An examination of enzyme systems in 'Haden' and its known relatives and in 'Turpentine' tends to confirm the speculation about 'Turpentine's' close relationship to 'Haden.' 'Mulgoba,' 'Turpentine,' 'Haden,' and six 'Haden' seedlings were analyzed for five enzymes, following procedures previously described by Schnell and Knight (1992). Based upon the material we used, results were consonant with 'Haden's' origin from 'Mulgoba' pollinated by 'Turpentine' (Table 6-2). However, Degani *et al* (1990), working with 'Turpentine' obtained originally from the National Clonal Germplasm Repository, Miami, found two alleles that were not found in 'Haden' using the aconitase enzyme system. Schnell and Knight (1992) demonstrated that phenotypically indistinguishable trees of 'Turpentine' can be genotypically different. 'Turpentine' exists as a land race of primarily seed- propagated clones, with most seedlings of nucellar origin but with occasional zygotic seedlings. Thus, several genotypes apparently can occur within populations recognized as 'Turpentine.' In the work reported here, the gene frequency data from Table 6-2 were used to estimate relationships between individuals. A pairwise difference matrix was established using the similarity for genetic data program and Rogers (1972) genetic distance. Cluster analysis was performed, employing the unweighted pair group method using arithmetic averages, and a phenogram was produced (Figure 6-2). Principal coordinates using the difference matrix were estimated to determine degrees of relationship. The first three coordinates with a minimal spanning tree superimposed are shown in Figure 6-3. All computations were performed using the microcomputer program NTSYS (Numerical Taxonomy System ver. 1.6, Rohlf, 1990). In Figure 6-3. 'Turpentine' is nearest the center of the field, and its nearest neighbors are 'Mulgoba,' 'Haden,' and 'Tommy Atkins.' This presents strong evidence that 'Turpentine' is genetically close to 'Haden,' and supports the belief that 'Haden' resulted from the pollination of 'Mulgoba' by 'Turpentine.'

Table 6-2. **Isozyme phenotypes of Mulgoba, Turpentine, Haden and six seedlings of Haden Mango.**

Cultivar	Isozyme phenotypes				
	GPI-2	IDH	LAP	PGM-1	TPI-1
Mulgoba	AC	AC	AA	AB	BB
Turpentine	AC	AC	AA	AC	AB
Haden	AC	AC	AA	AA	BB
Eldon	AA	CC	AA	AC	AB
Glenn	CC	AC	AA	—	AB
Lippens	CC	AC	AA	—	AB
Springfels	CC	CC	AA	BC	AB
TommyAtkins	AC	CC	AA	AC	BB
Zill	AA	AC	AA	AC	BB

GPI = Glucose-6-phosphate isomerase *IDH = Isocitrate dehydrogenase*
LAP = Leucine aminopeptidase *PGM = Phosphoglucomutase*
TPI = Tripsephosphate isomerase

Figure 6-2. **Unweighted pair-group method with arithmetic mean phenogram of individual data. Cophenetic correlation = 0.742**

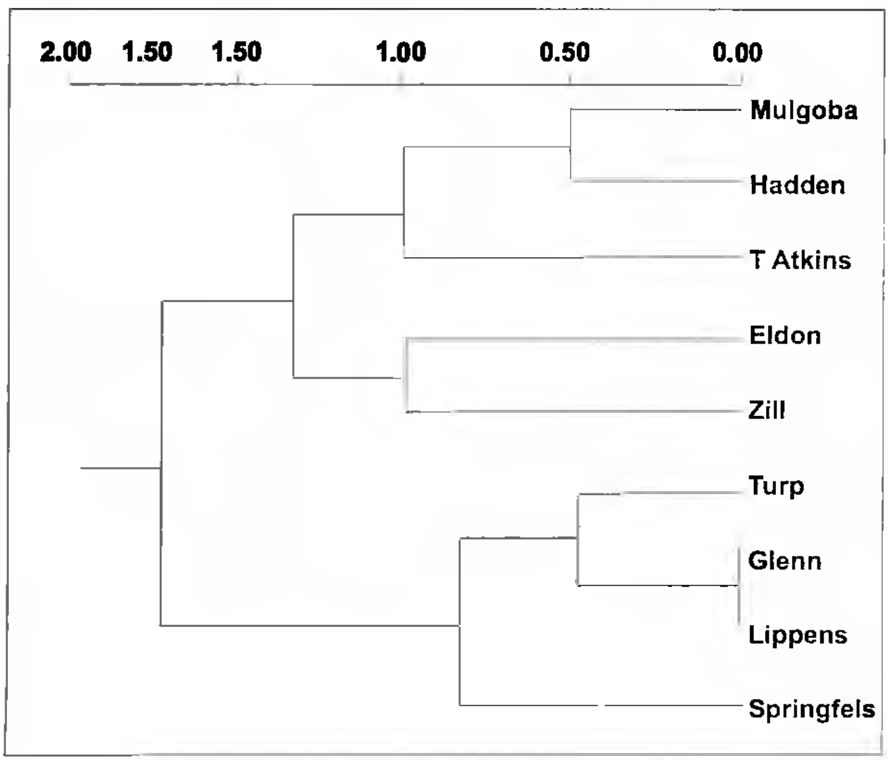
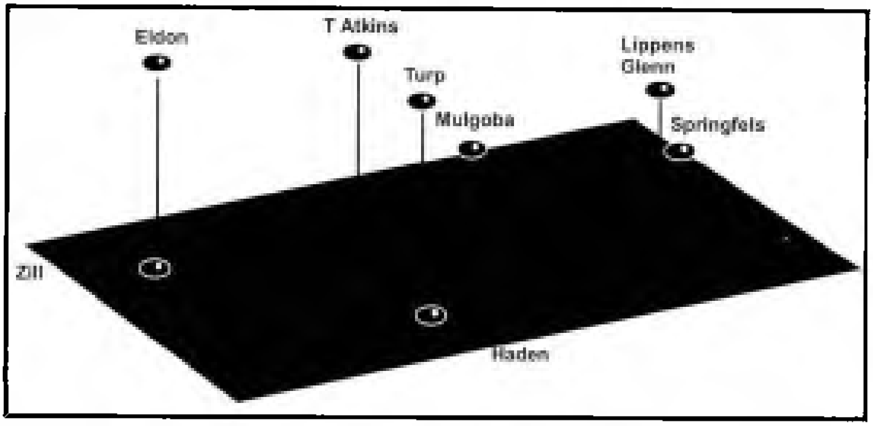


Figure 6-3. **First three axes of principal coordinate analysis of individual data.**



Whatever its origin, 'Haden.' has an important place in history as the first of a group of cultivars now known throughout the world as the Florida mangos. From its introduction to trade by a commercial nursery in 1912 until after World War II, a period of some 40 years, Haden' was the most important commercial mango in Florida. 'Haden' is the seed parent of other cultivars as well: 'Eldon,' 'Glenn,' 'Lippens,' 'Osteen,' 'Parvin,' 'smith,' 'springfels,' 'Tommy Atkins' and , zill' (Campbell, 1992). 'Lippens' in turn is the seed parent of 'Irwin' which gave rise to 'Pope' in Hawaii and 'Tahar' in Israel. The importance of 'Mulgoba's' genetic .contribution to the development of Florida's and the world's modern mango industry is thus evident. Other Indian introductions, notably 'Sandersha,' also have given rise to new cultivars in Florida (Ruehle and Ledin, 1955). To date, all cultivars named here have been chance seedlings; despite considerable effort, none has corne from controlled breeding—a humbling thought to plant breeders.

After improved Indian mangos were brought to Florida, the interest they kindled stimulated more introduction efforts, and these have continued to a greater or lesser degree up to the present. Between 1900 and 1937, USDA made 522 mango introductions to this country (Florida Mango Forum, 1951). These carne from Asia, Africa, Central and South America, and numerous Caribbean and Pacific islands. 'Kensington,' the polyembryonic Australian cultivar, was introduced as seeds hy USDA (P.I. 271268) in 1961, and brought to Miami from the Virgin Islands as scionwood (M-18409) in 1963. Not all the mango germplasm that was introduced survived in Florida but enough did, and continued interpollinating and producing new seedlings, to qualify Florida as' a secondary center of diversity for this crop. The mango obviously did not originate here, but at the present time Florida has as diverse a collection of mango germplasm assembled together as in anyone area of comparable size outside the crop's center of origin.

A few of the introductions made since 1900 have heen of more significance than most. For example, in 1902 Barbour Lathrop and David Fairchild sent home seeds from Saigon of 'Xoai Voy' (P.I. 8701), the best mango available there, called 'Cambodiana' in this country. 'Cambodiana' is polyembryonic, but not all of its seedlings corne "true from seed," and this fact has resulted in an interesting group of "Saigon seedlings" in Florida, some obviously the result of crossing between

Vietnamese and Indian mangos. The Florida cultivars, 'Alice,' 'Herman,' and 'Florigon' arose as Saigon seedlings.

With the introduction of 'Carabao' (P.I. 24927) from the Philippines in 1909, a second important polyembryonic cultivar was added to Florida's mix of genetic stocks. In 1973, a number of Thai cultivars were brought in, and new cultivars and selections from Israel recently were added to the material under test here. Evaluation of recent introductions obviously must continue over a period of years before their value in this part of the world can be well assessed.

One point strongly made by history to date is that even though a cultivar valuable elsewhere may not succeed here, it still can enter into genetic combinations that result in new cultivars of enhanced value. Also, even though the most widely grown modern Florida cultivars are superior in many respects to other mango clones tried here, none of them is completely problem-free. 'Tommy Atkins,' for example, is often plagued by internal breakdown and this same disorder can affect fruit of 'Van Dyke' severely. 'Keitt' has excellent eating quality, superior to that of 'Tommy Atkins,' but 'Keitt's' large size makes it unacceptable in some markets and its relatively dull color makes it less attractive to the consumer than 'Tommy Atkins' and 'Van Dyke.' 'Tommy Atkins' and 'Keitt' both show more disease resistance than most cultivars, but they are not immune to anthracnose (Colletotrichum gloeosporioides Penz.) which causes black streaking, spotting and decay and necessitates costly spraying with fungicides to ensure marketable fruit production in humid climates. The Florida cultivars as a group are more dependably productive than were improved clones tried here earlier, but the need for still more dependable production under a wide range of conditions is recognized.

The possibility that mango relatives from constantly humid areas may have traits that would be of value if transferred to commercial cultivars—notably disease resistance and the ability to fruit under constantly humid conditions—has long been recognized. In 1990 a team of USDA scientists made a plant exploration trip to Malaysia. On the island of Borneo (East Malaysia, Sabah and Sarawak States), they collected 11 species of Mangifera" in addition to M. indica (Table 6-3). Most of these are new to the western hemisphere although a few (notably the kwini [M. odorata] and the bachang [M. foetida]) have been established in Central America for some years. All of the species collected have fruits eaten by the local people where they grow, but little is known of what to expect of them here. Potentially the most exciting new introduction is the mangga air, called M. laurina by some taxonomists but reduced to M. indica by others. Whatever its taxonomic standing, it may have considerable breeding potential. It fruits well in Borneo's humid climate, and it is said to be immune to anthracnose disease. If that claim proves true, the magga air's in breeding for disease resistance can be great, and a new chapter in mango history will open, substantiating the hope that this magnificent fruit can be grown more efficiently and at less cost here in Florida and in other new areas of production.

Table 6-3. Taxa of Mangifera collected on the island of Borneo in 1990.

Species	P.I.	Vernacular Name
M. applanata Kosterm.	560995	n.r.
M. casturi Kosterm.	560996	Kasturi
M. decandra Ding Ho	560997	Bedu dahau
M. foetida Lour.	560998	Bachang, mangga pau
M. foetida Lour.	560999	Bachang, mangga pau
M. laurina Bl.	561000	Mang,ga air
M. laurina Bl.	561001	Mangga air
M. laurina Bl.	561002	Mangga air
M. laurina Bl.	561003	Mangga air
M. laurina Bl.	561004	Mangga air
M. indica L.	561005	Mangga [common mango)
M. odorata Griffith	561006	Kwini
M. odorata Griffith	561007	Kwini.
M. odorata Griffith	561008	Kwini
M. pajang Kosterm.	561009	pajang
M. pentandra Hook. f.	561010	Pau damar
M. quadrifida Jack ex Wallich	561011	Kumbang
Mangifera sp.	561012	n.r
M. torquenda Kosterm.	561013	Bunitan, Palimantan
M. torquenda Kosterm.	561014	Bunitan, palimantan

Progress in communication and transportation since 1945 has permitted greater interregional and international exchange of plant germplasm than was possible at the start of research on tropical fruit crops in this country, although it is difficult at the moment to predict whether this happy situation will long continue. Receipt of improved mango material from abroad indicates increased research activity in parts of the world where this is a relatively new or nontraditional crop. From this evidence it seems probable that the impact of Florida mangos on the world industry was a temporary phenomenon that never again will be what it was at the onset of research and development in new areas. However, the process that began in Florida—introduction of superior germplasm from abroad followed by selection of improved cultivars adapted to local conditions—is now underway in many areas, and world consumers will be the long-range beneficiaries.

6.4.3. References

Campbell, R.J. (ed.), 1992. A guide to mangos in Florida. Fairchild Tropical Garden, Miami. 227 p. Illus.

Degani, C., El-Batsri, R. and Gazit S., 1990. Enzyme polymorphism in mango. J. Amer. Soc. Hort. Sci. 115:844-847.

Fairchild, David, 1931. Some plant introduction experiences. Proc. Fla. State Hort. Soc. 44:54-58.

Fairchild, David, 1951. On the introduction of the mango into Florida. p. 12-17 In: Florida Mango Forum. Mango studies. Publications Comm., Eds. Stuart, Florida. 156 p.

Florida Mango Forum, 1951. Mango Studies. Publications Comm., Eds. Stuart, Florida. 156 p.

Rogers, J.S., 1972. IV. Measures of genetic similarity and genetic distance. In: Studies in Genetics VII. Univ. Texas Publ. 7213. p. 145-153.

Rohlf, F. J., 1990. NTSYS-pc numerical taxonomy and multivariate analysis system. Exeter Software, Setauket, New York. 163 p.

.Royal Palm Nurseries, 1887. Annual catalog and price list. Manatee, Florida.

Ruehle, G.D. and Ledin, R.B., 1955. Mango growing in , Florida. Exp. Sta. Bul. 574, University of Florida, Gainesville. 90 p. Map.

Schnell, R.J. and Knight, Jr., R.J., 1992. Frequency of zygotic seedlings from five polyembryonic mango rootstocks. Hort. Science 27:174-176.

singh, L.B., 1969. Mango. In: outlines of perennial crop breeding in the tropics. Ferweda, F.P. and wit F., Eds. Miscellaneous Papers 4, Landbouwhogeschool Wageningen, The Netherlands. p. 309-327.

U.S. Dept. of Agriculture, 1967. Plant Inventory No. 169. Govt. Printing Office, Washington, D.C. 316 p.

Wheatley, S.M., 1956. The mangoes of the Kenya coast. E. Afr. Agric.J. 22:46-54.

Wolfe, H.S., 1962. The mango in Florida -1887 to 1962. Proc. Fla. State Hort. Soc. 75:387-391.

7. PROPAGATION

Dr. Saeed Ahmed[4]

7.1. SEXUAL, ASEXUAL

The mango plantations are in majority of cases stocked with seedlings. This is largely due to the fact that mango does not lend itself easily to other convenient and easy methods of vegetative propagation. This mode of propagation has however contributed a lot to the mango industry in Indo-Pak sub-continent, as our all present day superior mango varieties are chance seedling selections, which have further been perpetuated through asexual methods of propagation.

Sexual Method: From Seed. The propagation of mangoes from seed or stone involves collection of the stones of fully ripe, syrupy type fruit in the months of July, August. They are stored at one place and kept moist till sown. They are planted in thoroughly prepared and heavily manured soil at a depth of 1.1 inch to 2 inches by either of the following two methods:

1. The stones are broadcasted throughout the field very closely. This is done just to ensure uniform germination. Seeds are covered with well rotted farmyard manure. By this method a large quantity of stones is required.
2. The stones are sown in lines. The distance from line to line and plant to plant is kept one foot and nine inches, respectively.

The irrigation water should be applied frequently to avoid drying up of the stones which results in poor germination. Burns and Prayag as reported by Hayes have shown that the stones stored and planted within one month gave 88°/, germination after 38 days gave 48% germination and the stones planted after 71 days gave only 12%, germination. It is, therefore, evident from the above results that the stones should be planted soon after they have been extracted from the fruit.

In an experiment conducted by Naik on the method of sowing the stones the husk of the stones was carefully removed before planting which resulted in somewhat early germination and the stem and roots were straight but he has not recommended this procedure due to expense and poor germination. He also found that when the stones were sown with their plumules up, common distortion of seedlings was avoided. Stephens stated that the stones sown on their ventral edge on a "pacca" or iron floor with a layer of eight inches sand, helps in the formation of fibrous roots and prevents the tap root. This method is helpful in transplanting the seedlings as the tap root is not injured. Seedling races of mangoes generally grown in Philippines, Indo-China, Burma and Hawaii Island are polyembryonic, and reproduce true to type from seed. However, our present-day knowledge shows that none of the mango varieties grown in Pakistan are polyembroyonic. Therefore, vegetative methods of propagation are being used as tools to preserve the desirable varieties of mangoes in Pakistan. The most common method of vegetative propagation of mangoes in this province has been enarching or grafting by

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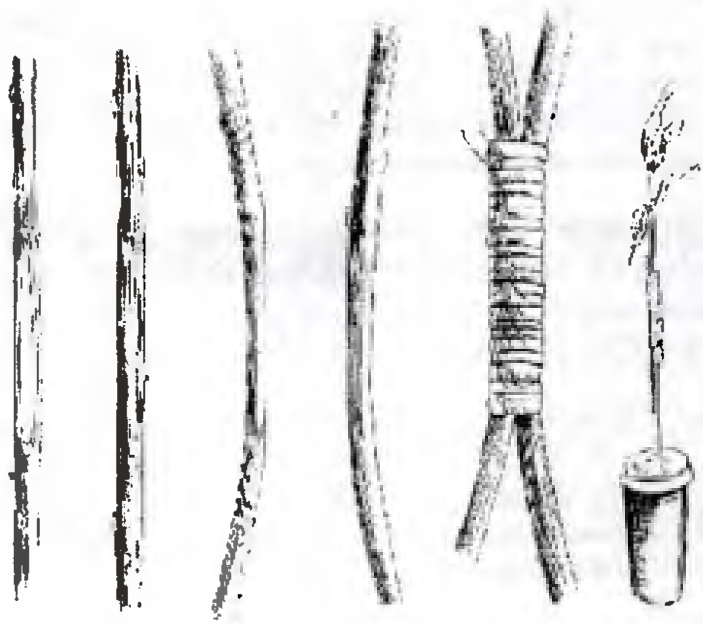
approach. However, being cumbersome has largely been replace by side and veneer grafting.

7.1.1. Asexual Methods

1. **Inarching** : (Figure. 7-1) The method involves potting of one year old healthy seedlings in earthen pots, which are usually 12 inches deep and eight inches wide at the top. Since mangoes have deep tap root system, every care is taken To least disturb the root system in removing the seedlings. The earth ball along with root system is kept intact and as such is placed in the pot. The unfilled space in the pot is then filled with mixture of well rotted manure and canal silt. The soil is firmly pressed around earth ball. The pots are then sprinkled with water. Potting of seedlings is usually done one month ahead of actual inarching operations. This allows sufficient period to the seedlings to set before grafting.

Figure 7-1. Inarching

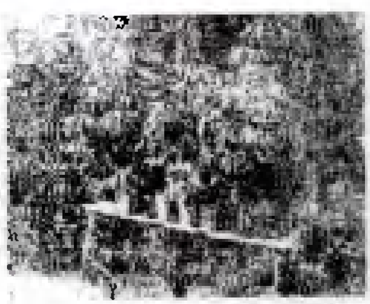


Inarching in the former province of Punjab can either be done in spring months or in rainy seasons (July and August). Months of July and August are preferred over spring season because after inarching operations in the spring months, the wind storms in the early summer months adversely affected the percentage of success. High wind velocity topples over the pots and results in loosening graft union.

The potted mango seedlings are brought close to the parent plants for marching, hence the name of grafting by approach has also been given to this method of grafting. If shoots of desirable size are available at ground level, pots are put underneath the trees and inarching operations are completed (Figure. 7-2). However, if shoots are available only at certain height, the pots are provided support (Figure. 7-3). It has been reported that in districts of United Province of India, in order to get maximum grafts without providing any support for pots, the progeny mango tree is bent over one side. This bending over is effected by heavily irrigating the plant and then bending over the tree on one side. Thus, when one side is exhausted the tree is toppled over on the other side to make use of the remaining shoots. In this case however the progeny trees are meant for grafts only, and in course of time they are totally exhausted. In another method the need of providing support for taking grafts is avoided by training the plants in such a way that central axis of plant is topped and growth is encouraged near the ground level. In some mango growing tract of India as well as in Sind areas the need of pots is not felt. The seedlings are uprooted and are wrapped around by a piece of Burlap.

Figure 7-2. Inarching done on ground level

Figure 7-3. Inarching done on top of grafting stool



Every care is exercised in the selection of root stock and scion shoot. The size of the rootstock and of the scion shoot should be uniform. About two inches long slanting cut about $1/8^{th}$ of an inch deep is made on stock seedlings at a height of 6 to 9 inches or so. A similar cut is given on scion shoot and the corresponding cuts are then brought together and tied with "San-Hemp". The graft union place is covered with a paste of equal parts of soil and cow-dung. This precaution is to avoid grafting-up of the tissue. However, in some trials at Lyallpur (1) waxed cotton tape has proved its superiority over "San-Hemp" covered with mud and cow-dung plaster, as tying material. Plastic films like polythene and alkathene would be even better substitute for this purpose. Moss should be used instead of soil and cow dung paste.

While tying care is taken to bring in contact the corresponding cambium surfaces. The union takes place within three to four months. When the grafts are with parent plants, the pots during summer months' receive watering twice a day. The removal of grafts from the parent plants is a gradual process, prior to the final cutting away of the grafts from the parent plants incision is made on the scion some two inches below the grafts union. The period between the incision and removal of the grafts should be 7 to 10 days. After the grafts have been removed, they are placed under the shade of trees. The top of the stock is also removed through a gradual process after they have been stored under the shade of trees for about two weeks. They are kept for about 4 to 6 months in the nursery before they are planted.

2. **Mango Budding in Situ:** The inarching method of mango propagation though still popular with nursery men, is very cumbersome, time consuming and expensive. In the Fruit Section at Punjab Agricultural College, Lyallpur, every effort had been made to develop some easier technique to propagate mangoes. This endeavour resulted in the development of "Mango Budding in Situ Technique".

3. **Cuttage:** The mangos are propagated very rarely by this method as very little success is achieved. Some hormones for the rooting of cuttings have been tried by the various workers. Thakurta and Duttl° succeeded in getting some success from cuttings by applying 3% Indole acetic acid as root promoting hormone.

Hussain[3] succeeded in getting 62.5% success in rooting of mango cuttings by applying "Rootone" (a commercial preparation of Alpha naphthyl acetamide) as a hormone for promoting rooting. Hs also concluded that the cuttings should b,- 12 inch °.s in length and the spring season was found to be the best time for planting the cuttings.

4. **Aerial Layering:** Some work on this methods of propagation had been reported from India. Jauhri and Shah working with Bombay green, Chausa and Baramasi, used Naphthalene acetic acid, Indole acetic acid and 2, 4 Dichlorophenoxyacetic acid in various concentrations for induction of rooting in aerial layering of mangoes. On the basis of percentage success, NAA was adjudged to be the best growth regulator for rooting the air layers in these varieties. NAA, 250) ppm. induced 100% 'rooting in Bombay Green, while the 2500 ppm. concentration accounted for equally good success in variety Chausa. The highest percentage rooting induced at 10,000 ppm. concentration was 60% in Baramasi variety.

The maximum percentage achieved with Indole acetic was (500 ppm.) 60 in Bombay Green, whereas in Chausa and Baramasi it accounted for 20% and 40 % success respectively, at 10,000 ppm. concentration. 2, 4-D failed to give encouraging results. However, 60% success was achieved at 25,00 ppm. concentration only in Chausa variety. Many propagation technique in practiced in Flnrida were tried with high success. Some of these are described below:

5. **Chip Budding:** In Florida, where mango has commercial importance, some other methods, of mango propagation have been developed and are being used with success. The more common methods of mango propagation in Florida are, however, described here for the interest of the mango- growing community of this

country. In chip budding age of the stock is very important consideration. Stocks 2 to 3 weeks old, when the seedlings are still in red and in succulent stage, are used. Lynch and Mustards have posulated that bud take on young seedlings is very high, due to the stock tissue being partially undifferentiated and there being a broader cambial area. The eyes spring within four to six weeks of budding operations and this has been attributed in part to the heavy and steady supply of food from the cotyledons.

The preparation of bud wood is done almost in the same way as we do in case of mango budding in situ operations. The bud wood is prepared by selecting terminal growth which is about to loose its pinkish tinge. Bud wood should not be more than ¼ to 3/8 in diameter. Leaf petioles are cut off to about 1/8 inch, leaving 2 or three leaves at the tip. Depending upon the climatic conditions the buds in the axil of the petioles will swell within two to three weeks. The bud shield is kept 1 inches to 2 inches long. The front of the shield below the eye is cut off through the bark, leaving exposed the cambial area. To receive the bud shield a slanting cut 2 inches deep and 1/3 through the stem is given. The shield is held in position by wrapping around the stem a plastic film known as vinylite. This film has the advantage that it retains the moisture and allows the carbon dioxide to diffuse out. The film is further held in position by wrapping around with rubber band as shown in the Figure. 7-4. In Pakistan polythene and alkathene plastic films can be used as a substitute with equal success. In order to ascertain bud union, rubber band and plastic film are removed after two weeks of budding operations, if bud is still green the stock seedling is topped 2 to 3 leaves and cutting away of the stock portion is done when the buds have sprouted to a length of 3 to 4 inches. In Pakistan this method can be practiced only during summer months, since mango crop to yield mango stones comes in markets from May to August.

Figure 7-4.

A-Chip-bud | **B-Bud in position** | **C-Bud wrapped with plastic film** | **D-Sprouted bud after six weeks of budding operations**

6. Veneer Grafting:- (Figure. 7-5).-This method can be practiced on stocks from ½ to 2 inches in diameter (one to 1½ year's old seedlings). Under our conditions veneer grafting would be possible both in spring and autumn months. For higher percentage of success stock. should. be in active growth and there should be abundant sap flow. In this method contrary to chip buddmg or shield budding, whole tip 3 to 4 inches in length, 3/8 to ½ in diameter is selected from well matured growth on which buds are just to break. Graft wood is prepared in the same way as we do for mango budding.

Figure 7-5.

A-Scion wood and stock **B-Scion wood in position** **C-Scion wrapped with rubber strip** **D-Scion covered with plastic film**

Lynch and Mustard' describing the method advocated giving a slanting cut about two inches long in the side of the stock, so that at the bottom the cut is 1/16 to 1/8 inch in length. An oblique cut at the base of the large cut allows the piece of bark and wood to be removed. They recommended a scion 2-4 inches in length and of the thickness of stock seedling. A slanting cut on one side of the scion is made starting just below the tip bud and continuing all the way to the base. On the opposite side of the scion a small wedge at the base is made which will fit into the notch of the stock. The scion is then placed in position, so that the cambia of both cut surfaces come in contact. The scion wood is held in position by wrapping with rubber strip. Graft union is then covered with vinylite film which is tied with rubber strips one inch above and below the graft. In case of successful union, growth starts within two to three weeks. The plastic film is removed and the top of the stock is notched to encourage growth of the scion shoot. Removal of the stock above the graft union is completed in gradual steps (Figure. 7-6).

Figure 7-6. Mango graft propagated by veneering grafting

7. **Top Working:**- Top working of large, interior mango seedling to a more desirable variety, is possible, though the practice is not very common. The common method practiced in this part of the province is to dehorn the tree branches or main limbs within a toot or so of the main trunk of the tree. This is done in early spring months. The shoots which spring from the stump become fit for budding in the following summer or autumn months. Since in our plains there is danger of sun burn injury, the naked trunks are protected by whitewashing. A few of the weaker branches are sometimes not dehorned for providing shade until the new top is established. So the complete changeover of the top may extend over more than one season. The left over branches can be pruned back in the same way and shield budded in the subsequent season.

Lynch and Mustards Ruehle and Ledin" and Nelson *et. al.*, have also advocated use of cleft grafting, and side veneer grafting in top working the old inferior varieties (Figures. 7-7 and 7-8). According to them young plants in the field with trunk diameter from I to 8 inches can easily be veneer grafted on the main branches at a height of I to 2 foot from ground level. If trunk is too large or difficult to work, the lower main limbs can be veneer grafted.

Figure 7-7.

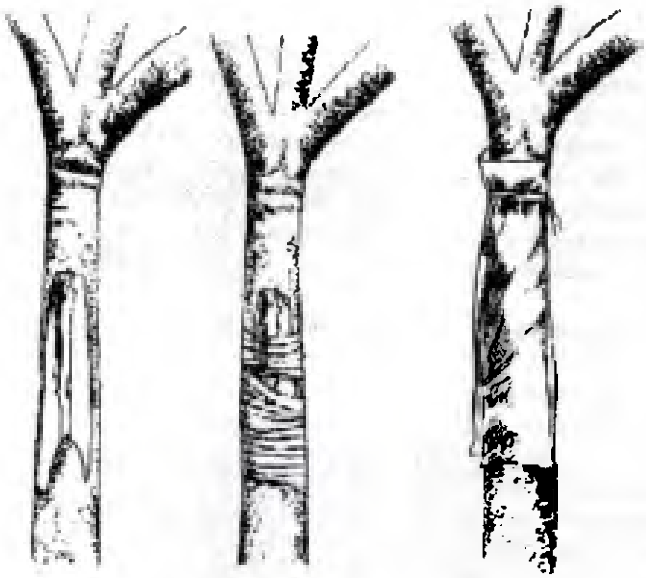


Figure 7-8. An old seedling mango tree, top superior scion variety.

7.2. ROOTSTOCK STUDIES IN MANGO

Professor Musalih ud Din Khan

The effect of rootstock on the scion is well known. A number of studies in several countries as well as in Pakistan have been made in citrus trees. Hodgson *et. al.*, (1973) found that rootstock might either invigorate or dwarf the scion. Rahim and Ali (1964) noted a significant difference in the yield of valentia late orange on different rootstocks. Kharna Khatla came out to be more prolific than all other rootstocks except jamberi. Sweet lime was inferior to rough lemon. Jawanda and Malhotra (1974) working on five sweet organe scions budded on different rootstocks concluded that rough lemon excelled inthe tree vigour. Hilgeman (1975) compared the performance of different cultivars of valencia organge on rough lemon, sour organge, cleopatra and willow leaf mandarin. The maximum vigour was observed on rough lemon and the lowest on willow leaf.

In year 1985 a germination trial was made and the stones of Samar Bahisht, Anwar Rataul, Dusehri, Langra and Desi, were sown on 31-7.87 and height recorded on 1.12.85 showed the height of the seedlings was 40.80; 31.13; 31.59; 25.58 and 28.75 respectively.

Infact, this was the first experiment which showed different height behaviour and led to the rootstock experiments.

Considerable work has been done in India and other countries on the rootstock studies on mangoes. In addition to mangifera indica, several other species of mangoes have been used as rootstocks for mangoes. Parson (1931) found .M,. zeylanica as a compatible rootstock for mango scion varieties. Seedlings of other mangifera species such as M. odorate and M. foetida did support the scion for 2 years but later developed symptoms of incompatibility. Swamy *et al* (1939) described a rootstock trial in south India. In these trials Beneshan and Neelum were used as scions. For them polyembryonic and monoembryoonic varieties were used as rootstocks. In case of Neelum the plants grew larger on polyembryonic rootstocks compared with monoembryonic. Pahutan, a polyembryonic variety which proved most vigorus rootstock for Baneshan proved least vigorous for Neelum. Sen (1939) found kalapadi variety as a promising dwarfing rootstock. As regards Langra, a vigorous variety, showed some dwarfing effect on the dwarfing rootstock Kalapadi. After 20 years however, langra scion, irrespective of rootstock used, gave vigorus growth. In Jamaica the scion varieties like Julie and Bombay manifested more vigour on Kideny, Turpentine and Beef rootstocks, Nambair (1957) observed that a polyembryonic variety, Bappakai gave a higher germination percentage, grew fast and produced vigorous seedlings large eough for grafting within one year of sowing of seed. Bakshi (1964) working in Indian Punjab found seedlings of some monoembryonic varieties to be very vigorous, some were only mediocre in this respect, while others were slow to grow. Giri and Chaudhry (1966) found Samar Bahisht seedlings to be more vigorous as compared with langra and three other seedlings. Kusumo *et al* (1923) working in Indonesia found that scion varieties like Madu, Arumanis and others made perfect bud union with seven different rootstocks. jauhari (1972) tried Dusehri as well as 4 polyembryonic varieties as rootstocks for Dusehri scions. Dusehri seedlings proved to be more vigorous as compared with other varieties. Majumdar (1972) classed some rootstocks as very vigorous, vigorous and dwarfing. The use of dwarfing rootstock helped to keep the tree low headed and this reduces the cost of spraying, harvesting and other operations. Shah (1986) raised seedlings from various scion varieties and found that Samar Bahisht was the most vigorous followed by anwar Rataul, Dusehri and Langra.

7.2.1. Material and Methods

Freshly extracted stones of Samar Bahisht, Anwar Ratual, Malda, Langra and Dusehri were collected and were sown on 30th July 1986 at the Horticulture Nursery of Agriculture University and Ayub Agricultural Research Institute, Faisalabad. Data on germination of seeds, length and girth of the rootstock were taken on 16th August 1987.

7.2.2. Stionic Combinations

The plants of all the seedling varieties used as rootstocks were side grafted with Samar Bahisht and Langra 16.8.87. The success of the combination was recorded on 5.12.87.

The girth of rootstock as measured on 16.8.87 was divided into three grades according to their girth:

Grade I = 0.41-0.95 cms
Grade II = 0.96-1.20 cms
Grade III = 1.21-1.88 cms

Data on the effect of rootstock on length of scion as well as on the increase in girth of scion and increase of total scion wood were recorded.

7.2.3. Presentation of Results Germination of Seed/Stone

The maximum germination 65.68 was given by Samar Bahisht followed by Malda 50.33, Anwar Rataul42.5, Langra 40.47, Dusehri gave the least germination of 27.83.

7.2.4. Length of Seedlings

Samar Bahisht made maximum growth in length 67.92 and was significantly superior as compared with Anwar Rataul (57.82), Malda 47.52, Langra 44.53 and Dusehri 41.56 which did not differ among themselves.

7.2.5. Girth of the Plant

Maximum girth was made by Samar Bahisht 1.20 cms followed by Malda 0.86, Langra 0.84 and Dusehri 0.84, Anwar Rataul was second in position and the girth recorded was 1.05 cms.

7.2.6. Sammar Bahisht Scion

In all 49 seedlings, 22 of Samar Bahisht, 9 of Anwar rataul, 6 of Malda, 7 of Langra and 5 of Dushri were side grafted with Samar Bahisht scion. Langra as a rootstock failed to give any success with Samar Bahisht scion. The percentage of success with Anwar rataul (55.55) was the maximum followed by Samar Bahishı (54.54) and Dusehri (40.00). Malda gave only 16.66 per cent) success.

7.2.7. Langra As a Scion

A total of 45 seedlings were side grafted, 18 of Samar Bahisht, 8 of Anwar rataul, 6 of Malda, 7 of langra and 6 of Dusehri. All the combination with langra association were successful. Malda which was the last on the list, when Samar Bahisht was used as scion, gave the maximum success of 83.33 percent, while Samar Bahisht 72.22, langra 42.86 and Dusehri 33.33 per cent followed in order.

7.2.8. Effect of Girth of Rootstock on Success Percentage

To assess the total vigour the total scion wood was calculated in cubic centimetres by the formula R x 11 x length. Anwar rataul made the maximum total scion wood, so it was a most vigorous rootstock for Samar Bahisht scion. The least vigorus was Malda. As regards langra rootstock it made the maximum total scion wood of 3.169 c.cms for langra scion. It is interesting to note that Anwar rataul which is responsible for making the maximum total scion growth 0.933 cms for Samar Bahisht made only 0.07 c.cms for langra while, langra as rootstock gave the maximum total scion wood for langra.

7.2.9. Summary and Conclusions

Maximum germination was made by Samar Bahisht followed by Malda, Anwar rataul, langra and Dusehri. As regards vigour as measured in terms of length and breadth, Samar Bahisht led all the rootstocks followed by Anwar rataul while, Dusehri was the least vigorous.

As regards Samar Bahisht, Anwar rataul was responsible for making maximum scion wood with 0.933 c.cms. Samar Bahisht itself as a rootstock occupied second position, for Samar Bahisht scion producing 0.630 c.cms.

For langra scion, langra rootstock induced maximum total scion wood (3.169 cms), other rootstocks were far less. Even Anwar rataul which induced maximum total scion wood (0.933 c.cms), in Samar Bahisht scion could only induce 0.074 c.cms. Therefore, langra was found to be the most vigorous rootstock for langra scion.

The experiments were repeated with Samar Bahisht and langra as scion and Samar Bahisht and langra as rootstocks in the year 1989. The stionic combination Samar Bahisht over Samar Bahisht gave an average girth of 1.126 cms while that of langra on langra produced 1.31 cms girth. The conclusion can again be drawn that langra as rootstock gave the maximum vigour. It may be said that these studies from 1987 to 1989 were of preliminary nature but the purpose of this article is that such investigations need be started by the Research Institution. However, the progressive growers may make a trial themselves. Desi was also included hut did not compete other varieties.

7.2.10. References

Bakhshi, J. C. 1963. Propagation studies with monoembryonic and Polyembryonic varieties of mango. Punjab Hort. J., 3: 185-93. Propagation of tropical fruit trees by Garner, R. J. and Saeed Ahmad.

Giri, A. and M. Y. Chaudhry. 1966. Relation of mango stone weight to its germination and seedling vigour. Pakistan J. Sci., 18(5,6): 148-50.

Hodgson, R. W., S. H. Comeron, and E. R. Eggars. 1937. Rootstock and scion influence in citrus. Calif, Cit. 22:110-113.

Hilgeman, R. H. 1975. Yield and tree growth of seven valencia type cultivars on four rootstocks. Hort. Sci., 16(1):66-68. (Hort. Abst., 46(1):57-1975).

Jauhari, O. S. 1972. Rootstock studies in Mangifera indica l. Acta. Horticulturae, 24:82-84.

Jawanda, J. S. and N. K. Malhrotra. 1974. Prebearing performance of five sweet orange cultivars on different rootstocks. Indian Jr. Agri. Sci., 74(2):119-126.

Kusumo, S. and tjiptosuhardjo. 1971. Tjabang lembleage Penelitian Hortikult, Malang, Indonesia. Djenis mangga jang haik untuk buah media. Bull. Hort., Tjahort, 5:1-24.

Majumdar, P. K. 1972. Selection and classification of mango rootstocks in the nursery stage. Acta. Horticulturae, 24:101-6.

Nambair, K. P. P. 1957. A note on nursery investigation on Mango rootstocks. S. Indian Hort., 5:33-34.

Parsons, T. H. 1931. The mango in Ceylon, Trop. Horticulturist. 76:199-211.

Shah, M. A. 1986. The vegetative and floral malformation of mango studies on the role of seeds (stones) in the transmission of vegetative and floral malformation. Thesis submitted to the Univ. of Agri. Faisalabad for the degree of M.Sc. (Hons.) Agri. Degree.

Swamy, G. S., B. V. R. Rao and D. S. Raju. 1939. Polyembryonic rootstocks for mango. Acta Horticulturae (1972). No. 24, 110, 113, (En 4 refes.) Regional Fruit Research Station Anantherajupet, South India.

Sen, P. K. 1939. A. R. Fruit Rest. Station. Sabour Bihar.

8. MANGO DISEASES

*A. Saleem and Khalid Majeed Akhtar**

8.1. MANGO DISEASES AND THEIR CONTROL

8.1.1. Abstract

Mango is attacked by a number of diseases. Malformation of mango inflorescence, powdery mildew in the form of whitish grey mycelium on the inflorescence and foliage, root rot, anthracnose and die-back are responsible for decline of plants. Sooty mould, appears in the form of velvety growth on the leaf surface.

Proper management, application of balance fertilizer, three consecutive sprays per year with suitable chemical can go a long way in keeping the plants comparatively free of infection.

8.1.2. Introduction

Mango (Mangifera indica) is an important fruit of Pakistan and is grown over an area of 78959 hec. (Annonymous 1987-88). In the Punjab its area is about 44679 hec. which is 13.91 % of the total fruit area of the province (Annonymous, 1987-88). The mango is relished and liked by everyone for its flavour and dietetic value and the name "King of fruits" reflects its popularity in this subcontinent.

The mango is attacked by a number of diseases caused by different organisms. No information regarding the extent of damage to the plant is available. However, if we take into account the accumulative damage of all the diseases the loss is colossal. Different diseases like malformation, decline, powdery mildew, etc. are rampant in the area and during certain years causes spectacular losses. In this paper a brief account of the diseases, their identity symptoms and known control measures are given.

8.1.3. Malformation

Malformation of mango inflorescence is very common and widely distributed in orchards of Indo-Pak subcontinent was 1st recorded by Maries (Wett, 1891) at Derbhonga (Bihar). It was also been reported from Egypt, Central America, Mexico and Israel (Malik, 1979). mango malformation is present in almost all the orchards of the country to a lesser or greater extent (Khan & Khan 1960).

8.1.4. Symptoms

There are different types of symptoms of malformation known are as under:-

a) Bunchy top of seedlings;
b) Vegetative malformation;
c) Floral malformation;

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In bunchy top of seedling, compact leaves are formed at the apex of shoot or in the leaf axil to form the bunchy top seedlings and are usually shallow with few tertiary roots. The top root may be twisted and may show necrosis (Schlosser, 1971).

In vegetative malformation, small leaves appear as a shootlets. Growth of these shootlets is checked and subsequently several similar shootlets arise from the axil of the scaly leaves and forms bunches which are thicker than the main stem. Vegetative malformation is more pronounced in young seedling trees.

In floral malformation, floral aggregations appear on shortened primary axil of the inflorescence which is further branched to be secondary tertiary branches, on which flowers are borne in clusters, on these malformed flowers there is no fruit or very poor fruit setting is observed.

On the early stages of penical formation, no differentiation between the healthy and diseased penicals can be made. In the later stages growth in normal inflorescence stops the fertilization and fruit setting, while growth in diseased penicals continues till the heavy rains. Such inflorescence remains green for long time. Later no malformed heads dry up in black masses and "' persist on the trees for long time (Schlosser, 1971 and Pathak 1980).

8.1.5. Casual Organism

There are many findings/views about the cause of the disease but they are contradictory and confusing. Broadly speaking there are three types of causal agents reported by various workers.

1. Physiological
2. Fungi, Mycoplasma and viruses
3. Acerological

Physiological Marries (Wett, 1981) believed that excessive soil moisture causes mango malformation. It has been found that lower levels of phosphorus and potassium and increasing levels of nitrogen decrease the incidence of the disease. It has also been suggested that peculiar behaviour of malformed shoots may be due to imbalance between growth promoters and growth inhibitors. Less nitrogen and high level of auxins and gibberelline in plant extracts is found as compared to healthy ones and no difference in protein fractions of healthy and malformed inflorescence is reported (Chandha, 1975, Abou Hussain *et al* 1975, Abdullah 1978).

8.1.6. Fungi Mycoplasma and Viruses

The work of the Sattar (1964) and Kausar (1959) showed that no fungus or bacterium was associated with malformation of mango as the causal agent. They suggested that disease might be viral in origin and transmitted by grafting the malformed trees on the branches of healthy trees.

Summanwar *et al,* 1970 first recorded the association of a fungus, Fusarium moniliforme with malformed mango shoots and inflorescence and also proved the pathogenicity of the fungus.

Verma *et. al.*, 1974 reisolated the same fungus from artificially produced in malformed penicals and vegetative shoots an thus demonstrated identical etiology for both the types of malformation and has also ohserved inter and intra cellular mycelium of the fungus from the cortex and phloem of the , diseased plants (Pathak, 1980).

Ali (1977) collected diseased as well as healthy floral and vegetative material from mango orchards of Faisalabad and Multan districts. The data showed the presence of Fusarium fungus in 92% of the diseased specimens. Apparently healthy inflorescence also showed the presence of Fusarium in 42 percent of the cultures.

The association of Fusarium oxysporum has been reported by many workers. (Mohyuddin *et al* 1971) and 1972, and Bhatna ger and *Beniwal,* 1977).

Mohyuddin *et al* (1973) indicated mycoplasma like structures in malformed inflorescence and bunchy top and first time it was proved that bunchy tops and malformed inflorescence were the manifestation of the same disease and found F. oxysporum was frequently isolated from the bunchy top and malformed inflorescence. They also studied the electron microscopy of the disease specimens and reported that mycoplasma like bodies were present in the diseased cut sections. Since the symptoms were reproduced with Fusarium oxysporum (P 32 labeled) it was suggested that the fungus acts as a MLB carrier. Dr. Wallar (1975) of Rothamsted failed to give any positive identification of the Mycoplasma by using the electron microscope technique in the samples sent to him by the Plant Pathologist, AARI, Faisalabad.

Akhtar and Pervez (1972) and (1978) found that Fusarium sp. and Rhizoctonia *solani* are associated with the roots and Fusarium oxysporum with the above ground diseased parts otthe sick plant. Through pathogenicity *trials* it has been fo,und out that when Fusarium sp. isolated from roots was added to the soil and F. oxysporum inoculated at the top, the disease appeared in 100 percent of the seedlings, similarly, in the treatment where R. solani was added in the soil and F. oxysporum inoculated at the top, the disease incidence was 100 percent and where only R. solani was added in the soil the disease incidence was 50 percent. Thus confirming that the soil infection plays a role in the disease causation.

8.1.7. Acerological

The reports on the role of mites and insects in the development of malformation of mango inflorescence are available in literature and are much contradictory. Malik et ai, 1985).

The mixed up concept of mites and virus become more complicated when it was concluded that there was correlation of mites and bud malformation and the presumption that mites were the only causative organism was doubtful (Malik, 1979).

Thus no definite cause of the disease is known. However, there is strong indication that Fusarium sp. and Rhizoctonia solani are associated with the roots of the diseased plants and Fusarium oxysporum with the above ground parts.

8.1.8. Control measures

1. In areas where there is high percentage of disease incidence, diseased plants or parts of plants be destroyed.
2. Certification of plants used for propagation by nurseries be made compulsory and only healthy seedling and plants should be used for grafting.
3. Broad spectrum pesticides should be used, encouraging results have been obtained with Benomyl.
4. Diseased tissues should be pruned and remove the malformed terminals alongwith 15-20 cm. apparently healthy portion.
5. The application of Arachniotus sp and Trichoderma sp amended with 2-3 kg. of wheat straw to mango plants has given reduction in the disease. The application of these antagonists has also been found effective in the control of root rot of mango (Akhtar 1982).

8.1.9. Powdery Mildew

Powdery mildew of mango is of common occurrence in Pakistan. This disease has also been reported from India, Ceylon, South Africa, Brazil, Australia and USA. (Pathak 1980 and Singh 1960). In the past the disease was not of regular occurrence in the Punjab but for the last few years it appears every year and has gained the status of a major disease.

It appears in February and March in the form of Whitish grey mycelium on the inflorescence and tender foliage. The infection spreads from tip of inflorescence and covers the floral axis, young leaves and stems. The disease affects the flower before fertilization and the fruits in the early stages. Flower infected to open and may be shed before fertilization which results in a substantial reduction of fruit set. In normal infection 20 to 30% of the flowers and fruit may be destroyed, while epidemic out break results in complete failure of mango crop. The disease is caused by the fungus Oidium mangiferae hreth. The fungus grows rapidly during cloudy weather accompanied with heavy morning mist (Kul Karni 1924). Warm humid weather and low (temperature favour spread of the disease.

For the control of the disease the following schedule of spray may be adopted.

a. Preblossom spray should be done when the inflorescence just starts appearing. For this Topsin-M @ 100 gm/100 lit. of water or Daconil @ 250 gm/100 lit. of water may be used.
b. If disease appears in epidemic form, the plants should be sprayed with any of the following fungicides at an interval of 10-15 days so " long as the protection is required.
   i) Topsin-M @ 100 gm/100 lit. of water,
   ii) Daconil @ 200 gm/100 lit. of water,
   iii) Bayfidan foliar 50 cc/100 lit. of water
   iv) Afugan @ 75 cc/100 lit, of water.

While spraying on the flowers due care should be taken not to hit the flowers directly and fungicide should be used alone and in proper dose.

8.1.10. Decline

Decline symptoms to a lesser or greater extent are present in almost all the mango gardens in the Punjab. The decline can be defined as a progressive dying back of the plants starting from the small twigs to backward. In the Punjab decline has generally been observed more in the neglected gardens. The proper up keep of the garden plays an important role in avoiding the infection of the pathogens which if goes unchecked becomes established and produces decline symptoms. Generally the following three diseases are responsible for the decline.

i) Root rot.
ii) Anthracnose,
iii) Die back.

Root rot Root rot is prevalent in almost all the gardens. The disease manifest itself in the form of withering and drying of the affected plants from the top downwards resulting in death of the plant. First the rootlets are affected and are rotten and then the smaller roots and ultimately the bigger roots are affected which result in gradual decline of the plant, and ultimately the plant dies (Khan 1977-78). With the rottening of the roots the uptake of the nutrients and water is blocked which results in drying of the plants from top to downward. The disease is caused by Rhizoctoria solani Khun and Fusarium, oxysporum Schl.

Anthracnose

This is an important disease in Pakistan. Sattar and Malik observed it for the first time in 1939 in several districts of the Punjab. Since then it has been found in all the mango growing tracts of the country.

The disease may attack leaves, petioles, twigs and fruits. On leaves it appears in oval shaped irregular brownish to greyish spot variable in size. Under damp conditions the spots grow rapidly and from necrotic areas and the leaves drop down from top to bottom. The disease is caused by Colletotrichum gloeosporioides, the acervuli of which become evident as minute dots on the affected portion. The fungus is basically a weak pathogen and requires pre-disposed plant for disease spread. The optimum temperature for infection is 25°C (Sattar and Hafiz 1952). The disease spreads rapidly in the rainy season. The fungus infects the fruits in its developing stage (Pathak 1980) and such fruits rot quickly and become unfit for consumption.

8.1.11. Die back

This is a very serious disease of mango plant and can be observed in every garden. In the Punjab often die-back and antharcnose are observed together on diseased plants. The onset of the disease become evident by discolouration and darkening of the bark some distance from the tip withering and shedding of the leaves advance from the twigs and dying back from the top downwards. The affected twigs become evident by discolouration and darkening of the bark and exudation of gum from the diseased portions. Brown streaking of vascular tissue can be seen on splitting the twigs length wise. Diplodia netalensis is responsible for this disease (Das-gupta al Zacharich 1945). High summer temp 25 to 31°C relative humidity above 80 percent and rains favour the disease development (Verma and Singh, 1970). Almost all the mango varieties are susceptible to this disease.

Out of these three diseases the die-back and antharcnose attack more on the plants which are pre-disposed. In case of die-back high temperature, high relative humidity and weak plants are main contributing factors in the , spread of the disease. This is why generally this disease is more prominent after the monsoon rains in the form of severe twigs infection which results in leaf shedding. Root rot hamper the uptake of the nutrient by the plants. This indirectly weaken the plants which is then pre-disposed to the infection of other organisms.

8.1.12. Control

i) Apply proper and balanced fertilizer to the plants.

ii) Pruning and destruction of diseased branches should be adopted regularly.

iii) When starting the control measures in a diseased gardens, three consecutive sprays with any of the following chemicals are required. Once infection is brought under control, 3 sprays/year can go a long way in keeping the plants free of infection. These sprays can be done (i) pre blossom (ii) before the start of monsoon rains (iii) after the rains.

Topsin-M @ 100 gm/100 lit. of water or Daconil @ 250 gm/100 lit. of water.

If these chemicals are not available then B. mixture (4:4:50) or Mancozeb based chemicals can also be used. In case of root rot problem antagonistic organism Trichoderma sp. and Arachniotus sp. (with commercial name Aspergopak and Trichopak) mixed with wheat straw should be applied in the root zone of affected plants. For plant 2-3 kg of chaffed wheat straw contaminated with antagonistic organism should be added in the root zone. After the application of the antagonistic organism phosphorus and nitrogen fertilizer must be used to supplement the roots for their nourishment. The antagonistic should be used one month before blossom or two month after blossom.

8.1.13. Sooty Mould

The disease is of common occurrence in Pakistan. It has also been reported from South Africa, Formosa, India and Israel (Singh, 1960 and Pathak, 1980). The disease appears in the form of black velvety growth on the leaf surface. The entire leaf surface or portion of the leaf may be covered by the fungal growth, in severe cases the whole plant and even the twigs are affected. The thin membrane formed on the leaf surface can be rubbed off easily, under dry conditions the membrane may be blown off in the form of small fragments by the wind. The sooty moulds are caused by Tripospermum acorium (Syd) Speg. The disease is more commonly caused by capnodium CKe. and Brow and Meliola mangiferae Earle. The fungi in the true sense are non pathogenic as it does not enter the host and drive its food from the honey dew secreted by the insects mainly by the hoppers, scales and coccids on the leaves and twigs. No direct damage is caused to plants, however, photosynthetic activity of the plant is impaired due to covering of the leaves.

8.1.14. Control

Proper control of the honey dew insects check the growth of the moulds on the leaf surface. In severe case spray with 0.2% wetable sulphur can check the fungal growth.

8.1.15. REFERENCES

1. Annonymous 1987-88 Agricultural statistics of Pakistan. Govt. of Pakistan, Islamabad.
2. Annonymous 1987-88 Directorate of Agriculture, Crop Reporting Service, Punjab, Lahore.
3. Abou Hussain, M. R. 1975 Some morphological and physiological M. S. Fadl and M. A. El. features of flowering malformation in Chandoar mango. Egypt Jour. Hort; 2 (2): 199-208.
4. Abdullah, M. 1978 Comparative studies on the protein fractions in healthy and malformed inflorescence and leaves of mango. M. Sc. thesis Univ. Agri. Faisalabad.
5. Akhtar M. and M. S 1972 Annual report of pl. Pathologist. AARI. Pervaiz Faisalabad (Un-published).
6. Akhtar, M. and 1978 Some investigations on mango malfor- M. S. Pervaiz mation in the Punjab. J. Agric. Res., 3: 407-9.
7. Bhatnager, S. S. and 1977 Involvement of *Fusarium oxysporum* in S. P. S. Beniwal. causation of mango malformation. Pl. Dis. Report; 61: 894-898.
8. Chandha, K. L. 1975 Mango industry in India. Improvement and development of the mango industry in Asia and the far east Bangkok, Thailand.
9. Kausar, A. G. 1959 Malformation of inflorescence in mango. Pg. Fr. Jour; 22: 19-21.
10. Khan, M. D. and 1960 Studies of malformation of mango inflo- rescence in West Pakistan. Fr. Jour. (Mango Number). 23(82, 83) 247-258.
11. Khan, M. D. 1977- 78 Report of the committee on mango problems. Punjab Agri. res. Inst. Faisalabad.
12. Malik, M. A; M. N. Malik 1985 Mango malformation, its past present M. A. Nasir and I. Ahmad and future. The Punjab Fr. Jour. 38 (1 & 2) : 25-34.
13. Malik, M. N. 1979 A comprehensive review report on malformation of mango. Deptt. of Hort. University of Agri. Faisalabad (Un- published)
14. Mohy-ud-Din, M; N. Khan, 1971 Studies on the cause of mango tree M. Aslam and A. Hussain malformation. Ann. Rept. (NAIB) year, 1970-71: 67-68.
15. Mohy-ud-Din, M; N. Khan, 1972 Studies on the cause of mango tree M. Aslam and A. Hussain malformation. Ann. Rept. (NAIB) year, 1971-72: 116-118.
16. Mohy-ud-Din, M; N. Khan, 1973 Studies on the cause of mango tree M. Aslam and A. Hussain malformation. Ann. Rept. (NAIB) year, 1972-73: 85-89.
17. Pathak, V. N. 1980 Diseases of fruit crops. Oxford and IBH Pub. Co. Delhi and Bombay.

18. Sattar, A. 1946 Diseases of the mango in the Punjab, Punjab. Fr. Jour.; 10-56.

19. Sattar, A. and A. Hafiz 1952 Researches on plant diseases of the Punjab. Sci. Monograph No.1. Pak. Asso. Adv. Sci. Lahore.

20. Schlosser, E. 1971 Mango malformation. Incidence of bunchy top on mango seedling in West Pakistan. FAO. PI. Port. Bull; 19: 41- 42.

21. Singh, L. B. 1960 The mango. Botany cultivation utiliza- tion. Interscience Pub. Inc. New York.

22. Summanwar, A. S. 1970 Plant disease problems. Proc. First intern. Symp. PI. Pathology Indian Phy- topathological society, fARI; New Delhi, pp. 627-631.

23. Waller, J. M. 1975 Studies of malformed specimens at CMI; London, England. report on the samples sent by Plant Pathologist, AARI. Faisalabad (Personal communication).

24. Wett, G. 1891 Dictionary of the economic products of India, 5: 149. 154

8.2. RECENT DEVELOPMENTS IN THE MANAGEMENT OF MANGO DISEASES

Ahmad Saleem and M. Zafar Iqbal[5]

Mango (Mangifera indica L.) is an important fruit of Pakistan. It is grown over an area of 93500 hectares. Its area in Punjab is about 48400 hectares (Anonym. 1998).

Several diseases caused by different organisms attack mango in the Punjab. No information on the extent of damage to the plant is available. However, if we consider the cumulative effect of all the diseases the loss is colossal. Diseases like powdery mildew, malformation, decline, etc, are rampant in the area. In the recent past diseases especially the decline and powdery mildew were considered of minor importance, but now these diseases have gained the status of major maladies. In many areas of the Punjab these two diseases have become limiting factor in mango production.

Agronomic practices adopted since the establishment, have a definite bearing on disease management in garden. Many practices in vogue pre-dispose the plant to the invasion of the pathogens. Therefore, it is essential that for a successful disease management proper recommendation, regarding irrigation, nutrition, planting height and depth, pruning, hoeing and inter cropping should be adopted.

Broadly speaking based on symptoms mango diseases can be divided into two groups:

1. Mango flower damage
   - i) Weather fluctuations
   - ii) Powdery mildew
   - iii) Mango malformation
   - iv) Blossom blight

2. Mango decline
   - i) Anthracnose
   - ii) Die back
   - iii) Root rot

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In this publication symptoms and control measures of important diseases based on the concept of Integrated Crop Management (ICM) (Kern, /1999) are given. It is recommended that disease management should be adopted as a part of the ICM.

8.2.1. Powdery Moldew

Powdery mildew in addition to Pakistan has also been reported from India, Sri Lanka, South Africa, Zimbabwe, Palestine, Brazil, Australia and U.S.A (21,25). Previously it was a minor disease and not of regular occurrence in the Punjab but for the last few years it appears regularly and has gained the status of a major disease.

It appears in February and March in the form of whitish grey mycelium on the inflorescence and .tender foliage. The infection spreads from top of inflorescence and covers floral axis, young leaves and stem. It affects the flowers before fertilization and fruits in the early stage. Flowers infected fail to open and shed before fertilization. As a result setting is massively reduced. In normal infection 20 to 30 percent flowers and fruit may be destroyed. When it appears in epidemic it can result in complete crop failure. Tahir (28) has reported that losses were more than (86%) in the infected than protected cwp (37%). The disease is caused by a fungus Oidium mangiferae Berth. The fungus grows rapidly during cloudy weather and low night temperature favors disease spread (21). Under local conditions .the disease perpetuates on the infected leaves.

8.2.2. Control

The disease can be controlled if the following spraying schedule is adopted:

1. First spray should be done when about 20-30% inflorescence has appeared. For the purpose, chemical given in appendix-1 can be used.

2. If disease appears in an epidemic form, the plants should be sprayed with any of the recommended chemicals (appendix-I) at 15-20 days interval, as long as protection is required. While spraying on the flowers due care should be taken that flowers are not hit directly and fungicides should be used alone and in proper dose.

Malformation

It is a common and widely distributed disease of orchards in Indo-Pak subcontinent. It was 1^{st}. Recorded by Marries (Watt, 34) at Derbhonga (Bihlar). The disease has been reported from Pakistan, India,' Egypt, South Africa, Brazil, Israel, Central America, Mexico, USA, Sudan, Cuba, Australia, Bangladesh, UAE and Israel (Kumar, *et. al.*, 1993). Mango malformation is present throughout the country to a lesser or greater extent (12). Maximum loss in India due to this disease has been estimated to be 86%. In South Africa 73% of the mango farms are affected and severity of the disease varies from 1 to 70% (Kumar, *et al.*, 1993).

8.2.3. Symptoms

Bunchy top seedlings, vegetative malformation arid floral malformation are the important types of symptoms. In the first type, compact leaves are formed at the shoot apex or in the leaf axil to form bunchy top seedlings. These are usually shallow with few tertiary roots. The taproot may be twisted and many show necrosis (24).

In vegetative malformation, small leaves appear as shootlets. Growth of these shootlets is checked and subsequently several similar shootlets arise from the axil of scaly leaves and forming bunches which are thicker than the main stem. This .malformation is more pronounced in young seedlings and seedling trees.

In floral malformation, floral aggregations appear on shortened primary axil of the inflorescence, which is further branched to be secondary and tertiary branches, on which flowers are borne in clusters. Malformed flowers do not set fruits, and if so it is very poor.

In the early stages healthy and diseased panicles can not be differentiated. In the later stage, - growth in normal inflorescence stop after fertilization and fruit setting, while diseased panicles continue to grow till the heavy rains. Such an inflorescence remains green for a long time. Later on malformed heads dry up in black masses and persist on the trees for a long time (21,24).

8.2.4. Casual Organism

There is no consensus on the causes of this disease. Broadly speaking three types pf causal agents have been reported by the various workers i.e. Physiological, fungi, mycoplasma and viruses and acerological.

8.2.5. Physiological

Marries (Watt, 34) believed that excessive soil moisture causes mango malformation. It has been found that lower P and Ka mad more N application increases malformation. It has also been suggested that pecular behavior of malformed shoots may be due to imbalance between growth promoters and inhibitors. Less nitrogen and higher auxins an GA levels in plant extracts are found as compared to healthy ones and no difference in protein fractions of healthy and malformed inflorescence is reported (2,7). Ibrahim and Hamdy (12) postulated that temperature lower than 5°C during bud differentiation and before bud break, causes some sort of distortion in the bud cells. This leads to mango inflorescence malformation.

Fungi mycoplasma and viruses

It has been suggested (11,23) that no fungus or bacterium was associated with mango malformation as the casual agent. It was suspected that disease might be viral in origin and is transmitted by grafting malformed trees on the branches of healthy trees.

Summanwar (27) was the first who reported the association of a funus, fusarium moniliforme with -malformed mango shoots and inflorescence and also proved the pathogenicity of the fungus.

Verma *et. al.*, (32) reisolated the same fungus from artificially produced malformed panicles vegetative shoots. Thus they demonstrated identical etiology for both the malformation types. They also observed inter and intra cellular mycelium of the fungus from the cortex and phloem of the diseased plants (21).

Ali (Malik *et al.*, 16) collected diseased and healthy floral and vegetative material from orchards of Faisalabad and Multan districts. The data showed Fusarium fungus was present in 92% of the disease specimens. Apparently healthy inflorescence also showed the presence of Fusarium in 42% of the cultures.

Many workers (5,18,19) have reported association of Fusarium oxysporum. Mohyuddin *et. al.*, (20) indicated mycoplasma like structures in malformed inflorescence and bunchy top. For the first time it was proved that bunchy top and malformed inflorescence were manifestation of the same disease and F. oxysporum was frequently isolated from the bunchy top and malformed inflorescence. They also studied the electron microscopy of the disease specimens. It was reported that mycoplasma like bodies were present in the, diseased cut sections. Since the symptoms were reproduced with Fusarium oxysporum (P32 labelled) it was suggested thai the fungus acts as a MLO carrier. Wallar (33) of Rothamsted failed to identify the mycoplasma by electrom microscope technique. The Plant Pathologist, Ayub Agricultural Research Institute, Faisalabad sent these samples to him. Hussain *et. al.*, (8) concluded that the disease is caused by Fusarium moniliforme var. subglutinans and can be controlled with the trunk injection of various fungicides. Encouraging results have been obtained with Benlate, Calixin and Rubigan. It has been found (2) that Fusarium sp. And Rhizoctonia are associated with the roots and fusarium oxysporum with the above ground parts of the sick plant. Through pathogenicity trials it has been found out that when Fusarium sp. Isolated from roots was added to the soil and F. oxysporum was inoculated at the top the .disease appeared in 100 percent. Where only R. solani was added in the soil the disease incidence was 50 percent. Thus it confirmed that soil infection plays a role in the disease causation. The author was successful in producing the disease on mango seedling with Fusarium sp, isolated from diseased plant. All efforts to produce the floral malformation artificially were not successful. Involvement of both F. subglutinans and bud mite as transfer and wounding agent has also been suggested (Kumar, *et. al.*, 1993.

The fungus Fusarium monilifforme Var. subglutinans was isolated from malformed parts of mango and its pathogencity was also proved by demonstrating identical etiology for vegetative and floral malformation (6). Use of nuclear magnetic resonance (NMR) technique in different tissues showed that the malformed parts has a higher spin lattice relaxation time when compared with healthier parts and seemed to be related to a lower solute concentration in malformed parts. NMRR technique also showed that primary site of infection is probably the meristematic region (29). As observed intracer studies using 14c sucrose (30) the fungus closer to the vascular channels competes for nutrients and could be a reason for the low uptake of assimilates by the malformed buds. Scanning electron micropscopic studies showed fungal mycelial infection at the base of the fully swollen malformed bud during bud inception stages. Malformed tissues when cultured produced white cottony mycelial growth of F. moniliforme Var. Subglutinans. The fungus/sucking pests may release secondary metabolites which could create hormonal imbalance and inhibit the normal growth of he meristematic tissue of the buds (31).

8.2.6. Acerological

Reports on the role of mites and insects in developing mango inflorescence malformation are available but are much contradictory (17). Concept of mites and virus becomes more complicated when it was concluded that there was a correlation between mites and bud malformation. The presumption that mites are the only causative organism is doubtful (17). Mangoes are usually heavily infested with mites without being any sign of malformation (26). The association of Aceria mangifera L. with malformation seems to be only a secondary infection, as the observed high levels of sugar in the malformed bud attract mites and many, other sucking pests to feed on it (31).

The definite cause of the disease is yet unknown and epidemiology is poorly understood.

8.2.7. Control

a) In areas where disease incidence is high, diseased plants be destroyed.

b) Certification of plants used by the nurseries for propagation may be made compulsory. Only healthy seedlings and plants should be used for grafting.

c) Broad-spectrum pesticides be used. Encouraging results have been obtained with Benomyl.

d) Diseased tissues should be pruned and malformed may be remoyed along with 20-30 cm apparently healthy portion.

8.2.8. Mango Decline

Mango decline is a widespread problem in all the gardens of the province. Term decline describes more of the symptoms rather any disease. It can be defined as progressive dying back of the plants starting from small twigs to backward, involving bigger and bigger branches. Ultimately the whole plant is killed. The disease appears and spreads more quickly in the neglected than properly maintained gardens. Generally 3 diseases, root rot; anthracnose and dieback are the cause of decline.

8.2.9. I. Anthracnose

This is an important disease in Pakistan. The disease was first reported in 1939 from several districts of the Punjab (21). Since then it has spread in all mango growing tracts of the country.

The disease may attack leaves, petioles, twigs flowers or fruits. On leaves it appears in oval shaped irregular brownish to grayish spots variable in size. Under wet conditions the spots grow rapidly and form necrotic areas. The leaves may drop down form top to bottom. During dry weather lesions may drop out. The disease may attack leaf petioles leading to premature ,leaf fall. Black necrotic areas develop on the infected twigs. Young twigs are attacked first. Then the disease progresses downward. During wet spring years the disease attacks the flowers and blossom blight phase can cause heavy loss to the crop. The disease in wet weather during flowering is also known to prevent fruit setting Gefferies, *et. al.*, 1990). In blossom blight of mango, lesions first appear on axes of flower panicles as small brown or black spots, which enlarge, coaleasce and can cause the whole inflorescence to blacken or wither before fruit set. Later infection produces depressed lesions on fruit which usually result in fruit drop, whereas infection on large fruit(^4-5 cm) usually does not develop further but becomes quiescent until fruit reopening when dark lesions appear(Peterson, 1968). Disease starts as minute dark spots on fruit, which enlarge to far bigger spots and the fruits become unfit for human consumption. Surface staining or russeting (tear staining) may result form spores being washed down upon the fruit from an affected twig or flower stalk. The disease is carried over from year to year through the diseased twigs and leaves, which remain lying on the soil surface and also on the diseased twig attached to the plants. The disease is caused by Colletotrichum gloeosporioides Penz. The acervuli of which become evident as minute dots on the affected portions. The optimum temperature for infection is 25C (2'5). The disease spreads rapidly in the rainy season.

8.2.10. II. Die Back

This is a serious mango disease and can be observed in almost every garden. In the Punjab, die- back and anthracnose are often together on diseased plants. The disease becomes evident as discoloration and darkening of the bark some distance from the tip. It progressed downward involving bigger and bigger branches. As a result the leaves are shed. Affected twigs become evident when the bark is discolored and darkened. Sometimes gum exudates from the diseased portions. Brown streaking of vascular tissue can be seen on the splitting the twigs length-wise. Diplodia natalensis Pole Evans, is responsible for this disease (3,21). High summer temperature (25 to 31°C), relative humidity above 80% and rains favour disease development (21,23). Almost all mango varieties are susceptible.

8.2.11. III. Root Rot

Root rot is prevalent in almost all the gardens. The disease causes withering and drying of affected plants from top to downwards. As a result the plant dies. First the rootlets are affected and are rotten. Then the smaller roots and ultimately the bigger ones are affected. It leads to a gradual decline of the plant which ultimately dies. With rottening of the roots, nutrients and water uptake is blocked which results in drying of the plants from top to downward. The disease is reported to be caused by Rhizoctonia Solani Khum and Fusarium oxysporum Sch(I).

Verticillium sp. Infects the roots and invades the water conducting cells producing a tree wilt. Leaves of part or all of an affected tree may wilt, turn brown, die, remaining, attached. Brown to grayish streaks can be observed in the sapwood of lower branches or trunk when the bark is peeled away. Soil with a .previous history of susceptible vegetable crops like eggplant pepper, potato, and tomato runs a higher risk of verticillium infestation.

Recently Fusarium solani and phytophthora sp, have also been isolated from root of Chuansa variety.

Out of these three diseases, die back and anthracnose attack on the plants which are pre-disposed. In case of die-back high temperature, high relative humidity and weak plants are the main disease spreading factors. This is why generally this disease is more severe after the monsoon rains, resulting in severe leaf shedding. Root rot hampers nutrients uptake by the plants. This indirectly weakens the plants; which become victim of other pathogens.

8.2.12. Control

1. Apply proper and balanced fertilizer to the plants.
2. Diseased branches alongwith 15-20 cm healthy portion should be pruned and destroyed regularly.
3. Three consecutive sprays are essential for a complete control of the disease. Once infection is .brought under control, three sprays/year can go a long way in keeping the plants free of infection. These sprays can be done (i) preblossom (ii) before (iii) after the monsoon rains. The chemical which can be sprayed are Topsin-M (100 g/100 l of Water) or Daconil 2787 (250 g/100 I of water).

If these chemical are not available then Bordeaux mixture (4:4:50)/ copper based or mancozeb based chemicals can also be used. In case of root rot, antagonistic organisms, Trichoderma sp., and Arachiniotus sp. (available under commercial names of Aspergopak and Trichopak) mixed with wheat strawc(2-3 kg) contaminated with antagonistic organisms should be added in the root Zone. After applying the antagonistic organisms, phosphorus and nitrogen fertilizers must be supplemented to the roots for their nourishment. The antagonists should be used one month before blossom or two month after blossom (I).

For the control of blossom blight, spray with copper and mancozeb based chemicals before blossom.

8.2.13. Sooty Mould

This disease is also common in Pakistan. It has been reported from South Africa, Formosa, India and Israel (21,23). It appears in the form of a black velvety growth on the leaf surface. Full or part of the leaf surface may be covered by the fungal growth. In every case the whole plant or even the twigs are affected. The thin membrane formed on the leaf surface can be rubbed off easily. Under dry conditions the membrane may be blown off by wind in the form of small fragments. The sooty mould is caused by Tripospermum acorium (Syd) Speg. The diseases is more commonly caused by Capnodium mangiferae Cke. and Brown and Meliola mangiferae Earle. The fungi in the true sense are saprophytic. They do not: enter the host and obtain their food from the honey dew secretion of the insects mainly by the hnppers, scales and coccids living on the leaves and twigs. It does not damage the plants directly. However, photosynthetic activity of the plant is impaired due to covering of leaves.

8.2.14. Control

Growth of these molds can be checked if honey dew insects are properly controlled. However, in severe infection 0.2 percent wettable sulphur can be sprayed.

8.2.15. Integrated Crop Management (ICM)-A Practical Approach

ICM is a whole farm policy aiming to provide the basis for efficient and profitable production, which is economically viable and environment friendly. The three words define the main elements of ICM.

Integrated : Combination of farming practices, including rotation and cultivation.

Crop : Involves all aspects of crop husbandry.

Management : Planning target setting, training, monitoring and auditing (Kern, 1999)

Based on the principles of ICM a project on rejuvenation of mango orchards was launched a year earlier in the Punjab by the Extension wing of the Agriculture Department. Under the project 80 mango orchards have been selected throughout Punjab; each comprising of five acres. The specially selected teams are providing technical guidance and the inputs are provided by the farmers. A management calendar guide (Pub. By Director General Agriculture (Extension and Adaptive Research), Lahore) for technical extension staff working in mango teams has been prepared. This calendar contains all the measures, like irrigation, fertilizer application, pruning, control of insect/pests and disease, to be adopted for maintaining successful productive mango orchard. Following are the key elements of the calendar for diseases management:

8.2.16. Pruning

Objective

- To produce a well structured tree from the very beginning to ensure a consistently heavy productivity and for ease of management.
- Removal of diseased parts of dead woods, for example, Batoor, die-back, Anthracnose, etc.
- Restoration of old orchards.

8.3. TOWARDS THE CONTROL OF A NEW THREAT "QUICK DECLINE OF MANGO"

M. T. Malik, Ch. A. Haq*, A. G. Grewal*, M. Ikhlaq* and M. Khan***

During the recent years, a new malady has been observed whereby apparently healthy looking mango plants collapse within days. That is why, it is named as "Quick Decline". Otherwise, the disease is actually known as collar rot, stem rot or crown rot. It is a soil borne disease and has been observed in the entire mango growing areas and its intensity is increasing day by day.

8.3.1. Symptoms

This disease does not demonstrate any sign initially, until it covers the note worthy segment of the stem. Dark brown to black spots at collar region below the soil level are observed and emergence of the light brown fluid underneath the affected bark is the next indicator by which this syndrome can be recognized. If the collar portion of the infected plant is scrapped, cankers become visible. Afterwards, the collar region of the infected plants becomes dark brown and is found putrid. Gumming out of the bark can also be noticed in advance arena. Tbe rotting of the bark at collar portion progresses and engulfs the whole stem. This is a stage where collapse occurs.

8.3.2. Etiology

The trials on the pathogenicity to corroborate the participation of the isolated fungi such as *Phytophthora sp, Botryodiptodia sp* and *Fusarium sp* are in progress.

8.3.3. Factors Responsible for Maximum Disease Intensity

1. Over irrigation in the mango orchards.
2. Inter cropping with high delta crops, like Cotton, Rice, Sugarcane, Sorghum, Maize etc in mango orchards.
3. Sheshum cultivation near by the sick orchards. 4. Termites infestation in mango orchards.
5. Deep ploughing and hoeing in mango orchards.
6. Soils deficiem in organic matter and the orchards having no regular application of F.Y.M.

8.3.4. Control

For the control of this menace, multidimensional experiments including cultural, chemical, biological and physical means have been started and all these studies are under progress. However, in the ligbt of the preliminary results, survey reports and information's down loaded through internet, a comprehensive preventive package for the plants infected with this disease has been formulated by the Punjab Mango Diseases and Management Committee Comprising of Agri. Scientists and mango growers. The plants to be treated against this disease have been divided into three categories

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8.3.5. Severely Infected/Dead Plants

(i) Up root the severely infected (Plants showing more than 50% disease severity) and dead mango plants with this disease immediately and expose the soil of these plants to the sum almost for 3-4 weeks to reduce the amount and spread of the pathogen.

(ii) Make a bund around the canopy of up rooted plants to avoid further contamination, if the -water is widely run of f in the orchard.

(iii) Although this disease .occurs sporadically, .but is strongly recommended to examine the adjacent plants especially the collar portion below the soil level. If the infection is observed, then it should be treated accordingly.

8.3.6. The Plants Showing Less than 50% Disease Severity

The plants with less than 50% disease severity can be evaluated with the following approaches.

(i) Keen observation to note blackish spots or oily material oozing from some weak points on the stem (above soil level) in the whole orchard and then little scratching of that area as well as collar portion to confirm the infection.

(ii) Careful watching of the collar portion (below the soil level) of mango plants preferably growing in the whole orchard, secondly those sections of the orchard having maximum disease incidence or finally adjacent area of the severely infected dead plants. After recognization of the disease severity less than 50%, the plants should be treated with the followings. Treatments should be applied immediately but moderate temperature may favour to arrest the disease properly.

(1) Scratch the infected portion:

The completely damaged and rotten rots may be removed. Then do three pastings with Ridomil on the scratched portions (Metalaxyl) @ 1: 20 at 10 days interval.

(2) Spray Topsin-M (Thiophanate-Methyl) 2g/lit after first treatment in such a way that all parts of plant including infected portions should be covered properly.

It is worth mentioning here that the plants may die within few months after above said chemical treatment. Therefore, it is also indispensable to spotlight the horticultural aspects even after chemical application.

(3) Minimize the root depending requirements of under treatment plants with the followings.

(i) Pruning of the plants to maintain the shoots according to root size.

(ii) Deblossoming of the plant.

(iii) Thinning of the fruit.

(iv) Removal of the current growth on the plant at initial stage of the growth. Spray of nutrient solution including all essential elements in appropriate quantity having low Nitrogen. Protection of the plant from extreme hot conditions with proper irrigation and spray of water.

(4) Optimize the soil conditions for root growth and to feed the plant with the followings.

(i) Keep the water 3-4 feet away from the stem either by making a watt or by making a slope.

(ii) Add organic matter in the form of F.Y.M or wheat straw (10kg), (60-80kg) to make the soil more fertile and porous under the tree canopy.

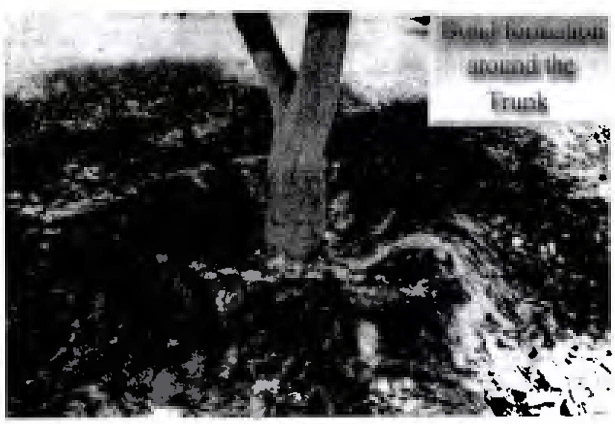
(iii) Make soil amendment with silt and gypsum 10 kg/plant in the root zone.

(v) Apply N.P.K ½:1:1 to encourage the root growth and development.

8.3.7. Healthy Looking Plants

(i) Strictly, avoid over irrigation in the mango orchards as It reduces the oxygen levels in the soil and plant get suffocation. This may lead them to weaken. Do the irrigation whenever it is required i.e., at dry water conditions.

(ii) Keep the water 3-4 feet away from the stem either by the making bund around the stem or by making such slope which start from the stem to 4 feet outward to reduce the spores activity near the collar portion which might appear the most favourite and destructive portion for the pathogen.



(iii) Formation of 6-9 inches deep basin under the tree canopy, to collect the water is a common practice among the mango growers; it strongly suggested that the same area should be kept at field level.

(iv) Avoid intercropping of high delta crops in mango orchards to minimize the allelopathic and over irrigational effects.

(v) Incase of termites attack, apply Chloropyriphos @ 2-3 litter/acre with irrigation to avoid root injuries.

(vi) Follow departmental recommendations for fertilizers application to maintain the health and vigor of the mango plants.

(vii) F.Y.M (80-120 kgm/Plant) and gypsum (10 kg/plant) should be applied in alternate years but preferably once in a year to maintain the physical properties of the soil and to increase activities of antagonistic fungi.

(viii) Avoid deep ploughing and hoeing to avoid root injuries which may provide invading place for the fungus, therefore, adopt clean cultivation or ploughing and hoeing should be restricted up to 4 inches depth.

(ix) Spray of Copper based fungicide or Thiophanate Methyl must be included in spray schedule preferably after monsoon. Further, preventive spray which is recommended at 25% mango flowering, should be of Thiophanate Methyl not only to the extent of foliage but stem, crown and even roots of plant.

8.4. MANGO MALFORMATION AND ITS CONTROL

Dr. Ishfaq A. Hafiz, Mr. Ali A. Asi[6], Ch. A. Haq**, Chulam A. Chaudhry****

Mango (Mangifera indica L.) the king of fruits has a premier status among the commercial fruits grown in Pakistan. It occupies an area of approximately 93.5 thousand hectares with annual production of 916.4 thousand tones (Anonymous 1998-99). Unfortunately, this crop suffers regularly a colossal loss due to malformation.

Malformation is two types, vegetative and floral. In vegetative malformation the terminal shoots are affected and potential sites for fruit production in the next year are eliminated. It is most serious on-young seedlings and small plants in nurseries, but it can also be important in mango groves of Pakistan. No fruit setting or early abortion takes place in affected inflorescence thus causing heavy losses to the growers. In addition, the affected inflorescence provide an ideal hibernating place for the insect/pests. The fruit is reduced in proportion to the severity of the disease, so much so that in acute cases no yield is obtained, so much so that- in acute cases no yield is obtained and disappointed growers decide to uproot the mango trees.

A large body of the literature provides circumstantial evidence to reveal that a fungus (*Fusarium subglutians*) (Usha *et. al.* 1997) is actually responsible for this disease.

The fungus inside the tissue of mother plants competes for nutrients by acting as a more powerful sink than the buds resulting in misshapen shoot and inflorescence. Among other possibilities this may suggest that the fungal pathogen may release secondary metabolites which create hormonal imbalance and inhibit the normal growth of the meristematic tissue of the buds. The levels of indoleacetic acid (IAA) and Gibberellic acid (GA3) were respectively, about ten and five times lower in malformed parts and level of the cytokinin were found to be about five time higher (Singh and Dhillon 1989).

8.4.1. Symptoms

Vegetative terminal or axillary buds produce .distorted shoots with shortened internodes and smaller leaves which are brittle and recureve towards the supporting stem resulting in a bunched shape on the portions of the plants (bunchy top) and stunted growth. Young nursery plants are generally the most affected.

In blossom malformation the axes of the panicles are shorter and thicker than normal, branch more of ten, and a profusion of enlarged flowers is produced, These panicles develop more slowly than normal, retaining their green color but flowers are mostly sterile or increased proportion of male versus perfect flowers or instead 'the whole mass takes the shape of a 'witches' broom. The abnormal panicles may be loose/open in shape or compact. The compactness is of three types i.e. heavy, medium or light. Thus when rest of the tree has already set fruit, these malformed flowers stand out clearly.

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8.4.2. Epidemiology

The fungus is easily spread by grafting and infected nursery trees. This is the usual mode by which the disease is widely spread. Its spread within and among trees in orchards is not so clear. The disease moves slowly even through masses of spores are produced from panicles left on the trees, perhaps because conidia of the pathogen die quickly when exposed to bright sunlight (Manicon. 19891.

Mango germ plasm comprising:, of 40 varieties at Mango Research Station, Shujabad and six varieties at Horticulture Section, AARI, Faisalabad were evaluated for susceptibility. For assessing the incidence of disease on a particular mango tree a rectangle of 20 x 1m was used on four sides of the trees canopy. The intensity of the disease was calculated by the following formula as described by Khan (1960)

M -x 100 : I

M-malformed inflorescence in the sample. T-'total inflorescence in the sample. I-intensity in terms of percentage of diseased inflorescence.

The data in respect of some leading cultivars of mango are presented in the table. None of the varieties was completely resistant or free from this malady. There was a wide variation in cultivars for susceptibility, depending upon cultivars.and agroclimatic conditions. The observation recorded at Shujabad showed that Chaunsa Sammer Bahisht was comparatively most affected ranging from 33.75% to 68.75%. But in case of some trees its disease intensity was seen upto 98%. Therefore, the growers of this variety should take special care of their orchards.

In Dusheri infecftion ranges was from 1 1.42 to 55.8% while in Malda and Sanglakhi, it was (43.27 to 68.38%) and (22 to 44.35%) respectively. Sensation, Langra and TomyAtkin showed comparatively less percentage of malformed inflorescence.

The observation recorded at Horticulture, Section, AARI. Faisalabad led to conclude that disease intensity varied considerably in the trees of a variety growing at the same site. The damage per affected trees in case of Anwar Ratual ranged from 31.5% to 76.72% followed by Malda (20.00 to 64.28°'0) and Chaunsa (29.09% to 51.56%) respectively. The incidence was moderate in case of Dusehri (18.90 or 45.00%) and Langra (27.71 to 41.07%). The disorder of malformation was lowest in case of sensation with a minimum value of 9.00% and maximum 20.93%. the sensation and Tomy Atkin cultivars can be exploited for plantation in the areas where severe malformation exists.

INTENSITY OF MALFORMATION ON MANGO VARIETIES AT HORTICULTURE AYUB AGRICULTURAL INSTITUTE, FAISALABAD, DURING 1999-2000.

Sr. No.	Name of variety	Mean	Value (%)	Range of Intensity	
1.	Dusehri	36.73	18.91	-45%	Medium low
2.	Anwar Ratual	56.63	31.57	-72.00%	High
3.	Langra	34.48	27.71	-41.00%	Medium low
4.	Chaunsa	44.05	29.09	-51.56%	Medium
5.	Sensation	16.51	09.00	-20.93%	Low
6.	Malda	43.05	20.00	-64.28%	Medium

Sr. No.	Name of variety	Mean	Value (%)	Range of Intensity
1	Dusehri	30.23	11.42	-55.80%
2	Smmar Bahisht	50.28	33.57	-68.75%
3	Fajri	35.00	27.77	-40.00%
4	Maldar	55.21	43.27	-68.38%
5	Sanglakki	31.78	22.00	-44.34%
6	Tomyatkin	11.16	07.50	-13.16%
7	Langra	19.36	15.00	-23.68%
8	Sensation	09.78	01.09	-21.50%

0.20% low 0.-10'% Moderate low,.0-10 -60% medium 60-hO'% high 80% above severe.

8.4.3. Control

The disease can be eliminated at little cost. All that is required, is that trees be inspected during April when fruit develops to pea size. The affected panicles are distinguished clearly from normal ones that should be excised along with three contiguous nodes (30 cm) from affected trees. Remove those tissues from the orchard, and burn -them, if roughing step is practiced regularly for a period of three, consecutive years, the disease is reduced upto 80%. Examine the orchard after harvesting in September and October again, if any affected panicles are seen, these should be trimed and disposed off. A spray of Topsin M or coper oxy-chloride is recommended after pruning or removal of shoots. Some workers have tested sulphates of Cobalt, Nickel and Cadium @ 1.00 -1.5 g/liters. These chemicals reduced the intensity of malformation but it is doubtful that either of these compounds could be used safely on this food crop.

8.4.4. REFERENCES

Anonymous (1999, Agricultural Statistic of Pakistan, ministry of Food, Agriculture and Cooperatives. Economic Division, Islamabad.

Khan, M. D. and A. H. Khan 1960. Studies on malformation of Mango inflorescence in West Pakistan. Pubjab Fruit J. (82,83) 247-258.

Manicon. B. Q (1989) Blossom malformation of Mango. South African mango Grower's Association Year book 10,1-12.

Singh, Z. and B.S. Dhillon, (1989) Hormonal changes associated with vegetative malformation of mango (Mangifera indica L,). Journal ofPhyt. Opathology 125, 193-97.

Osha, K. A. M. Goswami, H. C. Sharma and Bhupinder Singh (1997) Scanning electron microscopic studies on floral malformation in mango. Scientia Horticulture 71, 127-130.23

8.5. "SOFT-NOSE",'A PHYSIOLOGICAL DISORDER IN MANGO FRUITS

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A breakdown of the flesh on the ventral side and towards the apex in mango fruits while still on the tree has caused consider- able loss to growers in Florida. The trouble, now commonly and rather descriptively called "soft-nose, apparently was first recognized as a definite disorder in fruit on the tree, rather than a result of mishandling at harvest, by growers in Palm Beach County about 1950. Soft-nose now has been reported from all mango growing areas of the state. The break- down, or a similar one, has been reported in India. Investigations in Florida during the past four seasons have fairly well established the disorder to be physiological, but a remedy is unknown.

Soft-nose generally, if not always, starts on the tree. Unless already initiated at picking, typical or pronounced soft-nose apparently does not develop after the fruit is picked. Although not always discernible, an external symptom of soft- nose, particularly in Hadens, is a yellowing of the green skin in the area between the apex and the stigmal point. With some experience, one can also feel a lack of firmness in this area of affected fruits. Upon cutting, the flesh on the ventral side towards the apex of some soft-nose fruits merely appears to be over-ripe, while that around the shoulders and on the dorsal side is unripe (Figure 8-1F). This is the condition most frequently found in Hadens and evidently occurs mostly during ripening (as distinguished from maturity), which follows full maturity. Occasionally in Hadens, but more commonly in Kents, for example, the over-ripe flesh surrounds a mass of yellowish to brown tissue which is of firmer texture than the surrounding affected tissue (Figure 8-1E) and is bitter to taste. In more advanced cases some of the tissue may become a spongy, grayish-black mass (Figure. 8-1-B, C & D), which in extreme cases may extend through most of the fruit (Figure. 8-1A). The spollgy condition was always associated with the over-ripe at condition and perhaps results when the trouble is initiated before full maturity. It is possible, however, that the two may be distinctly different disorders.

So far, the trouble has been observed only in Indian varieties, such as Mulgoba, and first and second generation seedlings of these varieties, including Haden, Kent, Sensation, Keitt, Davis-Haden, Springfels, Irwin, Zill and Brooks. Soft-nose probably will be found, at least to some extent, in many of the newer Florida varieties, which are not yet widely planted, and on which critical observations have not been made.

The incidence of soft-nose, as reported by growers and shippers, varies widely with localities. In some areas there is a tendency to pick fruit less mature than in other areas. Fruit picked when it is barely mature enough to ripen to fair quality will show much less soft-nose than fruit left on the same tree to start ripening before picking. Grading standards and ability on the part of graders to recognize the trouble also accounts for much variation ill reported incidence of soft- nose. Of the commercially important varieties observed extensively, Haden and Kent appear to be the most commonly affected. Perhaps from five to 20 per cent of fruits harvested from these varieties will show the trouble ill most seasons, and as much as 50 per cent will be affected in severe cases. The trouble in other varieties commonly found on the market seems to range from somewhere between the above figures down to an occasional affected fruit. Observations on a limited number of Sensation fruits indicate that .this variety may be among those severely affected.

Figure 8-1a,b,c,d,e,f

The possibility that the trouble was pathological, was investigated since it was recognized that micro-organisms might gain entrance into the flesh through natural weak spots in the skin, cracks resulting from a disease such as scab, mechanical injuries or insect stings. Many affected fruits were examined, but rarely was a weak spot or break in the skin found in the soft-nose area in early stages of the trouble. It seemed improbable also those organisms, which might be involved, would invariably enter in this particular area rather than at any place a suitable opening occurred. Soft-nose fruits, with skins free of defects, have been stored for as long as 10 days at room temperature without noticeable increase in soft tissues, and with the firm portion ripening norm- ally. If an organism was involved it seems most probable that the breakdown would have progressed appreciably during this incubation. More conclusive proof that soft-nose was not pathologic in nature was secured through a series of isolations from all types of tissues of affected fruits. No organism was isolated consistently and those isolated were not always the same. The probability that a group of organisms, rather than a single pathogene, was involved was eliminated since a number of isolations were sterile. Apparently the organisms isolated were all secondary.

Little indisputable information is avail- able yet on the relationship of environmental factors and cultural practices to soft-nose. The trouble occurs on all soil types used for mangoes in the state, in warm or cold and wet or dry seasons, on young and old trees, on semi-neglected trees and on well fertilized and adequately sprayed trees, regardless of materials or program used. Perhaps soft-nose is a little less prevalent on the rocky alkaline soils of Dade County than on the acid sandy soils common in other mango growing areas of the state, but conclusive proof is lacking. In general, the incidence of soft-nose reported was somewhat less this past season, which was relatively wet, than in the previous two seasons, which were drier than normal. -The implicatio1'1 here is obvious, but again the evidence is meager and conclusions based on observations for such a short period are not justified. Moreover, in wet seasons t the amount of fruit discarded because of anthracnose, without even examining it for soft-nose, may be so great that the observed incidence of soft-nose would be less in wet than in dry seasons.

Fertilizer practices are thought by some to be responsible for soft-nose. Data from commercial groves in general have yielded little useful information on the subject because of differences from place to place in degree of maturity at picking, grading standards and ability to re- cognize the trouble. More acceptable information on the relationship between fertilizer practices and soft-nose has been secured from a series of field fertilizer experiments, initiated about four years ago on Hadens, Kents and Zills in commercial groves on sandy soils. These experiments include rate of application of nitrogen, phosphate and potash, time of fertilizer application and nitrogen source (nitrate *vs.* ammoniacal). Variations in treatments in these tests are considerably greater than ordinarily found in commercial groves. There has been no observable difference among different treatments within any individual experiments in the incidence of soft-nose, with the questionable exception this season of results from a nitrogen rate experiment on eight-year-old Kent trees. In these experiment individual trees under three different treatments received 0.2, 0.4 and 0.8 of a pound of nitrogen, respectively, per application this year. All other fertilizer elements were held constant. Approximately 6,000 fruits from these plots were carefully inspected and graded for soft-nose. The percentages of fruit from the three treatments with definite soft-nose, by increasing nitrogen application, were 7.7, 9.6 and 11.9, respectively. The exact internal condition of a large number of fruits could not be determined accurately by touch, but appeared to be in an incipient stage of soft-nose. The percentages of these doubtful fruits were also greater from the higher rates of nitrogen application than from the lowest.

The percentage of fruits that was un- questionably sound, decreased with increasing nitrogen. A possible contributing factor to these results may have been in the application of fertilizer this season .about a month before harvest started. It is conceivable that had the application been farther removed from harvest, as is the general practice, or had weather been dry, the difference among treatments in soft-nose would have been even less. As it is, these data may not be representative since only one season is included. At present it seems that there probably is an inherent tendency towards the disorder in some varieties which certain environ- mental or cultural factors may aggravate.

Although the evidence that the trouble is physiological has been fairly well established, the exact nature and mechanism of the breakdown remains for investigation. The over-ripe condition of soft- nose tissues indicates that starch has been hydrolyzed to sugars earlier here than in the firm tissues. Perhaps the over-ripe stage (or type) of soft-nose results from an inherent characteristic of some mangoes for certain enzymes to become activated towards the tip on the ventral side sooner than in the remainder of the fruit. An- other, or added, explanation of the trouble may lie in the quality of the skin. It is known that the skins of some fruits, e.g., grape and Japanese persimmon, are relatively impermeable to oxygen. In such fruits anaerobic respiration probably replaces aerobic respiration to some extent. Injury to plant tissue from anaerobic respiration may result from the accumulation of alcohol and other toxic substances in the cells and from low energy release which may be inadequate to maintain metabolic processes. Evidence of impermeability of the mango skin to gases is found in the bloated condition of an occasional soft-nose fruit; the bloating perhaps being caused by carbon dioxide released as an end product of anaerobic respiration. Also, alcohol, another end product of anaerobic respiration, apparently can be detected by taste in the flesh of some soft-nose fruits. The amount of alcohol, if present, is relatively small, however, and could not be detected by the xanhtate test[7] in a number of trials. Esters and related compounds interfere with this test and may have masked a positive test for small amounts of alcohol .present. The darkened, spongy condition of the flesh in some cases of soft-nose, illustrated here with Kent, could well result from an upset in the metabolic processes and effects of alcohol and other toxic products of anaerobic respiration in the fruit. Efforts this season to induce the soft-nose condition by enclosing fruits, both before and after picking, in various wraps and wax coatings which reduced gas exchange were unsuccessful. While a decided off-flavour developed in fruits thus treated, the resulting condition was not comparable to soft-nose. Field experiments to examine the influence of available calcium, soil reaction and soil moisture on the incidence of soft-nose have been established on a limited scale recently. Also on a limited scale, the fertilizer investigations on soft-nose have been expanded to include all fertilizer elements known to be essential for plant growth. These fertilizer tests are designed primarily to explore the direct influence of the element in question 18 and only incidentally will they show anything on the possible effects on the trouble of interactions of the various elements. Provided the trouble is not a strongly inherited characteristic, such investigations c eventually may lead to some alleviation, if not complete correction, of the disorder. On the other hand, correction of a strongly inherent physiological disorder tllrough cultural practices offers little promise. Under such circumstances the only solution may be in early picking or in growing varieties which may be found less inclined to the trouble.

8.5.1. Acknowledgments

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[7] *Feigl, Fritz. Spot Test, Vol. 2 (Organic Applications), 129-132. Elsevier Publishing Co., New York.*

9. INSECT PESTS AND THEIR CONTROL

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Mango, like most fruit tree crops, is usually attacked by two or three key pests, several secondary pests and by a large number of occasional pests in localized areas where it is grown. Worldwide lists of pests of mango have been published by Laroussilhe (1980), Tandom and Verghese (1985) and Veerish (1989). The pests of mango in Australia (Bagshaw *et al.*, 1989), Pakistan (Mohyuddin, 1981), Israel (Wysoki *et al.*, 1993) and USA (Pena, 1993) have also-been described. Some publications contain check lists of mango pests and most contain details of life histories and control of mango pests (Murray, 1991).

Of 260 species of insect and mites that have been recorded as minor and major pests of mango, 87 are fruit feeders, 127 are foliage feeders, 36 feed on the inflorescence, 33 inhabit buds, and 25 feed on branches and the trunk. A summary of the most commonly occurring mango pests worldwide is given in Table 9-1. The three to four key pests, including fruit flies, seed weevils, tree borers and mango hoppers require annual control measures. Secondary pests generally occur at sub-economic levels, but can become serious pests as a result of changes in cultural practices and mango cultivars or because of indiscriminate use of insecticides against a key pest, e.g. Mohyuddin and Mahmood (1993) reported that scale insects became serious pests following non-judicious use of insecticides against fruit flies. Similarly, mites, *Oligonycbus* spp., are secondary pests of mango, which can become serious because of human intervention. Occasional or incidental pests also can cause economic damage only in localized areas at certain times. The great majority of pests reported here are within this category.

9.1.1. Mango Fruit Pests

Mangoes are harvested green, unripe and ripe. With current world emphasis on quality fruit for local consumption and export, insects that blemish fruit by feeding, scratching or ovipositing in the pulp or seed can cause high losses. Only fruit flies, seed weevils and lepidopterous larvae actually penetrate the fruit pulp and seed. The feeding of other pests, such as *Othreis materna* (L.), *Conodonta pyrgo* (Cram.), *C. clotilda* (Stoll) and *Leptoglossus stigmai(Herbest)* (Angeles and Requena, 1966) often extends only into the pulp of ripening mangoes.

9.1.2. Fruit flies

Although fruit flies are found in almost all mango growing areas of the world (Hill, 1975; Umaya and Hirao, 1975; Anonymous, 1987; Yee, 1987; Singh, 1991; Aluja, 1994), their economic status as mango pests remains largely unresolved. White and Elson-Harris (1992), who have revised the taxonomy of fruit

		Bactrocera sp. near B. dorsalis (A)	9,10	F
		Bactrocera sp. near B. dorsalis (B)	7.9	F
		Bactrocera sp. near B. dorsalis ©	7.9	F
		Bactrocera sp. near B. dorsalis (0)	7,9	F
		B. facialis (Coquillett)	10	F
		B. frauenfeldi (Schiner)	1.7,10	F
		B. froggatti (Bezzi)	10	F
		B. incisa (Walker)	1,10	F
		B. kirki (Froggatt)	10	F
		B. latifrons (Hendel)	7	F
		B. melanota (Coquillett)	10	F
		B. neohumeralis (Hardy)	1	F
		B. occipitalis (Bezzi)	7	F
		B. opiliae (Drew & Hardy)	1	F
		B. passiflorae (Frogatt)	10	F
		B. psidii (Frogatt)	10	F
		B. trilineola Drew	10	F
		B. tryoni (Frogatt)	10	F
		B. tuberculata (Bezzi)	7	F
		B. versicolor (Bezzi)	7	F
		B. zonata (Saunders)	7,9,10	F
		B. (Hemigymnodacus) diversa (Coquillett)	7	F
		B. (Notodacus) xanthodes (Broun)	10	F
		B. (Zeudacus) cucurbitae (Coquillett)	7,9,	F
		B. (Zeudacus) tau (Walker)	7	F
		Ceratitis capitata (Wiedemann)	12,13	F
		C. catoiriiGuerin-Meneville	3	F
		C. (Ceratalaspis) cosyra (Walker)	5	F
Diptera	Tephritidae	*C. (Pardalaspis) punctata* (Wiedemann)	3	F
		C. (Pterandrus) anonae Graham	3	F
		C. (Pterandrus) flexuosa (Walker)	3	F
		C. (Pterandrus) rosa Karsch	3	F
		Dirioxa confusa (Hardy)	1	F
		D. pornia (Walker)	1	F
		Cochliomya macellaria	6	B

		(Fabricius)		
		Toxotrypana curvicauda Gerstaecker	2,4,6,8	F
Hemiptera	Coreidae	*Amblypelta lutescens lutescens* (Distant)	1	F
		A. nitida Stal	1	F
		Pseudotherapterus wayi Brown	3	F
		Veneza stigma (Herbert)	4	F
	Miridae	*Daghbertus fasciatus* (Reuter)	6,8	B
		Rhinacloa spp.	6,8	B
	Pentatomidae	*Brochymena* sp.	6	L
		Plautia affinis Dallas	1	L
		Stenozygum coloratum (Klug)	13	F?
	Scutelleridae	*Symphillus caribbeanus* Kirk.	6,8	F
Homoptera	Acanalonidae	*Acanalonia latifrons* (Cockerell)	6	BFL
	Aleyrodidae	*Aleurocanthus woglumi* (Asby)	2,4,5,6	L
		Aleurodicus dispersus Russell	6	L
	Aphididae	*Aphis craccivora* Koch	3	L
		A. fabae Scopoli	13	L
		A. gossypii Glover	13	L
		A. spiraecola Patch	13	L
		Toxoptera aurantii Boyer de Fonscolombe	6,8	BL
	Asterolecanidae	*Asterolecanium pustulans* (Cokerell)	6,13	L
	Cicadellidae	*Amrasca splendens* Ghauri	1,3,7,9	L
		Amritodus atkinsoni Leth.	9	L
		A. brevistylus Viraktamah	9	L
		Busoniomimus manjunathi Viraktamath	9	L
		Chunrocerus n;veosparsus (Leth.)	10	FIL
		Empoasca spp.	13	L
		Idioscopus anasuyae Viraktamah	9	FL
		I. clavos;gnatus Maldonado	9	FIL
		I. clypealis Leth.	7,9	FL
		I. decoratus Viraktamah	9	FIL
		I. jayashirae Viraktamah	9	FIL
		I. nagpurensis Pruthi	9	FL
		I. niveosparsus Leth.	7,9	LFIT

		I. nigroclypeatus Melich	9	FIL
		I. spectabilis Viraktamath	9	FIL
		Rabela tabebu;a (Dozier)	6	L
		Scaphytopius sp.	6	L
Homoptera	*Cixiidae*	*Myndus crudus* VanDuzee	6	L
	Coccidae	*Ceroplastes cirripediformis* Comstock	6	L
		C. floridensis Comstock	6,13	L
		C. martinae sp.	4	T
		C. rubens Maskell	1,3,6,7	L
		C. rusci (L.)	13	L
		C. trochezi sp.	4	T
		Coccus acutissimus (Green)	6	L
		C. elatensis Ben-Dov	13	L
		C. hesperidum L.	13	L
		C. mangiferae Green	3,4,5,6;7	L
		C. moestus De Lotto	8	L
		C. viridis (Green)	6	L
		Eucalymnatus iessellatus (Signoret)	6	L
		Kilifa acuminata (Signoret)	6	L
		Milviscutulus mangiferae (Green)	13	LFT
		Philephedra tuberculosa Nakahara & Gill	6	FL
		Protopulvinaria pyriformis Cockerell	13	L
		P. mangiferae (Green)	5	L
		Pulvinaria psidii Mask. pantrop	Pantrop	L
		Saissetia alBae (Bernard)	13	L
		S. neglecta De Lotto	8	L
		Vinsonia SiBllitera (Westwood)	4	L
	Diaspididae	*Aonidiella aurantii* (Maskell)	13	L
		A. orientalis (Newstead)	13	L
		Aspidiotus destructor (Signoret)	4,6,7	L
		Aulacaspis tubercularis Newstead	1,3,4,5,6,8	L
		Chrysomphalum aonidum (Linn.)	6,13	L
		C. dyctiospermi (Morgan)	4,5,6,8	L
		Fiorinia fiorinae (Targ. Tozz)	6	L
		Hemiberlesia lataniae	6,13	L

		(Signoret)		L
		Howardia biclavis (Comstock)	6	T
		Ischnaspislongirostris (Signoret)	4,6	L
		Lindingaspis floridana Ferris	6	L
		L. ferrisi Mckenzi	9	L
		Morganella longispina (Morgan)	6	T
		Parlatoria spp.	6	L
		Phenacaspis cockerelli (Cooley)	4	L
		P. dilatata (Green)	1	L
		P. sandwichensis (Fullaway)	10	L
		Pinnaspis strachani (Cooley)	3,6	L
		Pseudaulascaspis cockerelli (Cooley)	6	L
		Pseudaonidia trilibitiformis (Green)	4,6	L
		Radionaspis indica Marlatt	6	L
		Selanaspidus articulatus (Morgan)	4	L
		Unaspis citri	4	T
	Flatidae	Colgaroides acuminate (Walker)	1	FIF
	Margarodidae	*Drosicha stebbingii* Stebb.	9	L
		D. mangiferae Green	9	L
		Icerya seychellarum Westw.	3,7.9	L
	Ortheziidae	*Orthezia* spp.	4	L
		O. olivicola n. sp.	4	L
	Pseudococcidae	*Drosicha mangiferae* (Green)	9	L
		D. stebbingi (Green)	9	L
		Pseudococcus adonidum (L.)	3.4,5,9	LF
		P. elisae Borkhsenius	10	L
		P. longispinus (Targioni)	8	B
		Rastrococcus invadens Williams	3.5	BLF
		R. spinosus (Robinson)	9	BLF
	Psyllidae	*Apsylla cistellata* Buckton	9	L
		Pauropsylla nigra D.L.	7	L
Hymenoptera	Apidae	*Trigona sp.*	2	FI
	Formicidae	*Atta* spp.	2	L
Isoptera	Termitidae	*Coptotermes acinaciformis* (Frogatt)	1	TR

		C. formosanus Shiraki	10	T
		Microcerotermes biroi (Desneux)	1	T
		M. edenatus Wasm.	?	T
		Microtermes obesi Holmgren	9	T
		Neotermes insularis (Walker)	1	T
		Nisutitermis graveolus (Hill)	1	TR
		Odontotermes lokanandi Chatterjee & Thakur	9	T
		O. gurdaspurensis Holmgren & Holmgren	9	T
		O. wallonensis (Wasmann)	9	T
		O. obesus (Ram bur)	9	T
		O. horai Roonwal & Chhotani	9	T
		Termes cheeli (Mjober)	1	T
Lepidoptera	Arctiidae	*Diacrisia obliqua* (Walker)	9	L
		Lymire edwardisii(Grots)	6	L
	Coreuthidae	*Eccopsis praecedens* Wism.	3	F
		Lobesia vanillana (Joann.)	3	F
	Ctneuchidae	*Syntomeidaepilais jucundisima* Dyar	6	B
	Gracillariidae	*Marmara* sp.	6	F
		Acrocercops sp.	1	L
	Gelechiidae	*Thiotrina godmani* (Walsingham)	8	B
	Geometridae	*Oxydia* spp.	6	F
		O. vesulia (Cramer)	8	F
		Pleuroprucha insusaria Guenee	6	B
		Chloropteryx glauciptera Hampson	8	B
		Thalassodes dissita	9	L
	Limacodidae	*Latoia lepida* Cram.	7,9	L
	Lymanthriidae	*Lymanthria marginata*	9	L
	Megafopygidae	*Megalopyge defoliata trujillo Schs.*	6	L
		M. lanata (Ramen)	4	L
	Noctuidae	*Alabama argillacea* (Hb)	8	F
		Chlumetia transversa Walker	7	9
		B Gonodonta spp.	8	F
		G. pyrgo (Cramer)	8	F
		Othreis fullonia (Clerck)	1	F
		O. materna (L.)	8	F

		O. tyrannus (Guenee)	1	F
		Penicillaria jocosatrix Guenee	10	L
	Pyralidae	*Davara caricae* (Dyar)	8	B
		Noorda albizonalis Hampson	7,9	F
		Orthaga exvinacea Mi.	9	?
		Pococera atramentalis Lederer	6,8	BF
		Tallula sp.	6	F
	Saturnidae	*Nataurelia zambesiana* L.	3	L?
	Tortricidae	*Aethes* sp.	1,8	B
		Amorbia aequiflexa Meyrick	8	B
		Cosmetra anthophaga Diakonoff	3	F
		Episimus transferrana Walker	8	B
		Platynota rostrana (Walker)	6	BF
Orthoptera	Acrididae	*Anacridium melanorhodon* (Walker)	3,5	L
Thysanoptera	Paleothripidae	*Leptothrips sangularis* Hood	6	B
	Tripidae	*Frankliniella* spp.	8	B
		Frankliniella bispinosa (Morgan)	6	B
		F. fusca (Fitch)	6	B
		F. kelliae Sakimura	6	B
		F. occidentalis (Pergande)	13	B
		Heliothrips hemorroidalis (Bouche)	6,13	B
		Scirtothrips mangiferae Priesner	13	L
		Selenothrips rubrocinctus (Giard)	2,3.4,6,7	L
		Retithrips syriacus Mayet	13	L
		Thrips palmi Karny	6	B
		T. florum Schmetz	6	B

Plant part affected: B = bud; FI = blossom; F = fruit; L = leaves; R = root; T = trunk, branches Geographical area: 1 = Australia; 2 = Central America; 3 = East Africa; 4 = South America; 5 = West Africa; 6 = North America; 7 = Southeast Asia; 8 = Islands of the Caribbean region; 9 = India and Pakistan; 10= South Pacific; 11 = Spain; 12 = Cosmopolitan; 13 = Israel.

9.1.3. Bactrocera spp.

Bactrocera spp. are pests of major importance in the eastern hemisphere. The *Bactrocera* spp. reported on mango by White and Elson-Harris (1992) are indicated in Table 9.1. The common species reported on mango include Queensland fruit fly *B. tryoni* (Frogatt), *B zonata* (Saunders), oriental fruit fly *B.*

dorsalis(Hendel), *B. neohumeralis(Hardy)*, *B.jaroisi(Tryon)* and *B.frauenfeldi* (Schiner) (Umeya and Hirao, 1975).

9.1.4. Life cycle and damage

Bactrocera spp. female fruit flies insert their eggs beneath the skin of mango, especially in ripening fruit (Figure 9-1). White banana-shaped eggs arc deposited in clusters, e.g. 200-400 eggs are laid by *Anastrepha fraterculus* and 1200-1500 eggs by *B. dorsalis*. The larvae tunnel into the fruit, contaminating the fruit with frass and providing entry for fungi and bacteria (Figure 9-2). When the infested fruit is immature, the fruit ripens prematurely and is unfit for marketing. Fully grown larvae measuring c. 7 mm drop to the ground and enter the soil where they pupate. The egg period lasts from 2-20 days. There are usually three larval instars. Larval period and pupal periods are each 2-4 weeks. After emergence, the females require a protein source for egg maturation (Anonymous, 1989). Studies conducted by Singh 0991) with *B. dorsalis* in India indicated that pupal period was longest (18 days) at 15°C and shortest (6 days) at 35°C.Warm, humid weather is considered to be favourable for *Bactrocera* fruit flies and pest populations build up as mango ripening occurs. *Bactrocera* populations decrease during dry periods.

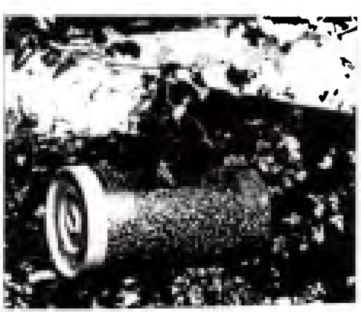
Figure 9-1. ***Bactrocera dorsalis* (Hendel) ovipositing in mango fruit.**

Figure 9-2. ***Bactrocera* larvae feeding in mango.**

Syed *et al.* (1970a) reported that up to 30% of mango fruits were attacked by *B. dorsalis* in July and August. Mohyuddin and Mahmood (1993) .reported that mango fruit are attacked in central Punjab in July with a maximum in August, when 35% of the fruits were damaged by *B. dorsalis* and *B. zonata*. Yee (1987) reported that *B. dorsalis* does not attack all mango cultivars to the same extent. The most susceptible cultivars in Hawaii are 'Hawaiian', 'Pirie' and 'Sandersha'. Singh (1991) .indicated that the frequency of *Bactrocera* injury to physiologically mature fruit of 'Oashehari' ranged from 3.6 to 10%, while in fully ripe fruit the frequency of injured fruit ranged from 10 to 25.9%. Highest damage was reported in fully ripe fruit of 'Mallika' followed by 'Tot.apuri'.

Fruit fly activity has been monitored in Australia using Oakpot fruit. fly traps hung beneath the tree canopy (Anonymous, 1987). Methyl eugenol was used successfully for control and eradication of *B. dorsalis* in Oahu (Steiner and Lee, 1955), Rota Island (Steiner *et al.*, 1965), Okinawa, Kume, Miyako and Uaekama Islands (Iwahasi, 1984) and has also been used for monitoring *B. umbrosus* in .the Philippines (Umeya and Hirao, 1975). Fruit flies of both species were controlled by mass trapping of males with methyl eugenol and infestations were brought to sub economic levels in Pakistan (Figure 9-3) (Mohyuddin and Mahmood, 1993).

Figure 9-3. **Fruit flies, *B. dorsalis* and *B. zonata* caught in a trap baited with methyl eugenol.**



9.1.5. Chemical control

Commercial mango plantations account for major insecticide use in the tropics (Cunningham, 1984). In Pakistan, application of pesticides cause reduction of fruit fly infestation but their use has created scale insect problems by eliminating their natural enemies (Mohyuddin and Mahmood; 1993). Singh (1991) reported that Aldrin dust 5%, when mixed in soil provided the highest' residual toxicity to falling mature larvae (23.4% after 15 days), as compared to BHC endosulphan and quinolphos. Yee (1987) concluded that weekly applications of malathion for 3 months can also provide effective control.

9.1.6. Biological control

The parasitoids of *B. zonata* that have been found in Pakistan inclyde *Opinus longicaudatus* (Ashm.), *Dirhinus giflardii* Silv. and *Bracon* sp. The parasitoids, *O. longicaudatus, D. giffardii* and *Spalangia grotiusi* Girault are commonly reported from *B. dorsalis* (Syed *et al.*, 1970b); however, their incidence is extremely low. *Opiusspp.* introduced from Malaysia into Hawaii became established against *B. dorsalis* (Clancy *et al.*, 1952); however, fruit flies directly damage produce that is to be marketed. As a result, a small fruit fly population can cause economic damage reducing success of classical biological control programmes.

9.1.7. Ceratitis spp.

9.1.8. Occurrence and Damage

Seven *Ceratitis* spp. have been reported to attack mango fruits (see Table 9.1). The Mediterranean fruit fly C. *capitata* (Wiedeman) is a common polyphagous pest in mango growing areas of Hawaii, Israel, Australia, Spain, Mexico, Reunion and South America (Etienne, 1966; Morin, 1967; Galan-Sauco, 1990). *Ceratitis cosyra* occurs in Africa whereas C. *catoirii* Guer occurs in Reunion (Etienne, 1968). In Israel, C. *capitata* females seek suitable sites for oviposition and puncture mango fruit early in the season, before the fruit has ripened.According to Wysoki *et at.* (1993) these 'barren' punctures damage the fruit, due to the leakage of resins from the fruit. The female can oviposit allover the fruit, with no preference for any part. Later, when fruit development is suitable for maggot development, the oviposition sites become light in colour and the tissue softens. The fully grown maggot-5 leave the fruit and pupate in the soil. T,he developmental period is approximately 3-'-4 weeks and 8-10 generations per year can occur depending on temperature and other factors intrinsic to the fly population (Hill, 1975). Similar damage is attrihuted to *C. cosyra* in Africa (Hill, 1975).

9.1.9. Chemical control

Without chemical control the damage from 'barren' and fertile punctures can l)e as high as 6000. Control is effected by aerial bait-spraying, ground cover spraying, and spot spraying of trees. In Spain, chemical control has been achieved hy applying organophosphates and hydrolysed albumen (Galan-Sauco, 1990). Chemical application is based on monitoring by Trimedlure-baited traps, and the appearance of the first trapped males. The chemical control agents are dimethoate (0.1%) and fenthion (0.15%). The bait spray is based on Neziman (1 : 1 p!otein hydrolysate: malathion in 4 I of water; Wysoki *et al.*, 1993). Removal of fallen fruits can prevent build-up of Mediterranean fruit fly populations. In mango orchards that are adjacent to citrus groves, the infestation idte can be high, because of earlier Mediterranean fruit fly appearance in citrus.

9.1.10. Biological control

Several parasitoids, i.e. *Opius fullawayi* (Silvestr), O. *bumilis* Silvestri, O. *illcisi* Silvestri, O. *kraussi* Fullavai, *O. tryoni* Cameron, *O. bellus* Gahan, *Biosteres longicaudatus* Ashmead, *B. tryoni* (Couron) and *B. oophilus* (Fellaway) have been reported parasitizing C. *capitata* (Beardsley, 1961; Wharton and Marsh, 1978). Bess *et at.* (1961) reported that the most important parasitoids collected from C. *capitata* in Hawaii were O. *vandenbosch i*, O. *oophilus* and *B. longicaudatus*.

9.1.11. Anastrepha ssp.

9.1.12. Life cycle and occurrence

A nastrepha spp. are endemic to the Western hemisphere and their range extends from the southern USA to northern Argentina and includes the Caribbean Islands (Aluja, 1994). Eight *Anastrepha species* have been reported to be associated with mango (White and Elson-Harris, 1992). Only the Caribbean fruit fly *A. suspense*, however, is considered to be a threat to mango in Florida, and its occurrence there as a pest is sporadic (Pena, 1993). The West Indian fruit fly *Anastrephcl ohliqua* has been reported to be the most common fruit fly pest when compared with other neotropical species (Jiron and Hedstrom, 1991; Nascimento *et al.*, 1992). Abundance of *Anastrepha* populations have been positively correlated with temperature and negatively correlated with relative humidity (Herrera and Vinas, 1977). Much of what is known today is based on basic biology studies carried out between 1900 and 1944 (Aluja, 1994). The basic life cycle is very similar among all *Anastepha* spp. for which the biology is known. Egg incubation of the Mexican fruit fly *A. ludens* In mango requires 3.8 days; larval development requires 14.2 days and pupal development has been known to need 14.2 days at 27:t 2°C (Leyva *et al.*, 1991). The biology of *A. obliqua* was determined by Toledo and Lara (1996) who considered different biological and demographic aspects of this species in mango in comparison with *Spondias mombin* L. These authors found that in general, populations of *A, obliqua* reared in mombin fruit have a greater life expectancy and better measures of demographic parameters, i.e. fecundity and fertility, compared to populations reared in mango. In the majority of *A nastrepha* species, the females deposit their eggs, e.g. c. 15-19 eggs per *A. ludens* female, in either the epicarp or mesocarp of ripening fruit. Depending on the species, eggs are laid either singly or in clusters. Larvae pass through three instars before emerging from the fruit and burrowing into the ground to pupate.

9.1.13. Trapping

The use of McPhail traps has been a standard procedure for controlling *Anas- trepha* spp. for 35 years (Jiron, 1992), even though such methods have been ineffective. The most widely used traps to monitor and in some cases control *Anastrepha* populations are glass and plastic versions of the McPhail trap, which is baited with a mixture of protein (occasionally hydrolysed cotton seed together with borax, molasses or fermented juices) and water (Balock and, Lopez, 1969). The McPhail trap, however, has several drawbacks. It is expensive, breaks easily and is cumbersome to service. Balock and Lopez (1969) reported that high concentrations of McPhail traps reduced the build up of fly populations and protect mangoes from severe injury at certain times of the year. Aluja *et al.* (I989), working in a mixed mango orcbard, found that only 31.1% of the *Anastrepha* population was caught by the McPhail trap. Colours such as yellow and orange, reflecting maximally within a narrow spectral region, i.e. 500-590 nm, have proven to be effective for capturing several *Anastrepha* species, e.g. *A frater- culus, A. ludens* and *A, suspensa,* when used in spherical, rectangular or cylindrical traps.

9.1.14. Chemical control

Anastrepha flies are susceptible to most insecticides (Shaw and Spishakoff, 1958; Shaw, 1961). Bait sprays applied from the ground and from the air are successful, but they could cause environmental damage, surges of secondary pest populations and reductions in parasitization rates (Lopez *et al.*, 1969; Soto-Manatiu *et al.*, 1987). In Peru, control measures against *Anastrepha* in mango begin when McPhail trap catches per week average two adults per trap (Herrera and Vinas, 1977). In Mexico, control starts when the fruit is 85 days old and is suspended 2 weeks before harvest (Cabrera *et al.*, 1993). Hot water treatments to destroy , *Anastrepha* in mango fruits are discussed in detail in Chapter 14.

9.1.15. Biological control

Both classical biological control and repeated augmentative releases of , mass-reared parasitoids have been used to suppress Anastrepha populations. Parasitoid species such as *Diachasmimorpha longicaudata, Doryctobracon crawfordi, Ganapis pelleranoi, Biosteres vandenboschi* and *Aceratoneuromya indica* have been imported and released in the USA, Mexico, Costa Rica, Brazil and Peru for the control of *A. suspensa, A. ludens* and *A. fraterculus.*

9.1.16. Cultural control

Jiron (1995) observed reduction of *A. obliqua* populations by increasing planting distances in order to reduce humidity and increase solar radiation within orchards, to eliminate fruit fly host plants in the hedges of mango orchards and to remove early or late fruit from the trees.

9.1.17. Resistant cultivars

Susceptibility of different mango cultivars to the attack of *A. obliqua* were measured by Carvalho *et at.* (1996) who observed that 'Espada' showed no infestation by *A. obliqua,* whereas 'Carlota' was highly infested. In this study, the survival of adults of *A. obliqua* was lower when the larvae have fed on 'Espada' compared to 'Carlota'. Furthermore, 'Espada' had an adverse effect on the longevity of *A. obliqua* females, possibly due to the presence of toxic substances or absence of essential nutrients. According to Joel (1980) the mango fruit is characterized by resin ducts located in the exocarp which confer protection against two types of movements in the exocarp: the vertical movement of the ovipositor and larval movement. It is possible that a mechanism causes different degrees of susceptibility of the mango varieties to *A. obliqua.*

9.1.18. Papaya fruit fly

The papaya fruit fly, *Toxotrypana curvicauda* Gerstaecker, almost exclusively attacks papaya *(Carica papaya* L.) fruit (Knab and Yothers, 1914), but occasion- ally is found in mango (Weems, 1969). *Toxotrypana* occurs only in tropical America. The infestation of mango fruit probably occurs under forced oviposition in the absence of papaya (Pena, 1993).

9.1.19. Mango seed weevil

9.1.20. Occurrence and damage

The mango seed weevil, *Sternochetus mangifereae(F.)* (Coleoptera: Curculion. idae), is an important pest of mango. The flesh of ripe fruit is damaged when adults emerge from the seeds, and weevil-damaged seeds may limit plant propagation in nurseries and orchards (Johnson, 1989). Premature fruit drop may be caused by severe weevil infestations (Subramanian, 1925). The mango seed weevil occurs in India, throughout southeast Asia, Australia, on tropical Pacific Islands and in parts of Africa (Block and Kozuma, 1964; shukla and Tandom, 1985). The Americas were believed to be free of the mango weevil until recently, when it was found in the southern Caribbean region (Johnson. 1989). Quarantine restrictions have prevented the importation of fresh mangoes from infested areas.

The mango weev.il produces only a single generation per annum. The development period from egg to adult is c. 1-2 months (Subramanian, 1925; Shukla and Tandom, 1985). Adults become reproductively active when mango plants begin to flower, and the females randomly oviposit on developing mango fruit (Hansen *et at.*, 1989). Small marble-size fruits are preferred, but almost fully grown fruits may also be attacked. The eggs are laid in depressions along the fruit surface. After hatching, the larvae burrow through the pulp to the young, developing seed. Generally, only a single larva completes development in each fruit, but as many as five larvae have been found (Hansen *et at.*, 1989). Larval development occurs within the seed and only very rarely in the pulp. The larvae excavate cavities within the seed and pupate. Adults are formed 1 week later. However, adults generally emerge from the seed about 1 or 2 months after fruit drop (Balock and Kozuma, 1964). The weevils over season under bark and stone walls, where they remain dormant until the next flowering season (Van Dine, 1906; Balock and Kozuma, 1964; Shukla and Tandom, 1985). ,

9.1.21. Cultural control

Field sanitation, i.e. the removal of all fallen fruits and seeds, is very labour- intensive, and demands complete removal and disposal of fallen fruits from affected orchards. This procedure has been inconsistently effective for pest control. In India, field sanitation reduced infestation of S. *gravis* (F.) by only 22% (Dey and Pande, 1987). In Hawaii, field sanitation failed to reduce infestation rates significantly (Hansen and Amstrong, 1990).

9.1.22. Chemical control

Various insecticides have been evaluated for controlling adult weevils, particularly during the oviposition period (Balock and Kozuma, 1964; Shukla and Tandom, 1985). The most effective chemical was the organophosphate, fenthion, which reduced the infestation rate below 17%. In a different field test, the pyrethroid, deltamethrin, and the carbamate, carbaryl, were effective, both resulting in infestation rates below 15%. Spot application of diazinon on tree trunks was recommended based on cost, efficiency and least damage to the environment. I'

9.1.23. Resistant cultivars

Mango cultivars resistant to the mango weevil would be useful if they also had good agronomic characteristics. Resistant cultivars might include seedless selections, cultivars that form seeds early, and cultivars that fruit out of season. Most cultivars grown in Hawaii and India are equally susceptihle (Bagle and Prasad, 1984; Hansen *et at.*, 1989), although others, such as 'Itamaraca', have shown some resistance (Balock and Kozuma, 1964).

9.1.24. Biological control

The mango weevil has few natural enemies. Parasitoids are unknown, probahly because of the concealed nature of most of its life: stages. Adults may he susceptible to predation by ants, rodents, lizards and hirds (Hansen, 1993).

Red-banded mango caterpillar

9.1.25. Occurrence and life cycle

The red-handed mango caterpillar or mango seed horer, *Nozorda albizonalis* Hampson, is a serious pest in parts of southeast Asia and in Papua New Guinea. It attacks hoth mango and 'kuini' *(M. odorata)*, spoiling the fruit at various stages of development and sometimes causing heavy crop losses. Caterpillars bore, through the skin and flesh; however, they feed mostly on the seed.

Golez (1991), reported that the eggs of the mango seed borer are laid in masses on the fruit apex and hatch in 3-4 days, .the life cycle is complete in 28-41 : days. The five larval instars complete their development in 14-20 days. The pre-pupal and pupal stages develop in 2-3 and 9-14 days, respectively. The .adults survive for 8 or 9 days. The insect can develop in both pulp and seed of 'Carabao', but individuals reared on the pulp are relatively higger, more fecund and require more time for development. In the Philippines, infestation can occur as early as 45-55 days after flowering and continue up to fruit maturity; however, medium size fruit are preferred 75-85 days after fruit set. In the absence of mango fruit, adults fail to reproduce in other parts of mango or in other fruit species. Damaged fruits may be secondarily attacked hy fruit flies, i.e. *B.frauenfeldi*, and various decaying microorganisms. They fall prematurely even if apparently ripe and are unfit for human consumption.

9.1.26. Control

Fenner (1987) ohserved that effective control measures are unknown;. however, Golez (1991) reported that cyfluthrin and deltamethrin were effective for control. ling the mango seed horer.

Two species of parasitoids and one species of predator have been observed attacking immature stages of the seed borer in the Philippines (Golez, 1991).

Tricbogramma cbilonis and *T. cbilotraeae* were recorded as egg parasitoids. while a vespid, *Rbycbium attrisimum,* was 1dentified as an important larval predator.

9.1.27. Fruit spotting bugs

Nymphs and adults of *Amblypelta. lutescens lulescens(Distant)* and *A. nitida* Stal are native to Queensland, Australia and cause considerable damage by piercing and sucking the fruit (Cunningham, 1989). According to this author, the symptoms of damage are dark staining and cracking, often accompanied by sap exudation. The adult bugs are yellow-green and about 15 mm long. The pale- green eggs, about 2 mm long, are laid singly on foliage. There are five nymphal stages. A generation is completed in 34-38 days (Cunningham, 1989).

9.1.28. Blossom Pests

Midges, caterpillars, hoppers, thrips and mites are the most important pests attacking mango inflorescences.

9.1.29. Midges

9.1.30. Occurrence and damage

The mango gall midge or mango blister midge *Erosomya mangiferae* Felt, is a major pest, destroying flowers and up to 70% of set fruit. It was first described by Felt in 1911 from material collected in St Vincent (West Indies) (Whitwell. 1993). Barnes (1948) recognized nine gall midges from mango; two of these, *Asynapta mangiferaeand E. mangiferaeare* from the West Indies; Butani (1979) reported five cecidomyiid species on mango blossoms including *Erosomya indica. Das.v- neura mangiferae(Felt)* was reported in Hawaii (USDA. 1981). Cecidomyiideggs are normally laid in folds between sepals and petals of the flower buds. Larval feeding prevents flower opening and consequently development of the fruit does not occur. Infested buds develop as long' pointed galls, in which pupation occurs (USDA, 1981). Studies of population fluctuation of *Erosomya* sp. 'have been conducted in India by Grover (1986a), who reported that emergence of adults was higher at 24°C and 60-82% RH compared to lower temperatures and relative humidity.

9.1.31. Control

In a survey of parasitoids of cecidomyiid pests of mango in India, Grover (1996b) reported that *Platygaster* sp., *Systasis dasyneurae* and *Eupelmus* sp. were as- sociated with *Dasineurasp.,* and *Tetrastvchu* ssp. was associated with *Erosom.va indica.* An external parasitoid, the pteromalid, *Pirene* sp., was found attacking *procystiphora mangiferae.* Predators of the cecidomyiids include *Fonnicaisp., Oecophila* sp. and *Campanotus* sp.

9.1.32. Mango hoppers

Some 18 species of leaf hoppers that have been reported as pests of mango in the world are included' in Table 9.1. Of these, *Idioscopus clypealis* Leth., *I. niveosparsus* Leth., *I. magpurensis* Pruthi and *Amritodus atkiiYoni* Leth., are important pests of mango (Soomro *et al.,* 1987):

life cycle and damage

The females deposit their eggs in panicles or mid-ribs of tender leaves. The adults and nymphs preferentially feed on young leaves and flowers or shoots. During feeding, hoppers excrete honey dew upon which sooty mould develops. This interferes with photosynthesis, adversely affecting plant growth and yield. Affected inflorescences turn brown, become dehydrated and fruit set does nor occur.

There has been no systematic study of the biology of most of the leaf hoppers .that attack mango; however, biology of *A. atkinsoni, I. clypealis* and *I. niveosparsus* has been studied by Sohi and Sohi (1990). Both *A. atkinsoni* and *I. niveosparsusare* multivoltine. In *A. atkinsonithe* egg, nymphal (five instars) and adult stages required 7-9, 15-17 and 3-4 days, respectively (Patel *et al.,* 1977). Development from egg to adult is normally complete in 25-30 days. There can be between one and six generations in different areas of India. In Pakistan there .I are between four and five generations in the central Punjab (A.I. Mohyuddin, unpublished data, Rawalpindi, Pakistan, 1994). In the Philippines, *I. clypealisis* reported to have between one and four generations, whereas it has five to six generations in India.

Idioscopus nagpurensis is univoltine. In Pakistan, it normally oviposits in mango inflorescences during March. Nymphs feed on inflorescences during March and April. Formation of adults begins in the middle of April. From May to February of the following year only aestivating adults are found (A.I. Mohyuddin, unpublished data, Rawalpindi, Pakistan, 1994). Most of these species are quire fecund. *Amritodus atkinsoni* has been reported to lay 200 eggs during its lifetime (Rahman, 1940) and *I. ciypealis* lays 101-190 eggs in the Punjab (Hussain and Pruthi, 1924). *Idioscopus niveosparsus* lays c. 238 eggs on average in 9 weeks under laboratory conditions (A.I. Mohyuddin, unpublished data, Rawalpindi, Pakistan, 1994). Mohyuddin and Mahmood (1993) reported that *A. atkinsoniand I. niveosparsus* were found in upper portions of mango trees during different times of the year.

The biology of the cicadellid *Amrasca splendens* was studied under laboratory and in field conditions by Patil *e. al.,* (1992). The egg stage lasted an average 3.83 days. There were five nymphal instars and this stage lasted for 6-12 days. The total life cycle was completed in an average of 12-13 days.

9.1.33. Biological control

A number of natural enemies have been reported from west and southeast Asia. Mohyuddiri and Mahmood (1993) reported the egg parasitoids, *Gonatocentrus* sp., *Miurfenssp.* nr. *mangiferaeViggiani* and Hayar, *Centrodora* sp. *nr. scolypopae* Valentine, *Aprostocetus* sp. and *Quadrastichus* sp., and the adult ectoparasitoid *Epipyropsfuliginosa* Tames in Pakistan. Fasih and Srivastava (1990) reported that *Aprostocetussp., Gonatocerussp.* and *Poiynemasp.* parasitize eggs. Five species of predators, including *Chrysopa lacciperda* (Kimmins), *Mallada boninensis (Okomote), Bochaniasp.* and two unindentified species (one each of Mantidae and Lygaeidae) have been reported preying on nymphs (Fasih and

Srivastava, 1990). No effort has been attempted for classical biological control of mango hoppers. Whitwell (1993) reported four genera of parasitoids from Dominica, the commonest being *Aprostocetussp.*, followed by Plat *gaslersp.*, *Synopeas* sr. and *Zatropis* p. Two entomopathogens, *VeniciLlium Lecani* and *Beauveria bassiana* Balsamo (Vuillemin), have been reported infecting *I. clypealis* in India (Srivastava and Tahdon, 1986).

9.1.34. Chemical control

A number of pesticides have been tried for control of mango hoppers. Khanzada and Naqvi (1985),reported that six sprays of fenitrothion during the year were effective for controlling mango hoppers in Pakistan. Nachiappan and Baskaran (1986). tested eight insecticides, including phasalone, endosulphan, carbaryl, penthoate, fenitrothion, monocrotophos, quinalphos and phosphamidom. Endosulphan provided the best control when spraying was done 1 week after flowering and then 14 days later. Mohyuddin and Mahmood (1983) reported that Monitor applied to a height of 5 m on tree trunks and leaves in May provided control of mango hoppers.

9.1.35. Lepidoptera

The lepidopteran flower feeders are the second most important inflorescence , pests of mango. Geometrid, e.g. *Chloropteryxglauciptera* Hampson a,nd *Oxydia vesulia* (Cramer), infestation was reported in Dominica by Wllirwell (1993), Infestations increased during the flowering season, averaging three larvae/ inflorescence (87% infestation) to almost 100% infestation later in the flowering' season, Eggs of the noctuidae *Penicilla ria jocosatrix* Guenee are laid predominantly on or near the inflorescences or new leaves, According to Nafus *et al.* (1991) larvae survive better and develop more quickly on young leaves or on flowers than on old leaves. The microlepidoptera complex attacking mango in Florida consists of the species, *Pococera atramentalis* Lederer, *Pleuroprucha insulsaria(Guenee)*, *Platynota rostrana(Walker)*, *Tallulaspp.* and *Racheospila gerularia* (Hubner). Most of the damage to inflorescences is caused by *p, atramentalis* and *P. rostrana*. *Pococera atramentalis* is also a common pest of sorghum and various tropical fruit trees. larvae of both species feed on the axis of the inflorescence, petals and ovaries, and usually make nests among blossoms. Later in the flowering season dried fallen flowers are webbed together and fastened to a flower cluster to form a nest (Pena, 1993). The lepidopteran complex attacking mango flowers in Australia consists of several species from the families Geometridae, Lymanthridae, Noctuidae, Pyralidae and Tortricidae.

9.1.36. Chemical control

Schreiner (1987) reported that use of Dipel rtduced caterpillar damage, but careful monitoring or constant spraying was necessary to prevent significant, damage. Control with pesticides mostly not justified in Florida and Australia, but regular monitoring is needed for early detection of population increases (Cunninghum, 1989, Pena, 1993).

9.1.37. Biological control

Classical biological control of lepidopteran insects attacking mango in Dominica was initiated with the introduction of the wasps, *Aleiodes* sp. and *Euplectms* sp., and the fly *Blepharella lateralis* Macquart. Populations of the pest were reduced to 25% of prerelease levels; parasitization rates ranged from 20 to 99%, with *Euplectrnssp.* being the most abundant parasitoid (Nafus, 1991). The parasitoid *Macrocentrns* prob. *delicatus* attacks P. *atramentalis,* however, the parasitism rate is unknown (Pena, 1993).

9.1.38. Thrips

9.1.39. Life cycle and damage

The western flower thrips, *Frankliniella occidentalis* (Pergande) has IJeen reported to damage flowers and fruits in Israel (Wysoki *et al*, 1993). The developmental time of *F. occidentalis* from egg to egg at 25°C occurs between 14.80 to 16.65 days (van Lenteren *et al.*, 1995). The duration of development of *F. occidentalis* from egg to adult is closely related to environmental conditions, especially temperature. *Frankliniella* (possibly *cubensis)* is present in the mango flowers during the dry season in Costa Rica, requiring several applications or systemic insecticides (Jiron, 1993). In Florida, the thrips complex consisting of *Frankliniella bispinosa* (Morgan) and *F. kelliae* (Sakimura) is the most frequently observed blossom pest on flowers and causes damage by ovipositing in the panicle and feeding on the floral nectaries and anthers, which may result in premature loss of pollen. The biology of *F. bispinosa* has been reviewed by Watson (1917), whereas taxonomic characteristics of *F. kelliae* have been studied by Sakimura (1981). Thrips density is related to flower phonology and the prevalent dry season in Florida. Flower inspection for motile thrips is the common monitoring tactic, but aerial traps provide better detection. Pena (1993) suggested that the aerial trap method is superior to flower inspection, but because there is no method for determining the true population size, the aerial trap method cannot be proven to be an unbiased estimator. In India, Verghese *et al.* (1988) determined that the lower mango canopy was more suitable for sampling, and recommended a sample size of 55 panicles per tree for survey purposes.

9.1.40. Chemical control

Wysoki *et al.* (1993) reported that during the flowering season in Israel, a mixture of dichlorvos (0.15%w/v) and endosulphan 0.2% (w/v) is applied to control the thrips. Much more research is needed to determine economic injury levels and control measures that would not significantly reduce pollinators.

9.1.41. Biological control

Several parasitoids and predators, i.e. *Ceranisus menes* in Israel (Rubin and Kuslitzky, 1992) and the predators, *Oriussp., An.ystisagilisBanks* and *Hypoaspis* t *aculifer* (Canestrini) (Loomans *et al*, 1995) have been reported as potential I;' candidates for biological control of *F. occidentalis.*

9.1.42. Mirids

Adult and immature stages of *Daghbertus olivaceous, D.fasciatus* Reuter and *Rhinacloa* spp., can feed and oviposit in the mango panicle. The extent of damage is unknown, and should be considered a factor in flower loss (Pena, 1993).

Galls

Numerous galls formed by *Apsylla cistellata* (Buckt.) were observed by Chatterjee and Sebastian (1965) in India on mango inflorescencds. Adults of the cicadellids, *Chunrocerus niveosparsus* (Leth.) and *Idieoscopus clypealis* (Leth.), are present on foliage and stems of mango in the Philippines (Glass *et al,.1966)*. These cicadellids can also destroy inflorescences, and injury is mostly observed during the flowering periods.

9.1.43. Scarab beetles

Scarab beetles, *Macarespis tristis* and *Euphoria sepulcralis,* have been reported from the Caribbean Region and in Florida, respectively (Prinsley, 1986). Mango is the only recorded host for *M. tristis,* and heavy infestation can cause severe damage as the adults eat the ovarioles of the flowers and consume them completely in 2 days. *Macarespis* spp. is also considered an important pest of mango in Costa Rica (Jiron, 1993).

9.1.44. Pests of Leaves and Buds

Foliage feeders are one of the largest groups of injurious insects of mango throughout the world. Pests of mango buds and foliage may cause damage by reducing the photosynthetic area of the plant, thereby reducing the quantity of photosynthates translocated to the root and back to the fruit. The most destructive mango leaf feeders are thrips, midges, mites, scales, whiteflies, mealybugs, weevils, ants, locusts and caterpillars (Bhole *et al.*, 1987; Jadhav and Dalvi, 1987; Jhala *et al,* 1987;Tlgvattnanont, 1988; Jiron, 1993).

9.1.45. Thrips

The Mediterranean mango thrips, *Scirtothrips mangiferae* Priesner, is a severe pest of mango in Israel, causing the young leaves to curl along the mid-rib, distorting their shape, and leading to premature drop (Wysoki *et al.*, 1993). The twigs of infested shoots are much shorter than those of uninfested ones. The.population of the thrips is low during winter, increases in early spring and reaches its peak during summer in Israel (Wysoki *et al.*, 1993). Yellow sticky traps can be used for monitoring thrips densities. Ganz *et al.* (1990) established that an average population of ten Mediterranean mango thrips per young shoot was the threshold above which chemical control is required. Efficient control has been achieved by spray application of fluvalinate or acephate (Ganz *et al.*, 1990).

The red-banded thrips, *Selenothrips rnbrocinctus* (Giard) is an important pest of cacao in the Caribbean Islands and attacks mango and avocado in Australia, Florida and Hawaii. The adults feed on the underside of leaves, causing necrosis and subsequent leaf drop. According to Hill (1975), *S. rnbrocinctus* is only a pest in mango nurseries, and only rarely damages mature trees. Its biology was reviewed by Moznette (1922). Adult thrips are dark-bodit.-d with a red band on the first abdominal segment. The immature stages are light orange with abdominal segments 1 and 2 and the anal segments bright red. llle population of this species peaks during the dry season and declines during the rainy season. According to Yee (1987), the thrips are easily controlled by spraying malathion (25% v/w). The parasitoid *Goethana parvipennis* Gahan attacks *S. rnbrocinctusin* Puerto Rico (Bartlett, 1938).

9.1.46. Gall midge

Mango is attacked by different species of Cecidomyiidae in Asia and in the Caribbean region. Two genera, *Procontarinia* Kieffer and Cecconi. and *Erosomyia* Felt, are particularly associated with mango and all known species have been reared from mango (USDA, 1981; Harris and Schreiner, 1992). Prasad (1971) published a detailed account of the biology of the main species attacking mango in India. A new species of gall midge, *Procontarinia schreinen.* Harris, which attacks mango foliage in Guam, lays eggs on young mango leaves and larvae, which develop rapidly over c. 5 days forming blister galls. Secondary damage to infested foliage is caused by the fungus *Colletotrichum gloeosporioides Penz,* which invades damaged leaf tissue and causes anthracnose. Harris and Schreiner (1992) reported that the main factors affecting populations of this midge were rainfall and location. More galls are present during rainy periods, possibly because high RH improves larval and pupal survival.

9.1.47. Mites

9.1.48. Acerla manguiferae

9.1.49. Damage

The mango bud mite, *Aceria mangiferaeSayed* [*=Eriophyes mangiferae* (Sayc:d) is one of the most common pests of mango buds. Ochoa *et al.* (1994) reported that two types of symptoms are produced by A. mangiferae gall formation and damage to buds. When the buds are attacked and the fungus *Fusarium* sp. is absent, the result is hypertrophia with a proliferation of stems at the terminal branch. This symptom is known as witches broom. When *Fusarium* is present the trees develop floral and foliar galls. According to Ochoa, *et al.,* (1994) the interaction of A. *mangiferae* with the fungus results in rapid necrosis of the hypertrophia producing multiple budding and subsequent gall formation where flowers and leaves would normally occur. *Aceria mallgiferae* Sayed was first found in Florida in 1959 in malfoffiled inflorescences. It is considered hy Denmark (1983) and Orozco and Nunez (1988a, b) that this mite is an efficient vector of pathogens that cause malformation in mango; however, these authors have not found a consistent relationship between its presence and symptoms of the disorder. Their life history has been described by Abou-Awad (1981), who reported that the life cycle is completed in 15 days at 25-27°C.

9.1.50. Chemical control

Osman (1979) reported that application of four full coverage sprays of di(.'hlorvos was very effective for control of A. *mangiferae* in Egypt. Rai *et al.* (1966) cautioned that chemical control should he directed to apparently healthy and not to malformed tissues.

9.1.51. Biological control

The phytoseiid, *Amblyseius swirskii* Athias-Henriot, has been found associated with A. *mangiferae(Abou-Awad,1981).*

9.1.52. Tetranychidmites

The punctures of several acarines also cause serious damage to leaves, which may dry and fall. The main cell feeder in much of Asia, Mauritius, India, Egypt, Israel and Perl) is the Tetranychidae *Oligon;.vchus mangifenls* (Rahman and Sapra). In Australia, the tea spider mite *Oligoncbus coffeae* (Nietner) is considered an important pest (Cunningham, 1989). In Israel, the spider mite *Tetranycbus cinanabarinus* (Boisduyal) lives on the underside of leaves and its puncture:- cause oronzing. The adult life span of *O. mangiferus* is 9.11 days for females and 4.21 days for males (Rai *et al.*, 1988). The avocado red mites, *Oligonichus .yothel-si* McGregor and *O. punicae* (Hirst), feed on the upper surfaces of leaves and cause considerable leaf stipling around the mid-rib at high population densities (Andrews and Poe, 1980). If the mites are sufficiently abundant, the infested leaves may fall. Mite problems are probably exacerbated by the application of pesticides directed against other pests. The broad mite, *Polyphagotaronemus latus* (Banks) has been observed by Rhuele and Wolfenoarger (1948). Its symptoms include shoot proliferation, crinkling of the terminal leaves, rolling of the leaf margins, glazing Of the leaf surfaces and defoliation. Yee (1987) recommended applications of wettaole sulphur as an effective control.

9.1.53. Scales

9.1.54. Damage

Several diaspidids in the Western and Eastern hemisphere, i.e. Aulacaspis mangiferae(tubercularis) Newstead attack shoots and leaves as does the oleander scale in Florida (Denmark, 1983) and the mango scale in Ghana (van Halteren, 1970). They are damaging not only because they feed on sap, but also because of the toxicity of their saliva. Scales are found on the upper or lower surfaces of leaves and also on fruits. vao Halteren (1970) studied the development of A. mangiferae, and concluded that development is completed in 35-40 days for females and 23-28 days for males. Other species of Coccidae, Coccu viridis (Green), Pbilepbedra tuberculosa Nakahara and Gill and the mango shield scale Milviscutulus mangiferae in Asia, Africa, Australia, Israel and the Americas cause similar nuisance. These coccids are mobile and injure mango as a result of the production of honeydew and the,. subsequent growth of sooty mould on the honeydew (Escalante, 1974). Heavy infestation of mango shield scale results in reduced tree vigour, reduced leaf size, yellowish areas on the leaves, leaf drop, death of branches and of the whole tree (Wysoki *et al.*, 1993), Cunningham (1989) reported that Coccus spp. is attended by the green tea ant Oecopbylla smaragdina (Fabricius), which probably provides protection from parasites and predators.

9.1.55. Biological control

In a survey of mango producing areas in South Africa, Labuschagne (1993) determined that the predatory thrips Auleurodotbripsfasciapennis Franklin and the parasitoid Aspidiotipbagus citrinus are the most important biocontrol agents of A.

tubercularis. Several parasites have been recorded in Israel parasitizing the mango shield scale: Coccopbagus lycimnia (Walker), C. eritraensis Compere, C. scutellaris (Dalman), C. bivittatus (Compere), Microterys flavus (Howard) and Metapbicusflavus Howard. Usually no chemical control is required for this scale in Israel, due to the activity of natural enemies (Kfir and Rosen, 1980). Natural , enemies for the control of the pink wax scale Ceroplastes rnbens Maskell in Australia include the parasitic wasps Anicetus beneficus Ishii and Yasumatsu, Aenasioidea varia Girault and Rbopalenc.yrtoidea dubiaGirault (Cunningham, 1989).

9.1.56. White flies/black flies

In mangoes, the two fly species of economic importance are the whitefly, Aleurodicus dispersus and the blackfly, Aleurocantbus woglumi. The whiteflies suck cell sap from leaves, which wilt when whitefly populations are high. The honeydew excreted by the nymphs collects dust and supports the growth of sooty mould. High infestations can almost blacken entire trees reducing photosynthetic efficiency and causing defoliation (Angeles *et al.*, 1971; Pena, 1993). A number of parasitoids, i.e. Encarsia opulenta (Silvestri) and Amitus besperidus (Silvestri), attack the immature stages and provide good control.

9.1.57. Margarodid mealybug

9.1.58. Occurrence and dynamics

The margarodid mango mealybug Drossicha stebbingi (Green) is a serious pest of mango in India and Pakistan (Prassad and Singh 1976; Mohyuddin ahd Mahmood, 1993). It is univoltine. After mating, females enter the soil in June and die after laying eggs at a depth of up to 15 cm. These begin to hatch at the end of December or at the beginning of January. The nymphs emerge from the soil and move to tender shoots where they settle. Prasad and Singh (1976) reported that the intensity of attack varied from year to year and locality to locality in India, probably because of soil and environmental conditions. Moderate rainfall (55-60 mm) during oviposition and dry conditions during hatching appear to be favourable for development. Adults develop in April. They mate, and males die soon afterward. The females enter the soil in May for oviposition, and the diapausing eggs renlain in the soil until the end of December.

9.1.59. Control

Various control methods, including banding tree trunks with various materials to prevent nymphs from climbing (Lakra *et al.*, 1980; Srivastava, 1980) and dusting chlorinated hydrocarbons on the soil (Srivastava, 1981) haveb,een tried with little success. In Pakistan the mango mealybug was controlled by hoeing or ploughing the soil and conservation of the predator, Sumnius renardi Weise by wrapping burlap around the trunks of the trees (Mohyuddin and Mahmood 1993).

9.1.60. Pseudococcid mealybugs

The pseudococcid fruit tree mealybug, Rastrococcus invadens Williams, is a serious pest of several crops, including mango. It has become a: serious pest of mango in West Africa (Agounke *et al.*, 1988). Mealybugs feed on leaves and fruits. Females have three moults and males have four moults. The entire life cycle can be completed in 31-84 days. The mealybugs weaken plants by puncturing the tissues and consuming sap, hut the major damage is caused by the production of large amounts of honeydew upon which saprophitic fungi develop. The resultant thick black layer of sooty mould causes a drastic reduction in photo- synthetic efficiency, resulting in premature leaf drop. Rastrococcus invadens severely reduces fruit production in some areas of Africa (Moore and Cross, 1993) Boavida *et al.* (1992) devised sampling plans for R. invadens, but advised that the sampling strategy was only practical for estimating medium to high mealybug populations in the field. Moore and Cross (1992) also reported that the parasitoid Gyranusoidea tebygi Noyes, introduced into West Africa, is providing excellent control of this pest.

The pseudococcid Rastrococcus spinous (Robinson) has become a sc.:riulis , pest of mango in southern Pakistan (Mahmood *et al.*, 1980) and in the Philippines (Morrill and Otanes, 1947). It was initially confined to coastal areas of Pakistan, but has spread to subcoastal areas. On mango, the males complete their development in 28-32 days and females in 30-32 days. Natural enemies of this mealybug have been reported by Mahmood *et al.* (1980) from Pakistan.

9.1.61. Weevils

The citrus weevils (Coleoptera: Curculionidae) are the only recorded coleopteran pests of mango foliage in the Caribbean region (Murray, 1991). They have been reported to occur in all islands, and at least seven genera with no fewer than 114 species have been listed by Woodruff (1985). Pachneus citriMarshall, the citrus root weevil, has been reported in Jamaica, while P. litusGermar has beenn found in Cuba (van Whervin, 1968; FAO, 1989). Adults are small and uniformly light blue or bluish green (van Whervin, 1968). The larvae, however, can cause extensive damage to the roots. Other weevils include Diaprepes abbreviatus L., D. ballouiMarshall, *D.famelicusOlivier* (FAO, 1989). The mango leaf-cutting weevil, *Deporaus marginatus* Pascoe, feeds on the epidernlis or young leaves, causing browning and death of leaves in Thailand (Tigvattnannunt, 1988). The females excavate small cavities on either side of the mid-rib of the leaves and deposit one egg in each cavity. Its life span is 20.83-71.80 days (Tigvattnannont, 1988).

9.1.62. Ants

Ant species, *Atta insularis, A. sexdens* L. and *Acromyrmex octospinosus* Reich, bave been reported to attack mango in the Caribbean region (FAO, 1989). They are known by the adult foragers' peculiar habit of cutting semi-circular pieces of living leaf and carrying them back to their nest. The leaf pieces are not eaten directly; but they are used to cultivate a fungus which is consumed by the colony (Hill, 1975). Because of the feeding habits of these insects and their colonial life styles, control should be aimed at destruction of the nest population (Jiron, 1993). This is achieved by using attractive poisoned baits (Pollard, 1982).

9.1.63. Pests of Trunk and Twigs

Stem boring Coleoptera and scales as a group of injurious mango insects have not been studied in great detail. The wide host range of borers and overlapping borer species has complicated their study. Tunnelling of borer larvae in branches and trunks of mango and the slow feeding of some scale species in certain seasons and regions may cause serious reductions in yields and might also contribute to mango decline. However, borer occurrence and injury tends to be sporadic and below levels requiring direct action. Few natural enemies have been reported for suppression of borer populations in mango. Detailed coverage of stem boring species is beyond the scope of this chapter; however, *Morganella longispina, Hypocrypbalus mangiferae, Apate monabusand Batocera* rubusare pests in this group.

9.1.64. Scales

Infestations of the mango scale, *Radionaspis indica,* and plumose scale, *Morganella longispina,* commonly occur on the trunk, branches and buds. Severe infestations can include cracking of the bark, exudation of sap and decline of the upper branches. Pena (1993) demonstrated that branches with both species of scale showed more decline symptoms than branches with low scale density. Research on the bionomics and control of these scales is necessary to confirm the role of these scales in mango decline symptomatology.

9.1.65. Beetles

The scolytids, *Hypocrypbalus mangiferae* (Stebbing) and *Xylosandrus compactus* (Eichoff), directly attack the main stem and branches (Silveira, 1960; Wolfen- barger, 1963). Fungus mycelium growth can extend terminally and basally from the beetle gallery in the mango tree and can kill the affected branches. The insects prefer trees that have been weakened by pathogens, wind, etc., but after a population has been established in one grove the infestation spreads to healthy trees. Scolytid beetles are attracted to mango trees in response to visual stimuli, to host-specific chemicals and to species-specific aggregation pheromones (Lind-green *et al.*, 1982). The evaluation of traps as tools for managing ambrosia beetles on mangoes in Florida is necessary in order to reduce their damage in newly established groves.

The cerambycids, *Batocera rubus* (L.) and *Indarbela quadrinotata* (Wlk.), are major borer pests of mango in India (Butani and Bajpai, 1965). The eggs of *B. rubus* are laid singly in crevices on the main stem or under loose bark, and hatch in 1-2 weeks. The larvae bore deeply into the main stem and branches, which in severe cases can kill the tree. Pupation takes place within the branches, from which the adults emerge after 6 months. The best control method is to cut away and bum the infested parts (Buttani and Bajpai, 1965). Buttani and Bajpai (1965) also describe the behaviour of *I. quadridentata,* a borer that feeds initially on the bark and then bores into the wood, thereby inhibiting sap flow. Tree growth and fruiting capacity are affected negatively. A mixture of carbon bisulphide and chloroform placed in the entrance hole has been recommended for control.

Black borers, *Apate monacbus* Boll. (Coleoptera: Bostrichidae), are black cylindrical beetles that are common in the Caribbean Islands, and are pests of mango branches (Murray, 1991). Their biology has been described by Le Pelley (1968). The presence of these beetles is indicated by the accumulation of fine dust at the base of affected trees (Murray, 1991). Hill (1975) recommended plugging the tunnels with cotton wool soaked with insecticide for. effective control. Le Pelley

(1968) emphasized the importance of field sanitation, prompt removal and burning of dead wood and collection of adults early in the morning.

9.1.66. Conclusions

Current mango pest management practices are affected not only by the domestic and export fruit market, but also by consumer attitudes toward health concerns and the cosmetic appearance of the fruit. In general, mango pest management is .largely dependent on the use of pesticides (Shaw, 1961; Balock and Kozuma 1964; Nachiappan and Baskaran, 1986b; Golez, 1991; Pena, 1993). Control of mango fruit pests by chemicals alone has been complicated by development of pest resistance and resurgence and elevation of minor pests to major pest status (Cunningham, 1989). Costs of pest control have mounted and in some cases increasing amounts of pesticides are required to keep the large number of pest species under control.

Mango is a perennial species offering continuity of habitat for both pests and natural enemies with some degree of stability. The potential for utilizing biological control agents is generally more efficacious in long-term than in short -term crops, and probably better in tropical and subtropical crops than in temperate crops. However, the extensive use of broad spectrum pesticides, e.g. dieldrin, largely overcomes any advantages of these factors and leads to the instability of pest populations.

Several fungal diseases occur in mango; these can require repeated applications of fungicides for control- of disease. Attempts to develop integrated pest management programmes for mango must take into account the effects of cultural control practices, horticultural sprays and disease control on pest and natural enemy interactions.

Mango as an export fruit has a relatively high value, and the highest prices are paid for undamaged, high quality fruit. On the other hand, mangoes grown for domestic consumption in many tropical countries have low values. For these reasons, the economic thresholds of those pests which attack the fruit will be low for export fruit and quite high for fruit destined for internal consumption. The foundation of integrated pest management as presented by Flint and van den Bosch (1981) is based on sampling, economic thresholds and natural mortality in agroecosystems.

Sampling techniques for mango pests have been described by Anonymous (1987), Boavida *et at.* (1992), Cunningham (1989), Kumar *et at.* (1993), Pena (1993) and Wysokl 0993); however, for some pests, adequate sampling techniques are not available. This is particularly true for pests like scales, stem borers and lepidopteran flower feeders. The sampling methods for fruit feeding pests, i.e. blossom thrips and mealybugs, provide the necessary information for pest management decisions. A major problem is being able to relate the results of sampling to infestation of the fruit at harvest. It is difficult to establish economic thresholds for species that attack foliage or flowers. On the other hand, it is relatively simple to assess damage due to fruit feeders at the time of harvest.

9.1.67. Tactics for integrated pest management

9.1.68. Selective chemicals

Pesticides that are used in integrated pest management programmes must have selective toxicity. The current trend is the development of chemicals that are highly effective for a limited group of insects. Diaz *et al.* (1995) suggested the use of cyromazineas. a means to reduce fertility of A. *obliqua*. Cunningham (1989) suggested that oils could be utilized for control of scales in mango; however, most of the recommendations from other countries are based on highly toxic or illegal, non-registered persistent chemicals (Singh, 1991).

9.1.69. Biological control

Biological control has great potential as a tactic for regulating pest populations in integrated pest management programmes in mango orchards; however, it will be difficult for biological control alone to reduce a pest from an economic to a completely non-economic status for pests attacking fruit. A combination of augmentative releases of parasitoids and the use of sterile insects at least from a theoretical perspective has been considered to be more effective for fruit flies than either method applied alone (Barclay, 1987). Biological control should be highly effective for indirect pests. Indeed. numerous studies have been con- ducted in many mango producing countries to promote the use of parasites and predators for this type of pest (Cunningham, 1989; Mohyuddin and Mahmood, 1993; Moore and Cross, 1993; Whitwell, 1993; Wysoki *et al.*, 1993)

9.1.70. Host plant resistance

Tolerance of mango to pests is mentioned for *Saissetia mangiferae, Noorda* sp., arid *Idioscopus* sp. (Bagle and Prasad, 1984; Cunningham, 1989), while mango resistance to *C. mangiferaeis* mentioned by Hansen(1993). Carvalho *et al.* (1995) has also demonstrated the different degrees of susceptibility of mango cultivars to A. *obliqua*. Most of this research, however, needs to be assessed further. Angeles (199.1) reported that *Mangijera altissima* does not seem to be affected by mango pests, i.e. leafhoppers, tip borers and seed borers, in the Philippines. There is little doubt that wild mangoes have potential value in breeding. Deter- mining the tolerance or insect resistance of mango cultivars and related species should be done in natural stands or in established germplasm collections. When the initial selection has been done the entomologist must obtain evidence of the pattern of resistance and verify that changes in the environment, whether geographical *or* temporal, should not disrupt or decrease the resistance to any great extent. Therefore, tests for resistance in mango to insects should include provision for exposure to insect under varying conditions whenever possible.

9.1.71. Pheromones and trapping devices

Recent developments in the identification and synthesis of sex pheromones have' resulted in their possible use for pest management in mango orchards. Food attractants, however, are the most common monitoring tools. Trapping techniques can be utilized to reduce pesticide use by improving timing of sprays as a result of better monitoring of pest populations. It remains uncertain if trapping techniques can be used to predict infestations by fruit feeding pests and if they can be used for direct control (by mass trapping) over several years.

The evolution of research concerning pest colltrol in mango during the past few decades, from the unilateral use of pesticides to integrated control is occurring out of necessity. Greatly increased regulation of pesticides, heightened public awareness of environmental contamination, pesticide resistance problems

.in pests and the high cost of chemical pest control has resulted in increasing reliance on integrated pest control as an important strategy in sustainable agriculture. Integrated insect control programmes on mango is inadequate for many pests, due to of inadequate sampling techniques (the inability to relate the results of sampling to levels of damage in many cases) and the absence of sound economic injury levels.

Research concerned with mango pest problems usually has involved the study of single pests in isolation. Cooperation among plant physiologists, plant pathologists and economists is necessary to develop truly comprehensive integrated control programmes based on sound cost-benefit relationships.

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9.1.73. References

Abou-Awad, B. (1981) Ecological and biological studies on the mango bud mite, *Eriophyes mangiferae* (Sayed), with description of immature stages (Eriophyoidea: Eriophy. idae). *Acarologia* 22, 145-150.

Abreu, E., Medina-Galld, S., Maldonado, J., Medina, S. and Maldonado.J. (1987) New , records of mites for Puerto Rico. *Journal of the Agricultural University of Puerto Rico* 71, 399-402.

Agounke, D., Agricola, U. and Bokonon-Ganta, H. (1988) *Rastrococcus invadells Williams* (Hemiptera: Pseudococcidae), a serious exotic pest of fruit trees and other plants in West Africa. *Bulletin of Entomological Research* 78,695-702.

Aluja, M. (1994) Bionomics and management of *Anastrepha*. Annual Review of Entomology 39,155-178.

Aluja, M., Cabrera, M., Guillen, .T., Celedonio, H. and Agora, F. (1989) Behavior of J' *Anastrepha ludens, A. obliqua* and *A. setpentina* (Diptera: Tephritidae) on wild mango tree *(Mangifera indica)* harbouring three McPhail traps. *Insect Science and its 4Pplication* 10, 309-318.

Andrews, K. and Poe, S. (1980) Spider mites of El Salvador, Central America (Acari: Tetranychidae). *Florida Entomologist* 63, 502-505.

Angeles, D.E. (1991) *Mangifera atL,sima* In: Coronel, R.E. and Verheij, E.W.M. (eds) *Edible Fruits and Nuts, Plant Resources of South East Asia* 2. Pudoc, Wageningen, pp. 206-207.

Angeles, N. and Requena, J. (1966) Moth injury of mangoes in Venezuela. *Plant Protection Bulletin, FAO* 14, 86-87.

Angeles, N., Dedordy, N., Paredes, P. and Requena, J. (1971) Citrus blackfly in Venezuela. *Agronomia Tropical* 21, 71;-75.

Anonymous (1989) *Mango Pests and Disorders. Information Series QI89007.* Queensland Department of Primary Industries, Brisbane, Queensland.

Anonymous (1987) Red-banded Mango Catetpillar Noorda albizonalis Hampsoni (Lepidoptera: Pyralidae). Plant Quarantine Leaflet. Australia No. 51.

Bagle, B. and Prasad, V. (1984) Varietal incidence and control of stone weevil *Sternochetus mangiferae Fabricius*. Indian Journal of Entomology 46, 389-392.

Bagshaw, J., Brown, B., Cooke, T., Cunningham, I. Johnson, G., Moyers, P. and Muirhead, I. (1989) *Mango pests and disorders, QI89007:* Queensland Department of Primary Industries, Brisbane, Queensland.

Balock,J.W. and Kozuma, T. (1964) Notes on the biology and economic importance of the mango weevil, *Sternochetus mangiferae* (Fabricius), in Hawaii (Coleoptera: Curculionidae). *Proceedings of the Hawaiian Entomological Society* 18,353-364.

Balock, J. and Lopez, D.F. (1969) Trapping for control of the Mexican fruit fly in mango and citrus groves. *Journal of Economic Entomology* 62, 53-56.

Barclay, H.J. (1987) Models for pest control: complementary effects of periodic releases of sterile pests and parasitoids. *7heoretical Population Biology* 32, 76-89.

Barnes, H,F. (1948) *Gall Midges of1:conomic Importance, vol. 3: Gall Midges of Fruit.* Crosby Lockwood, London.

Bartlet, K. (1938). *The Introduction and Colonization in Puerto Rico of Das.yscapus parvipennisGahan, a Parasite of7brips. Agricultural, Votes. Puerto Rico of Experiment Station.* United States Department of Agriculture No. 87.

Bateman, M.A. (1972) The ecology of fruit flies. *Annual Review of 1:ntomology* 17, 493-518.

Beardsley, J.W. (1.961) A new review of the Hawaiian Braconidae.(Hymenoptera). *Proceedings of the Hawaiian Entomological Society* 27, 333-366.

Bess, H.A., van den Bosch, R. and Haramoto, F.H. (I961) Fruit fly parasites and their activities in Hawaii. *Proceedings of the Hawaiian Entomological Society* 27. 367-378.

Bhole, S., Jadhav, V., Oumbre, R. and Oalvi, C. (1987) Seasonal incidence and chemical control of mango nursery pests in the Konkan region. *joufllal of Maharashtra Agricultural University* 12,387-388.

Boavida, C., Neuenschwander, P. and Schulthess, F. (1992) Spatial distributipn of *Rastrococcus invadends* Williams (Homoptera: Pseudococcidae) in mango trees. *Journal of Applied Entomology* I14,381-391.

Butani, O.K. (1979) *Insects and Fruits*. Periodical Expert Book Agency, Delhi.

Butani, D. and Bajpai, P. (1965) The destructive borers of fruit crops. *Indian Horticulture* April-June 1965, 1 pp.

Cabrera. H., Villanueva; J. and Ortega, D. (1993) Fruit fly infestation timing on 'Manila' mango fruit at Veracruz, Mexico. *IV International Mango symposium* p. 118 (abstract).

Carvalho, R. da S., Nascimento, A., Morgante, J. and Fonseca N. (1996) Susceptibility of different mango varieties to the attack of the fruit fly, *Anastrepha obliqua. In:* McPheron, B. and Steck, G. (eds) *Fro it Fly Pests: A World Assessment of their Biolog. and Management*. St Lucie Press, Delray Beach, pp. 325-331.

Chatterjee, P .N. and Sebastian, V. (1965) Inhibition of inflorescences of *Mangifera indica* L. by the gall-forming Psyllid, *Apsylla cistellata* (psyllidae: Homoptera). *Indian Forester 91*, 228-229.

Christenson, L.D. and Foote, R.H. (1960) Biology of fruit flies. *Annual Review of Entomology5*, 171-192.

Clancy, D , Marucci, P. and Dresner, E.(1952) Importation of natural enemies to control oriental fruit fly in Hawaii. *Journal of Economic Entomology* 45, 85-90.

Cunningham, I.C. (1984) Mango insect pests. *Australian Mango Research Workshop*. CSIRO, Melbourne, pp. 211-224.

Dakshinamurthy, A. (1984) The mango hopper and its control in Tripura. *Pesticides 18*. 13-14.

Dater, V.V. (1985) Synthetic pyrethroids in the control of mango hoppers *(Amritodus atkinsoni* Leth.). Pesticides 19,13-14.

Denmark. H. (1983) *Erioph.ves mangiferae (Sayed) a Pest of Mango (Acarina Eriophyidae). Entomology Circular. Florida Department of Agriculture and Consumer Services, Florida.*

Dey, K. and Pande, Y. D. (1987) Evaluation of certain non insecticidal methods of reducing infestation of the mango nut weevil. *Stenlochetus gravis* (F.) in India. *Tropical Pest Management* 33, 27-28.

Diakonoff, A. (1977) Tortricidae and Choreutidae from Reunion (Lepidoptera). *Anales Societe Entomologique de France* 13, 101-116.

Diaz, F., Toledo, J., Enkerlin, W. and Fernandez,J. (1996). Cyromazine: effects on three species of *Anastrepha. In:* McPheron, B. and Steck. G. (eds) *Fruit Fly Pests: a Warld Assessment of their Biology and Management.* St Lucie Press, Delray Beacl1, pp. 336- 337.

Escalante, J.A. (1974) Insects of economic importance in Quillabamba, Cusco. *Revista Peroana de Entomologia* 17, 51-53.

Etienne. J. (1966) Lune contre les mouches des fruits. *Institute Recherches Agronomiques Tropicales Reunion.* pp. 112-113.

Etienne. J. (1968) Lutte contre les mouches des fruits. *Rappolle de Institut de Recherchers Agronomiques Tropicales, Reunion.* pp. 117-124.

Fasih. M. and Sristava, R.P. (1990) Parasites and predators of insects pests of mango. *International Pest Control* 32, 39-41.

Fenner. T.L. (1987) Red banded mango caterpillar. *CDPI. Plant Quarantine Service.* Darwin. Australia.

Flint, M.L. and van den Bosch, R. (1981) *Introduction to Pest Management.* Plenum Press, New York.

Food Agriculture Organization (FAO). (1989) *Plant Pests of Economic Importance. Reported in the Region Covered by the Carihbean Plant Protection Commission. PROVEG-22.* FAO Regional Office for Latin America and the Caribbean, Santiago.

Galan-Sauco, V. (1990) *Los Frutales Tropicales en los Subtropicos.* Ediciones MundiPrena. Madrid, pp. 83-84.

Ganz, S., Hamieri, Y. and Nakach, Y. (1990) Control trials on the mango thrips. *Annual Report of the Eden Experiment Station.* Israel.

Glass, E.H., Reyes, S. and Calora, F. (1966) Note's on the biology of three leafhoppers on mango. *Philippine Agriculture* 50,739-743.

Golez, H.G. (1991) Bionomics and control of the mango seed borer, *Noorda albizonalis* Hampson (pyralidae: Lepidoptera). *Acta Horticulture* 291,418-424.

Grover, P. (1985) Protection of mango crop against newly discovered midge pests. *Cecidologia International* 6, 35-40.

Grover, P. (1986a) Integrated control of midge pests. *Cecidologia Internationale 7,* 1-28.

Grover, P. (1986b) Population fluctuation of *Erosomya indica* and *Dasineuraamaramanjarae* and corelated extent of damage. *Cecidologia Internationale* 7, 43-57.

Gupta, B.P. and Singh, Y.P. (1986) New record of *Orgya postica* Walker, as pest of mango. *Progressive Horticulture* 18, 3-4.

Hansen, J.*D.* (1993) Dynamics and control of the mango seed weevil. *Acta Honiculturae* 341,415-420.

Hansen, J. D. and Amstrong, J. W. (1990) The failure of field sanitation to reduce lnfestation by the mango nut weevil, *Cryptorhynchus mangiferae* (F.) (Coleoptera: Curculionidae). *Tropical Pest Management* 36, 359-361.

Hansen, J.D., Armstrong, J. and Brown, S. (1989) The distribution of the mango weevil, *Cryptorhynchus mangiferae* (Coleoptera: Curculionidae), in Hawaii. *Proceedings of the Hawaii Entomological Society* 29, 31-39.

Harris, K.M. and Schreiner, I.H. (1992) A new species of the gall midge (Diptera: Cecidomyiidae) attacking mango foliage in Guam, with observations qn its pest status and biology. *Bulletin of Entomological Research* 82, 41-48.

Herrera, A.J. and Vinas, L.E. (1977) Fruit flies (Diptera: Tephritidae) on mangoes in Chulucanas, Piura. *Revista Pernana* de *Entomologia* 20, 107-114.

Hill, D. (1975) Agricultural Insect Pests of the Tropics and their 'Control. Cambridge ,University Press, New York.

Husain, M.A. and Pruthi, H.S. (1924) A short note on the life history of the mango hopper *(Idiocerus* spp.*)* in the Punjab. *Report Proceedings of the Vtb Entomological Meeting*. Pusa, India, pp. 252-260.

Iwahashi, O. (1984) The control project of the oriental fruit fly in Okinawa. *Chinese Journal of Entomology 4,* 107-120 (in Chinese).

Jadhav, V. and Dalvi, C. (1987) Bionomics of mango nursery leaf eating caterpillar *.Journal of Maharashtra Agricultural University* 12, 384-385.

Jhala, R.C., Patel, Z. and Shah, A. (1987) Studies on the relative occurrence of the leaf-gall midge *(Procontannia matteiana* Keiffer and Cecconi) on different varieties of mango in south Gujarat, India. *7'ropical Pest Management* 33, 277-279.

Jiron, L.F. (1992) Mango fruit flies: sampling and management. *IV International Mango Symposium,* Miami Beach, Florida, 5-10 July 1992, p. 121 (Abstract).

Jiron, L.F. (1993) Plagas del follaje y de paniculas asociadas con el mango en Costa Rica. *Memorias I Seminario Nacional del Cultivo dell Mango*. Punta Arenas, Costa Rica, pp. 22-26.

Jiron, L.F. (1995) Opciones al uso de insecticidas en mango. In: Garcia, J., Fuentes, G. and Monge, *J.* (eds) *Opciones* al *(Iso Unilateral de Plaguicidas* en *Cosıa Rica.* Editorial Euned, San *Jose* 2, 129-155.

Jiron, L.F. and Hedstrom, I. (1988) Occurrence of fruit flies of the genera *Anastrephaand Ceratitis* (Diptera Tephritidae), and their host plant availability. Florida *Entomologist* 71,62-73. Ii

Jiron, L.F. and Hedstrom, I. (1991) Population fluctuations of economic species of *Anastrepha* (Diptera: Tephritidae) related to mango fruiting phenology in Costa Rica. *Florida Entomologist* 14, 98,-105.

Joel, D.M. (1980) Resin ducts in the mango fruit: a defense system. *Journal of Experimental, Botany* 30, 1707-1718.

Johnson, PJ. (1989) Mango Seed Weevil (Sternochetus mangiferae F.J: Identification, Biology and Management. University of Idaho, Boise, Idaho, pp. 6, 3-7.

Kfir, R. and Rosen, D. (1980) Parasites of soft scales (Homoptera: Coccidae) in Israel: an annotated list. Journal *of the Entomological Society of South Africa* 43, 113-128.

Khanzada, A.G. and Naqvi, K.M. (1985) The optimum time for the control of mango hopper *Idioscopus* spp. (Hemiptera: Cicadellidae). *Proceedings Entomological Society Karachi* 14/15, 149-156.

Knab, F. and Yothers, W. (1914) Papaya fruit fly. *Journal of Agricultural Research* 2,:447-453.

Kumar, S., Rai, A. Patel, C. and Bhatl, R. (1993) Studies on spatial distribution of *Amritodes atkinsoni* (Leth.) infesting mango in south Gujarat, India. *IVth International Mango symposium* p. 122 (Abstract).

Labuschagne, T.I. (1993) Progress with integrated control of the mango scale *Aulacaspis tubercularis* Newstead. *South Africa Mango Growers' Association Yearbook* 13, 134-135.

Lakra, R.K:, Kharub, W. and Singh, Z. (1980) Pest management systems for the mango mealybug *Drosicha mangifera* Green -A polyphagous pest of fruit trees in Haryana. *Indian Journal of Entomology* 42, 153-165.

Laroussilhe, F. de (1980) *le Manguier:* GP Maisonneuve and Larose, Paris. Le Pelley, R.H. (1968) *Pests of Coffee.* London, Longmans.

Leyva, JJ.L., Browning, H. and Gilstrap, F. (1991) Development of *Anastrepha ludens* (Diptera: Tephritidae) in several host fruit. *Environmental Entomology* 20, 1160-1165.

Lindgreen, S., Borden,J., Gray, D., Lee, P., Palmer, D. and Chong, L. (1982) Evaluation of two trap log techniques for ambrosia beetles (Coleoptera: Scolytidae) in timhe.r processing areas. *Journal of Economic Entomology* 75, 577-586.

Loomans, AJ.M. and van Lenteren,J.C. (1995) Biological control of thrips pests: a review on thrips parasitoids. *Wageningen Agricultural University Papers* 95.1, 92-95.

Lopez, F., Chambers, D., Sanchez, M. and Kamasaki, H. (1969) Control ()f the Mexican fruit fly by bait sprays concentrated at discrete locations. Journal *of Economic Entomology 62,* .1255-1257.

Mahmood, R., Mohyliddin, I. and Kazimi, S. (1980) *Rastrococcus spinosus* (Robinson) (Homoptera: Pseudococcidae) and its natural enemies in Pakistan; *Proceding.lst Pakistan Congress of Zoology.* Tandojam, pp. 291-294.

Malavasi, A. and Morgante, J. (1980) Biology of fruit flies (Diptera: Tephritidae). II Infestation indices in different food plants and localities. *Revista Brasileira de Biologia* 40, 17-24.

McPheron, B.A. and Steck, G. (1996) *Fruit Fly Pests: A Mould Assessment of their Biology and Management.* St. Lucie Press, Delray Beach, 587 pp.

McPherson, J .E. (1977) The first record of occurrence of *symbilus caribbeanus* (Hemiptera: Scutelleridae) in Texas. *Journal of the Kansas Entomological Society* 50, 529- 530.

Medina-Gaud, S. and Garcia,J. (1977) New arthropod records for Puerto *Rico. Journal of the Agriculture University of Pue110 Rico* 61,409-412.

Mohanasundaram, M. and Muniappan, R. (1988) A new mango bud mite, *Keiferophyes guamamenst's* sp. nov. (Eriophyidae: Acari) from Guam. *International Journal of Acarology* 14, 53-55.

Mohyuddin, A.1. (.1981) A review of biological control in Pakistan. Proceedings 2nd Pakistan Congress of Zoology Tandojam, 31-79.

Mohyuddin, A.I. and Mahmood, R. (1993) Integrated control of mango pests in Pakistan. *Acta Horticulturae,* 341, 467-483.

Moore, D. and Cross, A.E. (1992) Competition between two primary parasitoids, *Gyranu- soidea tebygi Noyes and Anagyrus mangicola Noyes,* attacking the mealybug *Raslrococcus invadens* Williams and the influence of a hyperparasitoid *G'hall ocerus hyalipennis Hayat. Biocontrol Science and Technology 2, 225-234.*

Moore, D. and Cross, A. (1993) Biological control of the fruit tree mealybug, *Rastrococcus invadens*. Williams; single or multiple introduction. *Acta Holliculturae* 341, 433-440.

Morin, C. (1967) Cultivo de frutales tropicales. *LibreriasABC* Lima, Peru, pp. 225-229. Morrill, A.W. and Otanes, F.Q. (1947) DOT emulsion to control mealybugs and scales. Journal *of Economic Entomology 40, 599-600.*

Mosquera, F. (1.979) The genus *Ceroplastes* (Homoptera: Coccidae) in Colombia. *Caldasia* 60, 595-627.

Moznette, G. (192.2) Insects injurious to the mango in Florida and how to combat them. *Fanners Bullelin* 1257.

Murray, R.C. (1991) Arthropod pests of mango in the Caribbean Islands. *Review Paper, ' Crop Protection.* University of West Indies, Kingston.

Nachiappan, R.M. and Baskaran, P. (1986a) 'Quantum of feeding and survival of mango leaf-hopper adults on the inflorescences of certain varieties of mango. *Indian Journal of Agricultural Science* 54,312-314.

Nachiappan, R.M. and Baskaran, P. (1986b) Field evaluation of certain insecticidal sprays against mango leaf-hoppers. *Pesticides* 20, 41-44.

Nafus, D. (1991) Biological control of *Pen icilllaria jocosatrix* I(Lepidoptera: Noctuidae) on mango on Guam with notes on the biology of its parasitoids; *Environmental Entomology* 20, 1725-1731.

Nafus, D., Schreiner, I. and Dumaliang, N. (1991) Survival and development of the mango shoot caterpillar (Lepidoptera; Noctuidae) in relation to leaf age, host, and distribution on the host in tropical Anacardiacea. *EnvironmentalEnlomology 20,* 1619-1626.

Nascimento, A., Malavasi, A., Morgante, J. and Duarte, A.L. (1992) Hot-water immersion treatment for mango infested with Anastrepha fraterculus, A. obliqua, and Ceraliti capitata (Diptera: Tephritidae) in Brazil. Journal of Economic Entomology 85, 456-460.

Ochoa, R., Aguilar, H. and Vargas, C. (1994) Phytophagous mites of Central America: an illustrated guide. *Centro Agronom ico de Investigacion y EnsenanzaJ Technical Series* 6. Turrialba, Costa Rica.

Orozco, M. and Nunez, R. (1988a) AchaparrariIiento, un desorden del mango en el estado de Colima. *Rellisla Mexicana de Fitopalologia* 6, 131-136.

Orozco, M. and Nunez, R. (1988b) Distribucion-y control quimico defacaro de las yemas del mango *Eriophyes mangiferae* Sayed (Acarina: Eriophyidae) en Colima. *Resu- menes XXIII Congreso Nacional de E:ntomologia.* Morelia, Mexico, p. 72 (abstract).

Osman, A.A. (1979) Notes on the control of the bud mite *Aceria mangiferae* (Sayed) in Egypt (Acarine: Eriophyidae). Bulletin of the Entomological Society of Egypt. Economic Series 9. pp. 119-126.

Patel, R.K., Patel, S.R. and Shah, S. (1977) Biology of mango hopper, *Amritodtis atkinsoni* (Leth.) (Jassidae: Hemiptera) in South Gujrat. *Indian Journal of Entomology* 37, 150-153.

Patil, S., PattI, A. and Kangane,J.B. (1992) Bionomics and efficacy of some insecticides against n1ango hoppers. *IV International Mango Symposium,* Miami Beach, Florida, p. 125 (Abstract).

Pena, J .E. (1993) Pests of mango in Florida. *Acta HrjlIiculturae* 341, 395-4()().

Pollard, G. V. (1982) A review of the distribution, economic importance and control of leaf cutting ants in the Caribbean region with an analysis of current control programmes. In: Brathwaite, C. W .D. and Pollard, G. V (eds) *Urgent Plant Pest and Disease Problems in the Caribbean.* Inter American Institute for Cooperation in Agriculture, Port of Spain.

Prasad, S.N. (1971) *IbeMango Midge Pests.* Cecidological Society of India, Allahabad.

Prasad, V. and Singh, R.K. (1976) Prevalence and control of mango mealy bug *Drosicba stebbingi(Green) in Bihar. Indian Journal of Entomology 38, 214-224.*

Prinsley, R.T. (1986) Mangoes in the Caribbean. Production and Post Harvest Treatment. CSC Technical Publication Series No. 203, CSC (86). AGR-4 Commonwealth Science Council, London.

Rai, B., Verma, S. and Kumar, K. (1966) Evaluation of pesticides for control of mango bud mite, *Aceria mangiferae Sayed* (Acarina: *Eriophyidae).Indian Journal of Entomology 28, 176-180.*

Rai, B., Shah, A. and Patel, R. (1988) Biology of *Oligonychus mangiferns (Tetranychidae:* Acarina), a pest of mango in Gujarat. *Gujarat Agricultural University Research Journal* 14, 5-10.

Rahman, K.A. (1940) Important insect pests of the mango and how to control them. *Punjab Fruit Journal* 3.

Rhuele, G. and Wolfenbarger, D.O. (1948) Diseases and Pests of the Mango in Florida. University of Florida, Sub-tropical Experiment Station.

Rubin, A. and Kyslitzky, W. (1992) First record of *Cera1zisus menes* (Hymenoptera: Eulophidae) in Israel. *Phytoparasitica20,* 123-124.

Sakimura, K. (1981) A review of *Frankliniella brnneri Watson* and description of F. *kelliae,* n. sp. (Thysanoptera: Thripidae). *Florida Entomologist* 64, 483-490.

Sarma, P.V., Sharma, V.K., Bahadur, U. and Chakravarti, K.B. (1981) Evaluation of Phenyl carbamate insecticides for the control of mango hopper *ldioscopus* spp. *Pestology* 5, 13-14.

Schreiner, I. (1987) Mango shoot caterpillar control on mango flowers, 1985. *Insecticide and Acaricide Tests* 12, 94.

Shah, A.H., .Jhala, R.C., Patel, G.M. and Paiel, S.H. (1983) Evaluation o(effective dose of "f mono< -rotophos for the control of mango hopper *AmritodllS atkinsoni* Lethierry (Cicadellidae: Homoptera) by injection method and its comparison with foliar ,i application. *Gujarat Agricultural University Research Journal 9,* 14-18.

Shah, A.H., Jhala, R.C., Patel, G:M. and Patel, C.B. (1984) Studies on the need-based chemical control of mango hopper *Amritodus atkinsoni* (Leth.). *Internaiional Pest Contlrol 26, 15-17.*

Sharma, D. and Kumar, H. (1986) How to control bark eating caterpillars. *Indian Horticulture 31, 25*

Shaw, J. (1961) Airplane applications of malathion bait spray for Mexican fruit fly control. Journal of Economic entomology 54,600-601.

Shaw, J. and Spisshakoff. L.M. (1958) Insecticidas para el control de la mosca Mexican: de la fruta en citricos y mango. *Memorias del Primer Congreso Nacional de Entomologia y Fitopatologia.* Escuela Nacional Agricola, Chapingo, Mexico, pp. 205-217.

Shukla, R.P. and Prassad. V.G. (1984) Evaluation of some insecticides against mango hopper, *Idioscopus clypealis* (Lethierry) (Homoptera: Cicadellidae). *Indian Journal of Agricultural Science* 54,677-681.

Shukla. R.P. and. Tandom, P .L. (1985) Bio-ecologyand management of the mango weevil. I *Sternochetus mangiferae* (Fabricius) (Coleoptera: Curculionidae). *Internation;Il Journal of Tropical Agriculture* 3, 293-303.

Silva, Q.M. and Cavalcante, R. D. (1977) *Vinsonia slellifera* (Westwood 1871), (Hom Coccidae), on various plants in the state of Ceara, Brazil. *Filossanidade* 2, 25-26.

Silveira da, R. (1960) Contribucao ao studo do *Hypocryphalus mangiferae(Coleoptera:* Scolytidae). Unpublished Engineer Agronomist thesis, Escola da Agricultura, Sao Paulo.

Singh, G. (1991) Loss assessment, ecology and management of mango fruitfly, *Dacussp. Acta Horticulturae* 291, 425-436. Ii

Sohi, A. S. and Sohi, A.S. (1990) Mango leafhoppers (Homoptera: Cicadellidae) a review. Journal *of Insect Science* 3, 1-12. ,

Soomro, A., Khuhro, R. and Ansari, H. (1987) Status of insects associated with mango blossom. *Proceedings V. Pakistan Congress of Zoology.* Karachi, Pakistan, pp. 123-125.

Soto-Manatiu, J., Jiron, L.F. and Hernandez, R. (1987) Chemical control and ecological observations of fruit flies of the genus *Anastrepha* Schiner (Diptera: Tephritidae) on mango. *Turrialba 37,* 245-251.

Srivastava, R.P. (1981) Comparative efficacy of various insecticidal dusts against mango mealybug eggs. *Lndian Journal of Entomology* 43, 225-229.

Srivastava, R. and Tandon, P. (1986) Natural occurrence of two entomogenous fungi pathogenic to mango hopper, *Idioscopus clypealis* Leth. *Indian Journal of Plant Pathology 4,* 121-123.

Steiner, L.F. and Lee, R,K. (1955) Large area tests of male annihilation method for oriental fruitfly control. Journal *of Economic Entomology* 48, 311-317.

Steiner, L.F., Mitchell, W.C., Harris, E., Kozuma, T. and Fujimoto, M. (1965) Oriental fruit fly eradication by male annihilation. *Journal of Economic Entomology 58,* 961-964.

Subramanian, C.K. (1925) A note on the life history of *Cryptorbynnchus mangiferae* Fab. *Madras Agricultural Department Yearbook* 29-36.

Syed, R.A., Ghani, M;A. and Murtaza, M. (1970a) Studies on trypetids and their natural enemies in West Pakistan. III. *Dacus (Stnlmeta) zonatus* (Saunders). *Technical Bulletin* 13. Commonwealth Institute of Biological Control, pp. 1-16.

Syed, R.A., Ghani, M,A., and Murtaza, M. (1970b) Studies on the Trypetids and their natural enemies in West Pakistan. IV. Further observations on *Dacus (Strumeta) dorsalis* Hendel. *Technical Bulletin* 13. Commonwealth Institute of Biological Control, pp. 17-30.

Tandom, P.L. and Lai, B. (1979) Studies on the chemical control of the mango hopper, *IdioscopuS clypealis* Leth. (Cicadellidae: Homoptera). *International Pest Control.* 21, 6-9.

Tandom, P .L. and Verghese, A. (1985) World list of insect, mite and other pests of mango. *Technical Document. Indian Institute of Horticultural Research* 5.

Tigvattnanont. S. (1988) Biological and autoecological studies of the mango leaf-cutting weevil, *Deporaus marginatus* Pascos (Coleoptera: Attelabidae). *Khon Kaen Agricultural Journal* 16, 51-62.

Toledo, J. and Lara, J. (1996) Comparsion of the biology of Anastrepha obliqua reared in mango (*Mangifera indica L*) .and in mombin (Spondias mombin) infested under field conditions. Fruit Fly Pest, Pests: a World Assessment of their Biology and Management. St Lucie Press, Delray Beach, pp. 359-362.

Umeya, K. and Hirao, J. (1975) Attraction of the jackfruitfly, *Dacus umbrosus F.* (Diptera: Tephritidae) and lace wing. Chrysopa sp. (Neuroptera: Chrysopidae) to lure traps baited with Methyl eugenol and cue-lure in the Philippines. *Applied Entomology and Zoology* 10,60-62.

United Stares Department of Agriculture (USDA) (1981) *Plant Pest Neues* 1.

van Dine, D.L. (1906) The mango weevil. *Ilawaiian Agricultural Experiment Station Press Bulletin 17, 1-11*

van Halteren, P. (1970) Notes on the biology of the scale insect *Aulacaspts mangifereae* Newst. (Diaspididae, Hemiptera) on mango. *Ghana Journal Agricultural Science* 3, 83--85.

van Lenteren, J.C., Loomans, *A.J.*, Tommasini, M.G., Maini, S. and Riudavets, J. (1995) *Biological Control of Thrips Pests*. Wageningen Agricultural University Press, Wageningen, 201 pp.

van Whervin, L. W. (1968) Citrus weevils of Jamaica and some of their parasites. T*echnical Bulletin No.1.* Citrus Research Unit, University of the West Indies, St Augustine.

Veerish, G.K. (1989) Pest problems in mango -world situation. *Acta Holliculturae* 231, 551-565.

Verghese, *A*., Rao, G. and Prasada-Rao, G. (1985) Sequential plan for mango ieaf hopper, *Idioscopus clypealts* Lethierry. *hntomology* 10, 285-290.

Verghese, *A*., Tandon, P. and Rao, G. (1988) Ecological studies relevant to the manage- : ment of *Thrips palmi* Karny on mango in India. *Tropical Pest Management* 34,55-58.

Watson, J.R. (1917) Thysanoptera of Florida. *Florida Buggist* 1,53-77.

Weems, H.V. (1969) Papaya fruit fly. Florida Department of Agriculture, Division of Plant Industry. *Entomological Circular no.* 86: Department of Agriculture, Florida.

Wharton, R.A. and Marsh, P.M. (1978) New world Opiinae (Hymenoptera: Braconidae) parasitic on Tephritidae (Diptera). *Journal of the Washington Academic Science 68,* 147-165.

White, I.M. and Elson-Harris, M. (1992) *Fruit Flies of Economic Significance.* CAB International, Wallingford.

Whitwell, A.C. (1993) The pest/predator/parasitoid complex on mango inflorescences in Dominica. *Acta Holliculturae* 341, 421-432.

Wolfenbarger, 0.0. (1963) *Controlling Mango Insect Pests.* University of Florida, Agriculture Extension Service, Circular *147A.*

Woodruff, R.E. (1985) Citrus weevils of Florida and the West Indies: preliminary report on systematic, biology and distribution (Coleoptera: Curculionidae). *Florida Entomologist 68, 370-379.*

Wysoki, M., Ben-Dov, Y , Swirski, E. and Izhar, Y. (1993) The arthropod pests of manHo in Israel. *Acta Horticulturae* 341,452-466.

Yazdani, 5.5. and Mehto, D.N. (1980) A note on the control of mango hopper, *Amritodus alkinsoni* Leth. at Dholi. *Indian Journal of Entomology* 42, 275-276.

Yee, W. (1987) The mango in Hawaii. Cooperative Extension Service, University of Hawaii, Circular 388, 19-22

9.2. THE MANGO BORER AND ITS CONTROL

Khawaja Abdul Haq, Economist and Muhammad Akhtar

The mango borer, *Batocera rufoma- cutaia* De Geer, better known as the fig borer, is widely distributed in Indo-Pakistan subcontinent, Ceylon, Malaya East Africa and Far East. In the old Punjab it was probably distributed all .over the province but as definitely recorded as a serious pest from Lyallpur, Sargodha, Hoshiarpur and the Kuluvalley (on wild fig trees).

It has a wide range of host plants belonging to eleven natural orders. In this region it is the most destructive pest of fig trees and also attacks mango trees. Besides, it has been observed attacking apple trees (grown experimentally) at Lyallpur.

The adults (beetles) feed upon the bark of young twigs and petioles of leaves. Consequently, the damage done by them is not of any great consequence. It is, however, the borers *(i.e.,* the grubs) wllich do more damage and arc really destructive. They do not kill the plant outright, for even a severely attacked plant may live for years. When the grubs feed in the heart-wood of the stem the plant usually does not dry up, but when they make zigzag tunnels in the sappy wood next to the bark the plant always dries up and dies.

In cases of severe infestation and in advanced stages of attack the infested trees can be recognized even from a distance from the mass of woody frass below an attacked portion of the stem or a branch. The bark over the attacked portion cracks and most of the woody fibre filling the; burrow thus becomes visible. In case of an old or severe attack numerous large circular and conspicuous holes on the trunk or branches are a common sight.

Identification: The different life stages of the pest are shown in the Figure 9-4.

Adult: The adult is an elongated and , a very powerfully built insect of a dull brownish yellow colour with long legs and very long 11-segmented antennae. It is about 2 inches long and 3/4 inch broad. It has a dirty white band extending from the head to the tip of the body down each side and there are a number of dirty yellowish spots on the elytra. The cephalic region of elytra is with numerous dark tubercles and one small sharp tooth on each shoulder. The pronotum is ornamented with two kidney-shaped orange-yellow spots.

Egg: Oval, dirty white, 5.5 to 6.8 mm. long and 1.8 to 2.3 mm. in diameter.

Grub: Freshly hatched grub is creamy white with a dark brown head; slender, thickest in the thoracic region, gradually tapering towards the anal end, 8.4 mm. long and 2.7 mm. broad at the thorax. Pronotum with numerous strongly chitinized flattened denticles. Body covered allover with minute spines. Full-grown grub is about 3" long and 0.8" wide at the thorax; body creamy- white, tapering towards the 8th segment and cylindrical further on.

Pupa: 50 mm. long and 22 mm. broad across the thorax; when freshly formed creamy white, later on changing to pale brown. Head slightly deflected; antennae very long, terminally making a spiral over the respective meta-leg. Pronotum shield-shaped and bearing one protuberance on each side. Abdominal tip tapering and curved with a sharp upward bend.

Seasonal history: The beetles start emerging about the end of May and continue to emerge till the end of August. The emergence is at its maximum during the months of July and August, i.e., during the monsoon rains. The adult is long-lived and in captivity it has been noticed to live up to 8 months. The egg-laying period may extend from May to the end of October or even the beginning of November. The grub stage is met with in the stem of the attacked trees throughout the year and the pupal stage from November onwards.

Life-cycle: The eggs are laid singly and they are pushed down under the bark of the stem or branch through a slightly .f curved transverse slit made therein by the female by the repeated action of its mandibles. After laying an egg the mouth of the slit is covered with a colourless liquid excreted by the female. The eggs may be laid at any time during day or night. The largest number of eggs laid by a female in 24 hours is seven and a single female can lay a total of 200 eggs.

Moisture is essential for hatching of eggs and the grub after hatching tunnels into the bat k without exposing itself. In case the egg projects beyond the slit, the grub on hatching is unable to bore into the bark and perishes. The duration of the egg stage varies from 7 to 14 days, most of the eggs hatching within 7 to 10 days.

The grub feeds upon the inner portion of the bark and xylem making a zigzag tunnel and filling it behind with frass. Evidently the grub cuts more fibre than it can actually eat. The grubs enter into the wood when they are sufficiently grown up and if an egg is deposited on a small branch then the grub enters into the wood very soon and its path is not zigzag. In such a case it enters the wood of the branch and makes a straight tunnel into the heart of the wood. The duration of the grub stage varies from about three to over six months. The grubs become full grown by about the end of September to the middle of November and prepare elliptical chambers for resting stage throughout the winter. In rare cases, however, they may pupate in November and the beetles are formed. These beetles continue in the resting stage throughout the winter and right up to the end of April.

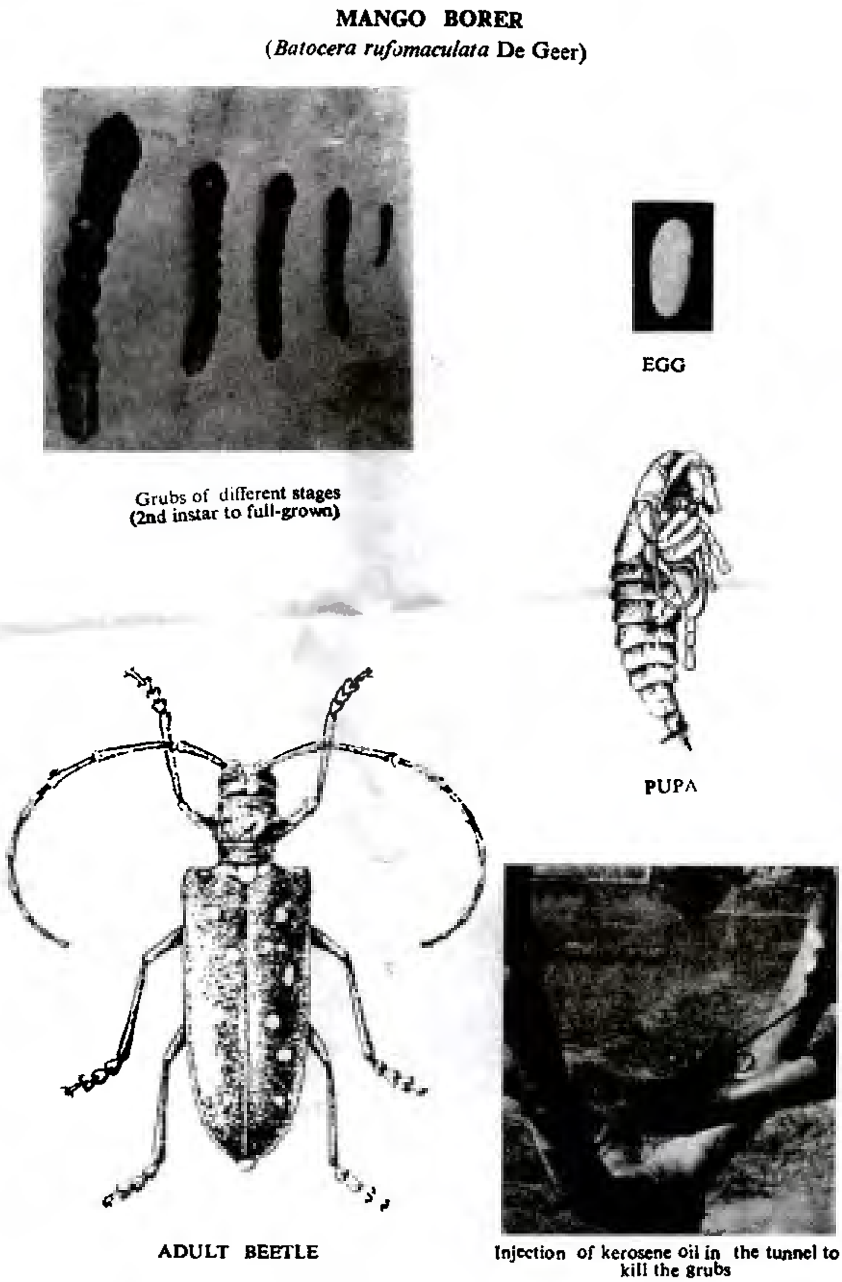
Pupation takes place in an elliptical 'chamber within the stem, usually at a distance of about 2" from the surface. The pupa lies naked in the chamber. The duration of resting and pupal stages varies from about 4 to 7 months. This includes the resting larval stage and the immature beetle stage. The pupal stage lasts for three to four weeks.

The beetle emerges by cutting out its own passage starting from the pupal chamber and terminating in a circular exit hole of about 0.7" to 0.8" diameter. There is only a single brood in a year.

Control: The pest can be controlled as follows :-

1. Uproot and destroy severely attacked trees.
2. Protect the stem against egg- laying by the adults by covering it with wire-gauze of 1/16 inch mesh or by painting coaltar over it. Spraying the stem five times with lime-copper sulphate-Paris green-solignum mixture during the egg-laying period can also prove helpful in this respect.
3. Collect and destroy the beetles.
4. Kill the eggs in the slits by means of a nail.
5. Kill the young larvae by means of a nail or a knife.
6. Clean the tunnel made by a grub with wire and inject kerosene oil or chloroform-creosote mixture (2:l) in it by means of a syringe. (Figure 9-4). Close the hole with mud after the treatment.
7. Plug the holes with cotton-wool soaked in kerosene oil or chloroform creosote mixture (2 : 1) and plaster with mud.
8. Introduce 1-2 grains of potassium cyanide into the tunnel and close the hole with mud. This method requires very careful manipulation.

Figure 9-4. Mango Borer



9.2.1. References

Husain, M. A. and Khan, A. W., 1934, *Batocera rubra* Linn. (Fig borer). *Proto Ind. Sci. Cong." Sect:* 1, p.21.

——— 1940, Bionomic and control of the fig tree borer *(Batocera rufomaculata* De Geer., Coleoptera : Lamiidae). *Ind. J. Agric. Sci.*, 10 (6) : 945-959.

Rahman. K. A., 1939, Important insect pests of the mango and how to combat them. *The Punjab Fruit Jourl1Cll,* 3 (11) : 512-517.

——— 1940, Insect pests of the Punjab. *Pb. Agri. Col. Mag.* (Insect Pest Ni,1mber), 7 (5-7): 44-46.

9.3. THE MANGO HOPPERS AND THEIR CONTROL

Khawaja Abdul Haq, Economist and Muhammad Kamal

The mango hoppers, known as *'am ka tela'* in local parlance, are small wedge-shaped sucking insects. They are a specific and most destructive pest of mango trees and there is hardly any mango orchard in this region where they are not present. They are very active and jump or hop about at the slightest disturbance even though it be the movement of a person passing under the infested tree. As they hop, they strike against the leaf surface and produce a typical sound resembling that of rain-drops falling on the leaves. This serves as a good indication of their presence in a mango grove.

Both nymphs and adults are responsible for causing damage, but the former, being more common during the active season, are most destructive. These insects suck the sap from the leaves and panicles as a result. of which the attacked plants become weak and their fruiting capacity is considerably reduced. In severe cases of infestation no fruit is set. Besides depriving the plants of cell sap, these insects also pass out a sugary material called honeydew, on which sooty mould develops and hinders the normal functioning of the leaves.

The following two closely allied species of mango hoppers are met with in this region.

1. *Idiocerus clypealis* L.
2. *Idiocerus atkinsoni* L.

Identijication: The different life stages of a typical mango hopper and damage done by it are shown in Figure 9-5.

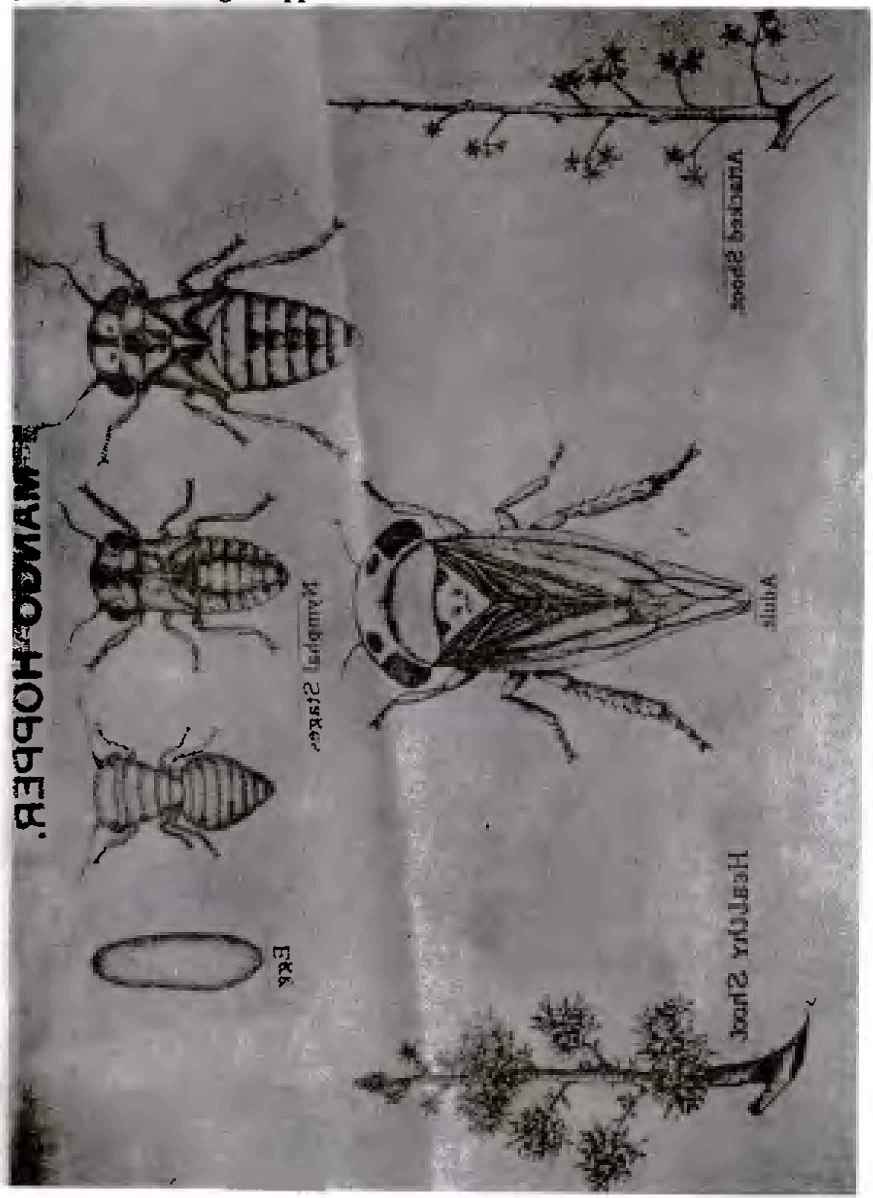
The description of stages of the two species mentioned above is as follows:-

Adult: The adults of both the species are grey in colour but they have the following distinguishing characters.

1. *Idiocerus clypealis* L: It is $^1/_5$ inch long, with no central longitudinal narrow dark streak on the scutellum.

2. *Idiocerus atkinsoni* L: It is ¼ inch long, with three dark brown spots on the head, a median band and two black spots on the pronotum, but the marking or the scutellum with triangular black spots and a central longitudinal narrow dark streak dilated anteriorly and posteriorly is characteristic of the species.

Figure 9-5. Mango Hopper



Egg: The eggs in both the species are dull white, pointed at one end and blunt at the other.

Nymph: Nymphs of *Idiocerus atkinsoni* L. are elongated, more active and pale yellow in colour while those of *Idiocerus, clypealis* L. are broader, lazy, dull and dust yellow in colour.

Life-cycle: Both the species are. present throughout the year and pass major portion of the year in the adult stage. During summer they cluster on the underside of branches and amidst leaves to shun light and heat. On approach of winter they conceal themselves under the leaves and in crevices in the bark. The pest becomes active in February and' migrates to the tender shoots and panicles to lay eggs. A single female may lay 200 eggs which are laid singly in slits made by her in the panicles, unopened flowers and young leaves of mango plants. The eggs hatch within 8-10 days and give rise to destructive young ones or nymphs which feed on the plant juice and become full grown winged insects in 17-19 days after undergoing five instars. The pest breeds twice a year, once during February-April and again in June-August.

Control: The pest can be effectively controlled by adopting the following sanitary and chemical measures which should be supplemented with each other to produce better results.

Sanitary measures

The thickly-planted mango groves should be thinned out and undesirable plants removed so as to ensure plenty of sunshine to them which will act as a deterrent for the pest. Besides, all dried up branches should be removed as these provide shelter to the insect from heat and cold.

Chemical measures

The infested mango trees should be sprayed with Malathion, Diazinon or DDT applied at the rate of ½ lb., ½ lb. and 1½ lb. active material per acre respectively in 100 gallons of water in each case. In case the aforementioned synthetic insecticides are not available, rosin compound or rosin soap should be used as a spray. In case of rosin com- pound the stock solution should be diluted with 5-6 parts of water for winter sprays and 7-10 parts of water for summer sprays. The rosin soap should be dissolved in 40 parts of water for spraying.

The most appropriate time for spraying operations is the pre-blossoming period from mid-December to beginning of February. It is best to spray in the morning when the insects are inactive due to cold. This precaution is particularly essential for spraying with rosin - compound or rosin soap.

9.3.1. REFERENCES

Hussain, M. A. and Pruthi, H. S., 1921, Preliminary note on winter spraying against mango-hopper *(Idiocerus spp). Rept. Proc. 4th Ent. Meet. Pusa,148-152.*

Husain, M. A. and Pruthi, H. S., 1923, Short note on the life-history of mango hoppers *(Idiocerus* spp.) in the Punjab. *Rept. Proc. 5th Ent, Meet. Pusa,252-260.*

Husain, M. A., 1925, The mango hopper and how to control it. *Seasonal Notes Dept. Agri. Pb.*, 2 (I): 5-7.

Latif, A. and Qayyum, H. A., 1950, The use of synthetic insecticide (Guesarol 550) against mango'hopper. *The Punjab Fruit Journal, 14 (49): 6-7.*

Latif, A., Khan, J. A. and Akhtar, M., 1958, Toxicity of Malathion and Toxaphene for the control of mango hopper. *Proc. 10th Pak. Sci. Colif, Agri. Sect.*, pp. 41-42.

Rahman, K. A., 1939, Important insect pesls of the mango and how to combat them. *The Punjab Fruit Journal,* 3 (II) : 512-517.

Rahman, K. A., J 940, Insect pests of the Punjab. *Pb. Agri. Coli. Mag.* (Insect Pest Number), 7 (5-7) : 40-41.

9.4. THE FRUIT FLIES ATTACKING MANGO AND THEIR CONTROL

Khawaja Abdul Haq, Economist and Muhammad Akhtar and Ghulam Dastigir

The fruit flies are quite a serious pest of mango fruit. The damage caused is considerable since a fairly high percentage of the ripe mangoes goes to waste every year because of fruit fly infestation. The attacked fruits get decayed due to the presence of maggot inside, which feed on the pulp, turn it into a semi-liquid mass and render it unfit for human consumption. The infested fruit in the beginning does not betray any visible sign of attack. Later on, however, it can be made out by the presence of a brown spot which appears on its sickly and yielding surface. When such a fruit is cut open, numerous white maggots could be seen lacerating the pulp and wriggling about in it.

The fruit flies attacking mango in this region, in the order of importance, are the following three:-

1. *Dacus ferrugineus* Fb.
2. *Dacus zonatus* Saund.
3. *Dacus diversus* Coq.

Rarely, however, *Dacus cucurbitae* Coq., has also been reported infesting mango in this region, but it can be easily ignored as a pest of any significance as far as this fruit is concerned. Therefore, only the first-named three species meriting consideration in relation to mango need to be dealt with here.

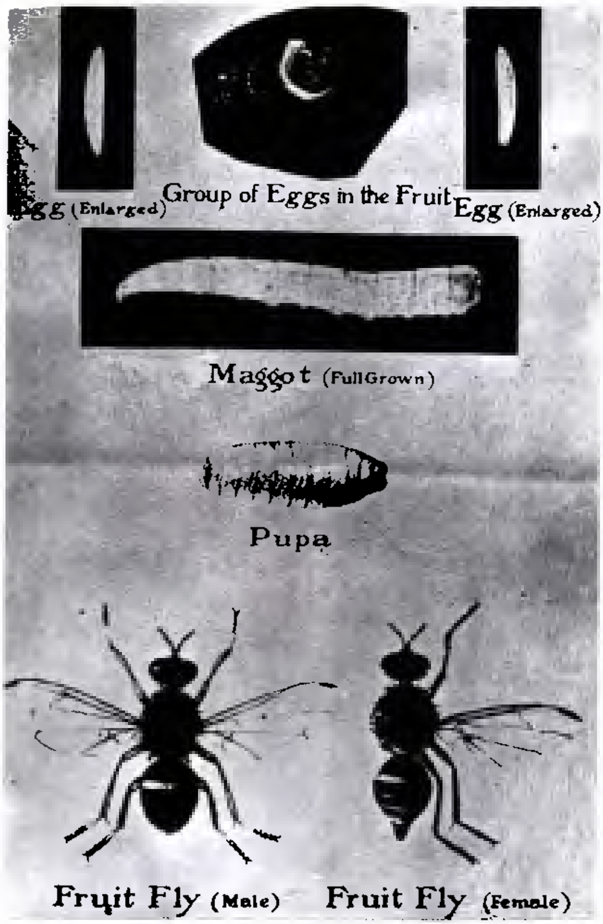
Identification: As is well-known, the fruit flies are generally a closely allied group as far as the morphological characters are concerned. The different life stages of a typical fruit fly have, therefore, been shown in the Figure 9-6 illustrate the general appearance of these stages in the three fruit flies being discussed here.

The identification and differentiating characters of these three fruit flies are, 4owever, .described below, as far as possible:

Adult stage: The adults of the three species .under reference are of the size of a house fly with vari-coloured bodies ranging from reddish-brown to grayish black. Their wings are transparent, each wing being ornamented with a brown spot -about its tip. Although otherwise almost alike, the three species can be differentiated as adults by comparing their general body colouration, the number and disposition of stripes on the thorax and colour and size of the ovipositor.

In case of *Dacus ferrugineus* Fb. the body colour is reddish brown, there are two longitudinal yellow stripes on the thorax and the ovipositor is short and brown. In case of *Dacus zonatus* Saund, the body colour is reddish-brown, there are yellow cross bands on the abdomen but no longitudinal stripes on the thorax and the ovipositor is short and brown.

Figure 9-6. Fruit Fly



The case of *Dacus diversus* Coq. The general body colour is greyish black, there are three longitudinal yellow stripes on the thorax and "the ovipositor is long and black.

Immature stages: The immature stages, viz., egg, larva and pupa, are very similar in the three fruit flies' and, hence, the description of these stages given below in case of *Dacus ferrugineus* Fb. will hold good, for all practical purposes, for the remaining two species as well.

Egg: It measures 0.1 x 0.2 mm., is white and cylindrical, narrow at both the poles and slightly curved on one side with distinct micropyle at the anterior end.

Larva: The full-grown larva is light yellow and measures 8.97x 1.74 mm. It has long micro-cylindrical body which is pointed at the head and composed of 12 visible segments.

Pupa: It measures 5.57 X 2.28 mm., is barrel-shaped, light orange when freshly formed and light ochraccous at the time of emergence of the fly. The anterior end is narrow as compared to the posterior end which is almost rounded.

Life-cycle: As in morphological characters, the three species are also closely allied in biological processes and life-cycle. The females puncture the fruit with their needle-like extensile ovipositors and deposit white long tiny eggs, singly or in groups, under the skin of the fruit. The white legless headless maggots which emerge from the eggs penetrate into the pulp, feed on it and cause decay in the fruit. The full-grown larvae leave the fruit by making hole in the skin and drop on the ground. They enter the soil to a depth of 1"-3" and pupate under the infested trees. The pupa is enclosed in a brown or yellowish white cylindrical puparium from which adult flies emerge.

The duration of different stages of development differs only slightly in the .three fruit flies, but, in all cases, it varies significantly with the season.

In case of *Dacus ferrugineus* Fb. the female deposits 4-13 eggs in a single puncture 1-2 mm. below the skin of the fruit. The egg stage lasts for 2-4 days in summer season and 4-8 days in autumn and early winter. The maggots are full grown in 5-9 days in summer and 9-20 days in autumn and early winter. The duration of pupal stage varies from 6-12 days in summer and 12-30 days in winter. The adult flies live for 27-44 days. The pest completes its life-cycle in 12-35 days in summer and 29-60 days in winter. It remains active from middle of March to October-November and passes through 7 generations in a year.

In case of *Dacus zonatus* Saund, a single female lays 44-55 eggs in all. The eggs give rise to maggots in 2-4 days in .summer and 8-9 days in winter. The maggots are full-grown in 7 days in summer and 13-22 days in winter. The pupal stage lasts for 8 days in summer and 20-44 days in winter. The adults live for 37-41 days. The pest remains active throughout the year and passes through 8-9 generations during this period.

In case of *Dacus diversus* Coq. the eggs hatch in 3-5 days and maggots become full-grown in 8-12 days during summer. The pupal stage lasts for 8 days in summer and 20-44 days in winter. The adults live for 30-43 days. The life-cycle is completed in 19-31 days. The pest re- mains active from March to September.

Host plants: The hosts that are common to all the three species, besides mango, are, guava, mulberry, ora1lge, malta, grapefruit, chakotra, fig, gourd, vegetable marrow, sponge gourd, bitter gourd and musk melon. The fruits which serve as common hosts to the two species, *Dacus Jerrugineus* Fb. and *Dacus zonatus* Saund, are peach, pomegranate, apricot and ber. Besides these, *Dacus ferrugineus* Fb. is also found on plum, loquat, mitha, banana, persimon, quince and crab apple, while *Dacus diversus* Coq. attacks long melon, cucumber, pumpkin and tomato.

Control: The following control measures which are applicable to all the species of fruit flies are recommended.

Sanitary measures

All fallen infested fruit should be carefully collected and buried 4'-5' deep in the soil to kill the maggots contained therein. In no case should such fruit be thrown away carelessly or sent to the market.

The soil under the infested trees should be kept frequently stirred by hoeing or ploughing to kill the pupae by exposing them to the inclemencies of weather. Applying irrigation to the soil, preferably by mixing some insecticide like sanitary fluid, BHC, Aldrin, etc., in the irrigation water, should prove further helpful in killing the pupae. Growing some cover crop on the infested soil also proves of advantage in this behalf. These operations should be a 'MUST' particularly during winter, when the pupae are hibernating in the soil.

Chemical measures

The chemical control of fruit flies comprises the use of cover sprays and bait sprays. Before taking up these measures it is preferable to determine the presence of the pest in the orchard by using bait traps which should be hung up on the trees. The trap bottles should be half-filled with clensel diluted with water (1 : 20) or other attractants like amyl acetate, vanilla essence, melon pulp, malt, etc. As soon as the fruit flies start appearing on the bait material spraying operations should be set afoot. In the case of mango, this will coincide with the time when the fruit is about to ripe.

(a) *Cover spray:* The control of fruit flies has remained a baffling problem in the past but, thanks to the evolution of modern synthetic insecticides, these serious pests are now amenable to being dealt with effectively by these poisons which are recommended for use as cover sprays.

Before mango fruit starts ripening the orchards should be sprayed twice at a fortnight's interval with one of the suitable synthetic insecticides. The materials that have so far given good results are Endrin, Dieldrin, Dipterex, Diazinon, Phosdrin and Dimecron used at the rate of ½ lb., 1½ lb., ½ lb., ½ lb., ½ lb. and ½ lb. active material per acre respectively in 100 gallons of water in each case.

(*Precautions:* All these insecticides are extremely deadly poisons and utmost care should be exercised in their use. The worker should wear respirator, apron, gloves and goggles while handling these poisons and performing the spraying operations. He should avoid smoking, eating, drinking, etc., while at work and should invariably wash his hands and face with soap after the day's work is over. He should take ample quantity of milk after undertaking spraying with organo- phosphorus compounds, viz., Dipterex, Phosdrin, Dimecron, Diazinon, etc. Care should be taken that the treated fruits are not consumed until after a fortnight of the final spraying and that they are properly washed before they are eaten or sent to the market.)

(b) *Bait spray:* In case the aforementioned synthetic insecticides for cover spray are not available, sodium fluosilicate or lead arsenate can be used as bait spray against the fruit flies according to the following formula:-

Sodium fluosilicate	...10 oz.
or	
Lead arsenate	...3 oz.

Molasses	...2-5 lb.
Water	...4 gallons.

All these ingredients should be mixed to obtain thin syrup. The bait solution should be sprayed on small patches of the foliage here and there on the trees at weekly intervals during the fruit-bearing period. One gallon of bait solution is sufficient for spot spraying 16 average sized trees. Instead of spraying, the bait can also be painted on the plants. The paint may be renewed twice a week.

It must be remembered that, howsoever effective the chemical measures of control may be, these must be supplemented with the sanitary measures to achieve better success.

9.4.1. REFERENCES

Rahman, K. A., 1939, Important insect pests of the mango and how to combat them. The Punjab Fruit Journal, 3 (11) : 512-517.

Anwar, M., 1956, Control of melon fruit fly. A thesis presented to the University of the Panjab for M.Sc. (Agri.) Degree.

Latif, A., Khan, J. A. and Akhtar, M., 1958, Control of guava fruit fly with Dieldrin. Proc. 10th Pak. Sci. Cong., Agri. Sect., pp. 40-41.

Latif, A and Akhtar, M., 1959, Further .studies on the control of fruit fly *Dacus zonatus* Saund. Proc. 11th Pak. Sci. Cong., Agri. Sect., pp. 77-78.

Haq, A and Dastgir, G., 1960, Host specificity of different Dacus species at Lyallpur. Proc. 12th Pak. Sci. Cong. Agri. Sec.

9.5. THE MANGO MEALY BUG AND ITS CONTROL

By Khawaja Abdul Haq* and Mahmood Akmal*

The mango mealy bug, as its name implies, is primarily a pest of mango. The nymphs and adult females of this insect are quite familiar objects with a flattened body which is covered with a white mealy powder. They are seen crawling about on the stems and branches of some fruit and shade trees and on hedgerow plants, etc., in spring and early summer and are sometimes also noticed slowly moving about on roadside or even gaining inroad into houses from the neighhoring infested trees during that season. Besides being a pest of some important fruit and shade trees, the presence of this insect in immensely large numbers in early summer on trees in and around residential premises and human habitations becomes extremely menacing and annoying. Huge armies of this crawling nuisance leave neighboring trees and move freely everywhere in the houses reaching the living rooms, kitchens, apartments, etc., and spreading allover. They are frequently crushed under feet and render the whole dwelling filthy and unpleasant for normal daily functioning of the household. In certain cases they even drop into the wells in huge numbers and render the water unfit for drinking.

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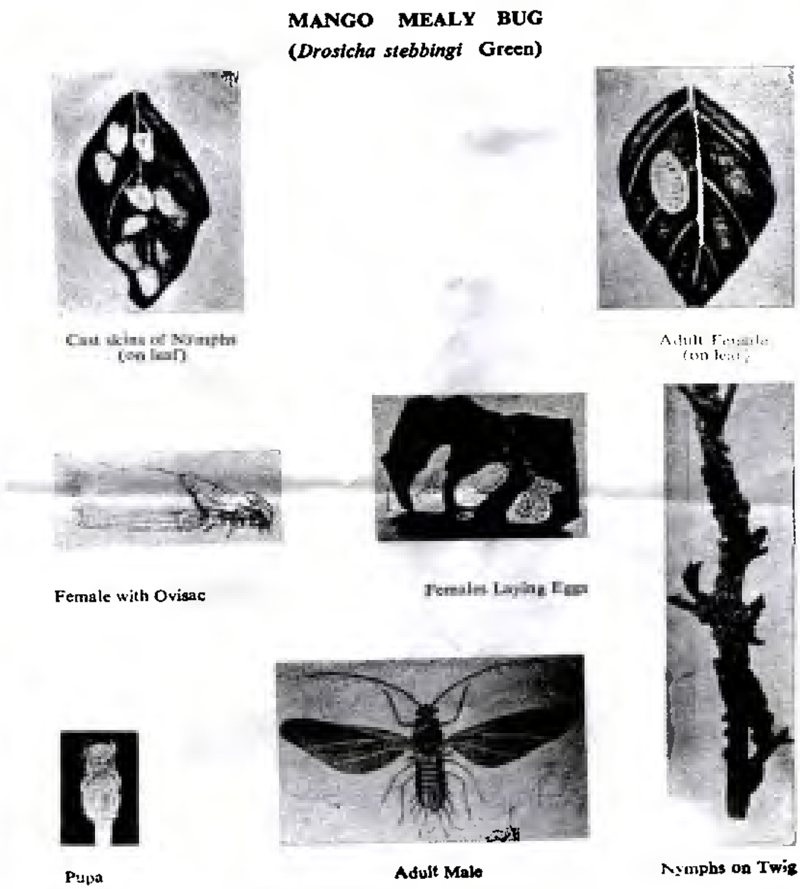
Distribution and food plants.-It is one of the common pests in the region and is fairly wide in its distribution. Although it has been found feeding on 62 different varieties of plants in Northern and Central parts of Indo-Pakistan sub- continent, its more important hosts in this region are mango, citrus, *ber,* guava, mulberry, plum, peach, fig, ficus, etc.

Damage.-The damage to the trees is caused by the nymphs and adult females. They crawl up the host plants, fix up themselves on the terminal shoots and flowers and suck the sap with their needle-like piercing mouthparts, thus rendering the plants weak and lowering the fruit yield. In severe cases of attack the infested trees do not bear any fruit. These insects also pass out honey dew on which sooty mould develops.

identification.- The different life stages .of this insect is shown in the Figure 9-7.

Figure 9-7. Mango Mealy Bug



Their description is given below:-

Adult female.- The adult female measures about ¾ of an inch in length. It is wingless with a flattened body covered with a white mealy powder from which it derives its name "mealy bug". Its mouthparts are suctorial.

Adult male.- The adult male has a beautiful crimson body and two black wings. Its antennae are very long, 10-segmented and furnished with whorls of setae. It has no mouthparts and, in consequence, it does not feed. It measures 4 to 6 mm in length and 1.6 mm. in breadth.

Egg.-The eggs are oval in shape and chocolate in colour resembling turnip seeds. They measure 0.9 to 1.1 mm. X 0.65 to 0.7 mm each and are laid in an ovisac which is a whitish silken purse secreted by the female and measures 0.75 to 2.0 cm. x O.6 to 1.1 cm.

Nymphal instars.- There are three nymphal instars in the case of both female and male. The third nymphal instar in male is also known as prepupa and is followed by the pupal stage which is missing in the female.

First instar nymph.-It measures 1.31 to 2.30 mm in length and 0.70 to 1.19 mm in greatest breadth. It is elliptical in shape and chestnut brown in colour. The antennae are 5-segmented.

Second instar nymph.-It resembles the first instar nymph in general appearance and measures 2.9 to 4.7 mm in length and 1.7 to 2.6 mm in breadth. In the beginning the colour of the body in this stage is reddish-brown but later on it becomes covered with white mealy powder. The antennae are 6-segmented.

Third instar female nymph.-It differs from the second instar nymph in length and breadth which are 4.55 to 7.7 mm and 2.5 to 3:7 mm respectively. The antennae are 7-segmented.

Third instar male nymph.-It resembles the third instar female nymph but differs from it in length and breadth which are 4.5 to 4.9 mm and 2:2 mm respectively. The antennae are 9-egmented.

Pupal stage.- This stage occurs only in the male. The pupa lies in a cottony cocoon which it is capable of reconstructing, if removed, and repairing, if damaged. It measures 5.43 mm in length and 2 mm in breadth: Its antennae are 10-segmented arid its mouthparts are atrophied.

"Life cycle.-The females lay up to 372 eggs each in May and June in whitish cottony ovisacs 2 to 6 inch deep in the soil. The egg stage lasts for about eight months under our conditions and hatching starts in the end of December or beginning of January and continues till February. The nymphs that hatch out are tiny chestnut brown in colour.

In the beginning these tiny bugs climb up low-growing vegetation, *i.e.,* weeds, bushes and small trees, and, later on, they start ascending mango and other host trees and by the end of March they are fixed up in large numbers on terminal shoots sucking up the plant sap on which, they thrive. The female passes through three nymphal instars, while the male passes through three nymphal instars and a pupal stage to reach maturity. This takes 78-135 days in the case of female and- 77-134 days in the case of male as under:-

Stage	Duration (days)	
	Female	Male
1st nymphal stage	45 – 71	45 – 71
2nd nymphal stage	18 – 38	18 – 38
3rd nymphal stage	15 – 26	7 – 10
Pupal state	Not met with	9 – 15
Total	78 – 135	77 - 134

Copulation starts soon after emergence of adjust. The pairing seasons lasts from the second week of April to the first week of May. The males live from a few days to a week and die soon after mating. The females live from 22 to 47 days and after fertilization they start descending to the ground for oviposition in the beginning of May. They come down mostly by crawling along the stem or, in some cases, by dropping straight from the tree. This continues till about the middle of June when egg-laying stops. For laying eggs the female enters into the soil to a depth of 2 to 6 inches and dies there after oviposition with her shrivelled body remaining attached to the egg-sac.

Natural enemies.-An Ichneumoi1id and a Dipteron parasitise this insect and some lady bird beetles and lace-wings and some birds prey upon it. Effort should be made to encourage these natural enemies.

Control.- The control of mango mealy bug is not difficult to achieve, provided the following measures to eradicate this pest are adopted in a systematic and skilful manner.

1. Destruction of eggs

This can be done by first sweeping all rubbish from under the infested trees and then scraping off soil to a depth of about 6 inches. The rubbish should be destroyed by burning, and the scraped up earth should be used as litter for cows, etc. The trampling by these animals will ensure destruction of the eggs. Cultural operations like ploughing and hoeing resored to in the egg-laid area will expose the eggs to weathering agencies, birds, etc., and destroy them. Root opening and replacing the soil at the bases of fruit trees are also very useful practices, which help in exposing the eggs to the adverse climatic conditions. These measures may be adopted any time frnm June to December before the commencement of hatching.

2. Banding the trees

There are three types of bands, *viz.*, slippery, fluffy and sticky bands that can be used to prevent the ascent of the nymphs on the trees for protection against damage.

These bands should be applied around the tree trunks 3-4 feet above the ground surface towards the end of December, before the emergence of the nymphs starts, and should be kept up till the end of April.

(a) Slippery hand.,--As its name implies, this band presents a slippery surface over which the nymphs are unable to crawl and reach the upper parts of the tree for doing damage. The best material so far known for use as a slippery band is

the black oil cloth. A 2"-2½" wide strip of this cloth should be tied firmly around the tree trunk as shown in the figure below.

In case the tree trunk does not have a uniformly smooth, surface, the depressions should be filled up with mud, so that no space is left in between the band and the tree trunk through which the nymphs could crawl up. The band is liable to get covered with a film of dust and lose its glossiness; therefore, it should be occasionally inspected and all dust gathered on it removed. This is a very simple and economical device for averting damage from the pest.

(b) Fluffy band.- Barriers that will not allow bugs to crawl up the trees can also be made of fluffy cotton wool, which may be wrapped round the trunk of trees and held in position by thin strings. The legs of the bugs get caught in the fluff and they cannot get out of it. However, rats and particularly squirrels steal away this cotton, and thus help bugs to find a way up. If this cotton wool band is dusted with D.D.T., or similar other insecticides, these animals avoid it. These bands must be regularly watched and repaired when damaged through any cause. After rain these bands must be examined and reset.

(c) Sticky band.- A sticky band, about 3 to 4 inch in width, painted round the trunk of a tree will provide an effective barrier. Any sticky material will serve the purpose, as long it remains sticky and does not dry up and does not get covered with dust. Molasses may be as effective as coal tar, if care is taken that it is sticky.

There are several other sticky bands which are recommended. Rosin (1.5 lb.) heated with crude castor oil (1 pint) makes an effective sticky material. Similarly axle grease (1 lb.), fish oil (1 pint) and rosin powder (2 lbs.) heated together produce a good sticky maletial, which can be painted round the trunk of trees with a brush or a rag wrapped round a flat piece of wood. The main point is that the band must remain sticky, so that no insect can crawl up. A 9" wide band of san hemp rope or thick "munj" rope soaked in a mixture of coal tar and- crude oil emulsion in equal parts can also be used. The mixture should be applied to the band after every 14 days. Of the various types of sticky band that have been used in the past; Ostico and "Namhar" have proved the best. The former is a commercial proprietary product and the latter, which is preferable, being cheaper, has been evolved in this Section. It remains effective for about 3 months and requires two applications in a season. The cost per pound of this material comes to 8/4 rupee only and this quantity is sufficient for banding 10-20 trees for the first application and 15:.20 trees *for* the subsequent one. The nymphs sticking on the band should be brushed off to avoid any chance of cross over of other nymphs over the bodies of the former. The method of preparation of the 'Namhar' sticky material is as under:-

Part A: Heat one lb. of castor oil and remove it from fire when quite hot, add to it ½ lb. of con. sulphuric acid, stir vigorously after mixing the two in gredients.

Part B: Heat 2 lb, of axle grease, add to it 2½ lb. of powdered rosin gradually and stir well. Add 2 oz. of glycerine and 5-10 grams of unslaked lime, remove from fire.

The two pastes should be mixed as required for use.

3. Destruction of nymphs and adult females.

During January-February when the bugs are very small in size they can be crushed on the stem with the help of a rag.

In the past, a fairly large number of insecticides have been used to control this noxious pest, but they either proved wholly ineffective or were efficacious against the initial stages only. In the advanced stages, the pest was impregnable because of the presence of the waxy coating on its body which proved impervious to most of the insecticides tried. Fortunately, however, some new synthetic insecticides, particularly the organophosphorus compounds having a deep penetraing action, have given amazingly good results when tried against the pest and made its control a more successful proposition.

The following insecticidal measures are recommended depending upon the situation and the stage of the pest.

(a) Insecticidal rings around the tree bases.-:-Spreading Agrocide 7 dust (1 :10) in the form of rings around the bases of the tree has proved effective

against 1st and 2nd stage nymphs trying to reach the trees from low vegetation. This measure should be adopted in case the preventive bands have not been applied. The treatment should be repeated at fortnightly intervals.

(b) *Spraying against nymphs amassed below, on or above the preventive band.*- The first and second stage nymphs so amassed should be destroyed by spraying DDT 0.5%, BHC 0.4%, Folidol 0.1 %, Diazinon 0.05%. Nematox 0.1 %, Hanane 0.1 %, Pestox 0.03%, Systox 0.05% or fish-oil resin soap (1.5 lb. in 4 gallons of water). For controlling 3rd instar nymphs and female adults Folidol 0.3%, Diazinon 0.35%, Nematox 0.25%, Hanane 0.35% and Pestox 0.35% should be used as spray.

The nymphs sticking on the band can also be destroyed either by brushing them off in a vessel containing water with a film of kerosene oil on the surface or into the irrigation ring round the infested tree containing water with a film of (kerosene oil on the surface.

(c) *Cover sprays.*-In case no preventive measures have been adopted and the nymphs have crawled up the plants unchecked and reached an advanced stage of development, they should be sprayed with Folidol 0.3%, Diazinon 0.35%, Malathion 0.35 %, Nematox 0.25%, Hanane 0.35% and Pestox 0.35%, fish-oil resin soap (1.5 lb. in 4 gallons of water) or rosin soap (1 part in 16 parts of water). All infested hedges and other infested plants in the neighbourhood of the orchards should also be similarly sprayed to kill the pest.

9.5.1. REFERENCES

1. Latif, A., 1941, Control of the mango mealy bug. *The Punjab Fruit Journal,* 5 (19): 995-997.
2. Latif, A and Beg, A. M., 1955, Control of mango mealy bug. *Proc. 7th Pak. Sci. Cong, Agri. Scc.* pp. 74-75.
3. Latif, A and Chaudhry, M. I., 1957, Effectiveness of some synthetic in- secticides for the chemical control of mango mealy bug *Drosicha stebbingi* (Gr.). *Pak. Jr. Sci. Res;,* 9 (2): 63-71.
4. Latif, A. and Alam, M. M., 1959, Studies on the control of *Drosicha stebbingi* (Gr.) with some organic phosphorus compounds. Proc. *11th Pak. Sci. Conf., Agri. Sec.* pp. 78-79.
5. Latif, A. and Akhtar. M., 1960, Effect of Malathion on adult females of mango mealy bug *(Drosicha stebbingi* Gr.) *Proc. 12th Pak. Sci. Cong, Agri. Sec.,* pp. 29-30.
6. Rahman, K.A., 1940. Insect Pests of the Punjab. *Pb. Agri. Coll. Mag.* (Insect Pest Number), 7 (5-7): 42-43.
7. Rahman, K. A., 1940, Final report on the combined Entomological Scheme Punjab and N. W.F. Province.
8. Rahman. K. A. and Latif, A., 1944, Description, Bionomics and Control of Giant mealy bug. *Bull. Ent. Res.,* London, 35 (2): 197-209.

9.6. INTEGRATED PEST MANAGEMENT OF THREE MANGO PESTS

*A. I. Mohyuddin**

9.6.1. ABSTRACT

The causes of low yield of mangoes may be attributed mainly to the severe attacks of many regular as well as sporadic insect pests. Mango crop is attacked by 86 insect species in Pakistan of which the fruit-flies Dacus Zonatus, Dorsalis, mango mealy bug Dorsicha Stebbingi, scale insects Aspidiotus destructor and mango hoppers Idiocerus ssp. are recognized to be the most destructive.

Following parasites/predators have been found effective against the serious pests of mangoes:

Pest	Parasite	Predator
Scale insects (Aspiodistus destructor)	1. Aphytis melinus 2. Thomsonisca Pakistanesis	Chilocorus nigitirus
Mealybug (Drosicha Stebbingi)	-	1. Suminus renardi 2. Rodolia fumida

9.6.2. INTRODUCTION

Mango is cultivated on about 73,000 ha in Pakistan. About 86 species of insect pests damage this plant hut fruit flies *Dacus Zonatus* and *D. dorasalis,* mango mealybug *Dorsicha stebbingi,* scale insects *Aspidiotus destructor, Parlatoria crypta, Lindingaspis ferrisi, Aulacaspis tubercularis, Coccus hesperidum, C. mangiferae, Rastrococcus spinosus, Pulvinaria psidi,* etc. and mango hoppers *Idiocerus* spp. are serious pests of mango in Pakistan.

Mostly pesticides were used for their control. PARC-CIBC Station International Institute of Biological Control developed technology to control fruit flies, scale insects and mango mealy bug by using hiological, cultural methods and methyl eugenol (lure) for their control, thus completely eliminating the use of pesticides.

Brochures in Urdu and English were prepared for farmers and extension workers. This technology was transferred to the mango growers in 1986 through field days and workshops where traps lure and brochures were distrihuted with the money provided by Pakistan Agricultural Research Council (PARC).

Work on mango hoppers Idiocerus ssp. has been started under a project financed by PARC.

The methods developed for control of fruit flies, mango mealy bug and scale insects are described below:

9.6.3. FRUITFLIES

Dacus zonatus and D. dossalis are serious pests of mango and other fruits and vegetables including citrus, guava, date-palm, papaya, jujube, apple, pomegranate, quince, peach, plum, pear, loquat, apricot, okra and bittergourd in

* *Common Wealth, Biological Control, Rawalpindi*

Pakistan. D. zonatus is in abundance in the Punjab, Sind and Baluchistan and is rare in northern foothills and Peshawar valley. Whereas, D. dorsalis is more abundant in northern foothills and Peshawar valley and is rare in the Punjab and Sind.

9.6.4. Control measures

A number of pesticides such as Dipterex, Nogos, Folidol, Dimecron, Metasystox, etc. are used for controlling the fruit flies. These costs approximately Rs. 600 per hectare. Their use creates other pest problems such as outbreak of scale insects because of elimination of their natural enemies. PARC-CIBC Station studies the efficiency of different lures in different ecological zones from 1968 to 1971. Methyl eugenol was most attractive for D. zonatus and D. dorsalis.

People at Atomic Energy Agricultural Research Centre, Tandojam, Sind studied its effectiveness for controlling D. zonatus in guava in Sind and recommended eight traps per acre and mixing of sugar and a pesticide with methyl eugenol. Six steps were described to prepare the trap and ten precautionary measures were recommended.

PARC-CIBC Station studied suitability of using methyl eugenol for controlling fruit fly a 100 hectare orchard for two years and simplified the method and reduced the cost of control. It was found that one trap per acre in large and two traps in small orchards, from may to August were enough for excellent control of fruitfly and no mixing up or hooks etc. were necessary. The technology was passed to the farmers. The simple method developed is described below:

9.6.5. Method of the lure application

Small cotton swab moistened with the lure is put in the trap measuring 10" x 6" fitted with two tubes measuring 2.5" x 1.25" on either side. It is suspended one to two meters from the ground on the branch of the tree which is not in direct sunlight and the leaves do not cover the openings of the tubes. Dead fruitflies are removed from the trap and fresh lure is applied at fortnight intervals.

9.6.6. SCALE INSECTS

The scale insects have extremely effective natural enemy ,complexes and are normally under control. But they become serious pests when insecticides are indiscriminately used against other pests. The pesticides used against mango hoppers in April-May and against fruitflies in June may kill the parasitoids of scale insects because they are active at this time resulting in outbreak of the scale insects.

9.6.7. Control measures

Indiscriminate spray of insecticides should be avoided. If the scale for insects become serious problem, their natural parasitoids Aphytis melinus and Thomsonisca pakistanensis and a predator Chilocorus nigritus should be augmented. Their augmentation gives excellent control of scale insects.

9.6.8. MANGO MEALYBUG

The mango mealybug Dorsicha stebbingi occurs in South West Asia. The females enter the soil in May-June and lay eggs. They remain in this condition till December the nymph start hatching in January and Crawl on to the plant and feed on twigs, leaves and inflorescence. The males and females complete development by April and May. After mating, the females continue feeding and come down from the plant hy the end of May and enter the soil for oviposition. By the middle of June most of all the females enter the soil and go down up to 6 inches oviposit. The eggs remain in the soil from June to Decemher. This insect has only one generation a year.

9.6.9. Control measures

A number of cultural practices for its control have been tried in the past including hands of different types, hoeing, etc. The effect of different types of hands including grease, polyethylene sheets, etc., were tried in the past. These were not found effective for various reasons. For example, grease bands because of excessive trapping of the mealybugs, other insects, dust and dry leaves become useless because a bridge is formed and the mango mealybug could cross the band. Similarly, polyethylene sheets are not effective.

Preliminary ohservations on hoeing hy some workers did not find it effective. Quantitative data were collected on its effect. At Lahore, in an orchard three to four hoeings, upto 6 inches, were done from October to Decemher to expose the eggs to predators and other environmental hazards. This resulted in 90% mortality of the eggs while in the orchard where hoeing was not done mortality was 22%. On the plants where hoeing was done, maximum mealybug density was 15 individuals per meter compared with 343.8 in February where hoeing was not done. Thus it gave excellent control of the mealybug. The ineffectiveness reported earlier might be because of shallow hoeing or at wrong time of the year.

9.6.10. Natural Control

Two coccinellids Sumnius renardi and Rodolia fumida are important predators of mango mealybug. The seasonal history of S. renardi is well synchronized with that of its host. It has one generation a year and a female lay up to 776 eggs.

It prefers to settle in sheltered places. To encourage this predator for controlling mealyhug, burlap bands were provided on mango trees. This resulted in an increase in S. renardi population and drastic decrease in the mealybug numbers. Maximum number of mealy bug per meter was 26.6 where bands were put compared to 170 in the control.

R. fumida attacks this mealyhug from April and, after completing one generation on this mealy bug in June, shifts to other hosts. A female lays up to 309 eggs.

By encouraging these predators by putting burlap bands on the trees, abundance of the mealybug was drastically reduced.

9.6.11. MANGO HOPPERS

Four species of mango hoppers (Idiocerus ssp.) have been recorded from Pakistan. At present pesticides are extensively used for their control. Recently, work on integrated pest management of mango hoppers has been started under a PARC project. Four species of egg and one specy of nymphal and adult parasitoids and some predators have been recorded. It is hoped that soon a method for their control, without using pesticides will be developed.

10. HANDLING OF MANGO FOR EXPORT

I. A. Gill, M. M. Sharif and M. Ashgar

Mango is the most popular fruit because of its superior organoleptic quality and finds it way to export market in Europe, Far-East and Middle East regions. Being a very delicate fruit its preservation in fresh state demands an extra vigil. Pakistan is one of the major mango growing countries and there is great potential for earning foreign exchange through export. High priority planning for its careful marketing is required and application of post harvest technology operation is of prime importance.

Under most circumstances, mango can be stored successfully for up to three weeks if the recommendations concerning maturity, harvesting, other handling and storage conditions are followed.

Quality Criteria

The quality of the fruit on arrival in the importing market is normally determined by the following parameters:

- Physiologically mature;
- Beginning to ripen, with 30-50 percent yellowish coloration;
- Relatively firm;
- Minimum sugar content of 12 percent;
- Free from disease, decay, sun-scald, cracks, bruises, latex stains, and insect and mechanical damage; and
- Conforms to the weight and size specifications;

Harvesting

It is better to consider intended marketing period before harvesting. Moreover, fruit should be harvested at such suitable time when the shoulders of the fruit are fully swelled out, and show signs of slight change in colour.

Harvesting techniques play an important role for quality retention and shelf life extension. Harvesting should be carried out either early in the morning or late in the evening using anyone of the following methods.

Hand Picking

This method involves climbing the picker on the tree and cutting the fruit stalk but the use of bamboo pole fitted with knife and bag is better to harvest mango from higher parts of the tree.

Fruit should not be thrown on the ground in any case otherwise it would receive injuries resulting a reduction in shelf life.

Mango Picker

It is a simple tool consisting of a bamboo pole with attached knife and a cloth or string bag held open by a ring. The fruit is harvested while standing on the ground by carefully cutting the stalk with knife so that fruit falls gently into the attached bag.

Latex Problem

During harvesting the fruit sap or heavy sugary waxy material locally called "Dook" gets exuded on the fruit. It causes following three major problems:-

i. This cell sap is very sticky due to which it attracts soils which adheres on the fruit making dirty.
ii. This cell sap is high in sugars and other nutrients, which attract .microorganisms. Which grow rapidly on the sap and cause quick decay of the fruit?
iii. This cell sap affects the fruit by staining which affect its appearance. This problem can be avoided by leaving S-mm stalk on the fruit at the time of packing, which can be trimmed off later to avoid damage during transport.

Hydro-cooling

The inside temperature of the fruit is 4-5°C higher as compared with environmental temperature. It is very essential to remove the field heat of the fruit so that its shelf life and quality of fruit is improved.

Although there are various methods of pre-cooling of the fruit but hydro-cooling s a good and effective method for the removal of field heat under our circumstances. A simple hydro-cooling system, using ice has been developed by the Post Harvest Research Centre and demonstrated to interested parties. There are two distinct advantages of hydro-cooling:-

i) It removes the field heat effectively from the fruit prior to packing.
ii) Water is used to clean the mango from dust, dirt and foreign matter. Fungicides could be mixed in water to prevent fungal infection. Water needs to be changed frequently to avoid spread of fungal spores.

Handling

The care should be taken during handling of fruit from the field to the pack-house. As the harvested fruit is damaged by unskilled labour who empty the harvesting container on to a heap 'of fruit in the field where it is exposed to the heat of the day. Fruit with more field heat, is likely to be damaged than pre-cooled and correctly packed produce. Five minutes exposure of fruit to sunlight increases the rate of decay and after two hours decay may become very severe, rendering the fruit some time un-marketable.

Mango Quality Standard

Minimum requirements

All fruit must be whole and intact. Fruit should be firm, clean, free from .back stains or trails on the skin surface, free from serious bruises and with no damages, sound no traces of diseases, fresh appearance, free of pests, free of foreign smell or taste and with short stalk.

10.1.1. Class I. Good Quality

Slight defect of shape and slight skin defects due to rubbing, sunburn, suberized stains or healed bruises up to a maximum of 3 cm2. Typical of the variety in development and color.

10.1.2. Class II. Reasonable Quality

Defect of shape, skin defects due to rubbing, sunburn, subersized stains, or healed bruises up to a maximum of 5 cm2 .Must be uniform in colour May have scattered rusty colored lenticels.

Grading and Packing

In this process mangoes should be graded to remove immature, undersized, damaged, bruised, scared or ripe fruit.

Mangoes that are to be exported to markets requiring fruit fly control procedures are treated after the washing process. The exporter should check the exact requirements for the operations specified by the importing market, including the treatment, equipment, and verification.

In most cases, mangoes should be packed with the stem end facing downward or slightly to one side, rather than directly on the base. This method does not display the red blush for those markets requiring it. However, because mangoes normally soften from the base, in long-term storage the method helps prevent bruising when ripening begins during shipment. Individual labels can be attached to the fruit for appearance and recognition.

Grading on the Basis of Size

Size Group	Weight in GMS	Maximum difference between largest and smallest fruit in any package
A	200-350	75 GMS
B	351-500	100 GMS
C	501-800	124 GMS

Packing

Export cartons should be made of long fiberboard, pure Kraft paper and good fluting. The design must have good strength in the corners to take the necessary loading, good ventilation and be a standard design.

10.2. POSTHARVEST TECHNOLOGY FOR THE SHELF LIFE EXTENSION OF MANGOES

Dr. Waseem Ahmed Farooqi

10.2.1. ABSTRACT

Mangoes like other fruits do not cease their metabolic activities even after harvest. Mangoes generally get deteriorated due to loss of water, faster rate of respiration, occurrence of physiological disorders and incidence of diseases: Post harvest techniques like antifungal treatment, wax-coating, gamma irradiation

packing, controlled atmosphere, hypobaric storage and refrigeration can significantly enhance the shelf life of this delicate fruit if used in the light of recent scientific knowledge.

10.2.2. INTRODUCTIONS

Mangoes like other fruits continue their metabolic activities even after harvest. i.e. they consume oxygen (O_2) and produce carbon dioxide (CO_2), convert starch into sugars, develop yellow skin colour and flavour, etc. Therefore, handling of mangoes is more delicate than other agricultural produce.

The causes of mango spoilage are:

- Loss of moisture from the fruit either through surface evaporation, transpiration and/or respiration which result in shrivellage ultimately deteriorating the appearance.
- Faster rate of respiration especially at higher temperatures resulting in early senescence.
- Incidence of physiological disorders like chilling-injury which deteriorate fruit appearance resulting in low market value.
- Attack of pathogens, i.e. fungi and bacteria resulting in fruit-rot.

10.2.3. LOSS REDUCING TECHNOLOGY

Considering the importance of mango fruit, efforts have been made in various parts of the world to minimize post harvest losses, which are:

Harvesting

Mangoes are generally picked when they are physiologically mature. This stage is indicated when few ripe fruits drop from tree, i.e. 'Tapka',

If the fruits are to be dispatched to distant markets, then they are harvested in hard green stage. The maturity standards are generally size and weight (according to the variety), acidity, total arytenoids and alcohol insoluble residues.

Mango picker consisting of a bambo; plastic or metallic pole attached with a knife and cloth bag, held open by a ring as used for harvesting. In no case the fruit should be allowed to fall on the ground, as any type of mechanical injury is likely to reduce the shelf-life of mango fruit.

- Gamma Irradiation

Gamma irradiation of mature hard green mangoes has been reported to delay their ripening. The optimum radiation dose has been reported as 250 -300 Gy which is a low dose radiation technology. Delay in ripening due to radiation has been reported from 3 to 5 days at room temperature. Higher doses may cause skin damage to the fruit.

10.2.4. CHEMICAL APPLICATIONS

Some of the chemicals (growth regulators, fumigants and fungicides have been reported to extend shelf -life of mangoes. Use of methyle hydrazide has given very encouraging results on the shelf life extension of mangoes. Maleic hydrazxide at a conc. of 1000 ppm has been reported to extend the shelf life of mangoes.

Phosphine is reported to retard the ripening of 'Keit' and 'Tommy Atkins' varieties. Methyl bromide is used as fumigant for mangoes as a quarantine treatment. Streptocycline, chloramphenical have been used to control decay, while betamaphthoxyacetic acid is to help to make the skin colour attractive with high carotine contents.

Hot Water Treatment

Hot water treatment (HWT) reduces fungal spoilage in mangoes especially anthracnose rot. HWT is generally done by dipping mangoes at 55 + 1 °C for 5 min. Effectiveness of this treatment can further be enhanced if it is combined with some antifungal treatment.

Packaging

Various types of traditional packages are used in different mango growing areas during transportation of this valuable fruit. Baskets and wooden crates are generally used as containers lined with straw or paper cuttings in the bottom and newsprint paper between the layers. The preference for such material is due to its availability at low cost. For better transport, especially in export business, perforated (ventilated) fiber board boxes, corrugated cardboard cartones are generally used. Tissue paper for individual wrapping, vinylite (R), Pliofilm (R) and polye thylene are also used.

Low-temperature Storage

Mangoes are susceptible to chilling-injury when they are stored at a temperature below about 10° C. Low temperature causes skin damage to the fruit in the form of pitting or 'scald' like discolouration of the skin as well as uneven ripening. This sensitivity of the fruit depends on many factors like variety maturity, the ecological factors where they are grown and also storage conditions. The cause of chilling-injury is that, in the metabolism of first at low temperature, there is the under production of certain essential or over production of some 'toxic' products. The chilled fruit has been reported to show less starch breakdown, decrease in the sugar contents (mainly sucrose), and less accumulation of ascorbic acid. Accumulation of minerals in the chilled peel tissue has also been reported. Precooling helps to increase the shelf-life of mango fruit.

Controlled Atmosphere Storage

The rate of respiration and general metabolism of mango fruit can be altered not only by varying storage temperature but also by varying the conc. of O_2 and CO_2 gases in the external atmosphere. This technique is termed as 'gas storage' or controlled atmosphere (CA) storage. The desired situation can be achieved either by reducing the conc. of O_2 or increase in CO_2 or combination. Mangoes (cv. Alphanso) stored for 5 weeks, ripened normally within 3 days when removed to higher temperature. Best results, however, have been reported in 5% O_2 + 5% CO_2 for 3 week storage. It may be remembered that at higher conc. of CO2 skin injury to mango fruit may develop and fermentation of aldehyde and alcohol produced may become a problem. Therefore, maintaining critical level of 02 in the storage atmosphere is essential from quality point which is dependent upon storage temperature. It has been reported that storage of mangoes in as atmosphere of 5% CO_2 + 2% O_2' the fruit remained in same condition for 3 weeks at 14 °C and they ripened normally in 5 days at 25 °C. Mangoes were kept in hard green state for 13 days at 20 °C but failed to ripen normal in air the reason for which may be the different supply of O_2 to the tissue.

Additional research work on the CA storage of mangoes is necessary to get practical benefit out of this technology for shelf life extension. Arrangements should also be made for the removal of C_2H_4 from the storage atmosphere.

Hypobaric Storage

Low pressure (LP) storage or hypobaric storage is a patented process which has a positive effect on the shelf life extension of many fruits and vegetables. In Florida, studies on LP storage on 'Irwin', 'Tommy Atkins', 'Kent' and 'keilt' varieties of mangoes have shown promising results. Shelf life of mangos can, therefore, be obtained by reducing the pressure in storage normal. In a study, when mangoes were stored at 100 mm Hg for 15 days at 30° C (increase of 10 days in the shelf life). Mangoes stored under LP remain green as (delayed ripening) compared to control. Due to high humidity, the decay % is likely to increase significantly; therefore, this treatment should be combined with some antifungal application.

10.2.5. RESEARCH WORK DONE AT NIAB

Studies on post harvest aspect (shelf life extension) on some commercial varieties of mangoes was carried out at NIAB; the results of which are briefly described as under:

i) Effect of Gamma Irradiation

Gamma Irradiation from CO60 on hard green mangoes (cv: 'Desi', 'Muhammadwala', 'SamarBahisht') has shown that a dose of 300 GY can double the shelf life of this fruit without any damage to the appearance, nutritive value, taste and flavour. Higher radiation doses cause phytotoxic effect.

ii) Wax-Coating

Wax coating of mangoes (cv. Sammar Bahisht) can also delay the ripening of this fruit. The quality of waxed fruit, however, depend on the thickness of wax-coat storage environment. A thick wax coat may cause anaerobic respiration (especially at higher temperatures) resulting in the development of "off-flavour".

iii) Effect of Chemicals

Studies on the use of maleic hydrazide (1000 -1500, 2000 ppm) on Sammar Bahisht) mangoes have shown that delay in the ripening by 3-4 days at 230 -300 can be obtained at a conc. of 1000 ppm. If this treatment is combined with gamma irradiation, a synergistic effect was observed.

iv) Antifungal Treatment

Research carried out on the postharvest application of Thiabendazole, Benlate, Captan and Antracol did not show any significant effect on the control of rot during storage (especially anthracnose), however, HWT (550 for 5 min) alone and in combination with gamma irradiation showed a significant decrease in the incidence of rot during storage.

v) Effect of C. A. Storage

Effect of N_2 atmosphere on the shelf life extension of langra mangoes

was carried out which showed that mangoes remained in hard green condition under the N2 atmosphere for 2 weeks but failed to ripen normally when transferred to normal air. The probable reason for this disorder was the unavailability of critical level of O_2 to mango tissue during storage.

vi) Effect of Packaging

A study on the packaging material on the quality of mangoes during storage was carried out in which tissue paper, newsprint paper, wax paper, and polyethylene (PE) film were used. The results showed that the use of PE significantly reduced weight loss followed by wax paper used as liner for wooden crate.

vii) Effect of Low Temperature

In a study on 'Sammar Bahisht' and 'Sensation' mangoes during refrigerated storage at 6, 9 and 12 °C for 4-16 days, it was found that 'Sensation' mangoes grown in Punjab were more sensitive to postharvest chilling than 'sammar bahisht' mangoes grown under similar ecnlogical conditions.

10.2.6. References

For more details the readers are suggested to consult the following literature:

1. Ali, M; W. A. Farooqi and A. Muhammad. 1968 Preservation of mangoes (Mangifera indica L) by gamma irradiation (In French) Food Irrad. 9,8.
2. Aziz, A; S. M. El-Nabawy; A. S. Abdil Kader and F. K. Wahab. 1977. Effect of chilling and non-chilling temperatures on some chemical compounds of mango fruits. Egypt. J. Hart. 2, 173.
3. Burg, S.P. 1967. Method for storing fruit. U.S. Pat. 3,333,967.
4. Burg, S.P. 1975. Hypobaric storage and transportation of fresh fruits and vegetables. IN : Postharvest biology and handling of fruits and vegetables. AVI Pub. Co. Inc. Westport C.T. pp. 172-188
5. W. B. and P. B. Mathur. 1959. Effect of Postharvest treatment with growth regulators on the ripenng of mangoes. Hort .Adv. 3, 108.
6. Deol, I. S. and S. S. Bhullar. 1972. Effect of wrappers and growth regulators on the storage life of mango fruits. Pb. Hort. J. 12, 114.
7. Farooqi, W. A. 1974. Controlled atmosphere storage of fresh fruits and vegetables. Pak. J. Sci. 28, 79.
8. Farooqi, W. A. M; Ahmad; A. Hussain and A. M. Hussain.1974. Effect of gamma radiation on mangoes (Mangifera indica L.) stored under different conditions. J. Agri. Res. 12, 31.

9. Farooqi, W. A. and M. J. Qureshi,1 976. Postharvest chilling of fruits and vegetables. Pak. J. Sci. 28, 79.

10. Farooqi, W. A. and M. Ahmad. 1980, Postharvest studies on citrus and mangoes. Proc. Nt In Dehydration Pres. of veg. & fruits, Fsld Nov. 23, (by ATDO) pp. 40-46.

11. Farooqi, W. A. 1982. Modern trends in maintaining the freshness of mangoes (In Undu). Sem. on Mango Production held in Multan Aug. 1 (Tech. Paper) 6. p.

12. Farooqi, W. A. A. Sattar. K. Daud and M. Hussain. 1985. Studies on the postharvest chilling sensitivity of mango fruit (Mangifera *indica L.)* Proc. Fla. State Hort. Soc. 98, 220.

13. Hatton, T. T. and W. F. Reeder. 1 965. Controlled atmosphere storage of 'Keit' mangoes.Proc. Am. Soc. Hort. Sci. 10, 114.

14. Murthy, S. K. and K. P. G. Rao, 1982. Regulation of ripening by chemicals in Alphanso mango. sci. Hortic. 16, 179.

15. Rashid, A. and W. A, Farooqi. 1984. Studies on the effects of gamma irradiation and maleic hydrazide on the shelf-life of mangoes. J. Agri. Res. 22, 151.

16. Salankhe, D. K. and B. B. Desai. 1986. Postharvest Biotechnology of Fruits. Vol. I. CRC Press Florida USA, pp. 77-84.

17. Spalding, D. H. and W. F. Reeder. 1972. Postharvest disorders of mangoes as affected by fungicides and heat treatments. Plant Dis. Rept. 56, 751.

18. Spalding, D. H., C. A. Benschoter ; D. L. Von. Windegutte, J. R. King; W. F. Reeder and A. J. Burditt, Jr. 1977. Methylbromide and phosphine fumigation injury to avocado and mangoes. Proc. Fla. State Hort. Soc. 90, 268.

19. Spalding, D. H. and W. F. Reeder. 1977. Low pressure (hypobaric) Storage of mangoes. J. Am. Soc. Hort. Sci. 102, 367.

20. Thomas, P. and M. T. Janave. 1973. Polyphenol oxidase activity and browning of mango fruits induced by gamma irradiation. J. Food. Sci. 18, 1149.

10.3. MANGO MARKETING FOR DOMESTIC AND EXPORT SECTORS

Mr. John Seymour

10.3.1. Abstract

To search out the variety wise market before production, is necessary. The appropriate production of mango requires the proper seed selection, propagation, irrigation, pest and disease control, proper harvesting techniques at right time of harvest and handling of fruit from orchard to market are important. After proper grading it should be loaded for cold storage and it should be free of disease and of proper size. Wrapping material should be used while packing in wooden boxes. The over loading should be avoided to save the mango from damage.

The facilities at airport and docks are not satisfactory for the transportation of fresh fruit, these should be improved. Produce is also damaged due to poor facilities available at whole sale level in Pakistan, So the whole sale markets are in urgent need of modernization.

10.3.2. Introduction

Mango are a high value horticultural crop which needs very careful post harvest handling.

It is also important to point out that growing mangoes requires expert technical knowledge.

Marketing can only present the crop grown it cannot make a good returns out of a poor crop.

10.3.3. Background

At present mangoes are mainly sold to contractors who harvest the crop as and when labour is available.

The correct harvesting time is critically important in order to maximize the shelf life of the fruit.

The fruit has to be harvested when it fully developed and before the ripening process has commenced.

The mango is harvested throughout the day when in fact it should only be harvested in the cool periods, early in the morning.

The fruit at present is packed in wooden boxes and left with the field heat in it. This means the fruit ripens far to quickly. The wooden boxes are over packed and the lids forced on, which means all fruit within the box are damaged. The damage is not obvious at the time of packing but manifests itself at a later stage of distribution.

From enquiries made there does not appear to be any consideration given to the length of time the produce will be in the distribution chain.

Quite frequently carbon is used as a ripening agent, this chemical is illegal in international trading and highly dangerous for domestic use. It has been reported that many packers in processing plants suffer skin damage as a result of the use of this chemical. It is the crudest form of ripening known and in the long term will only damage the mango industry. Many exporters buy their mangoes from wholesale markets and repack the fruit.

On occasions the damage caused by over packing and bad handling, is not clearly visible. Samples of mangoes seen in Europe and Gulf all show considerable signs of this over packing and also bad handling. Most exports are in 2.5 kilo and 5 kilo fibredoard boxes. In the majority of cases exporters have not studied international marketing requirements. The major complaints by importers throughout the world is poor quality, lack of shelf life, poor packaging and continuity of quality and supply. It has been observed whilst visiting exporters that the only grading is sorting out the poor quality produce for the bottom of the boxes and the best fruit on top. People should realize that this type of marketing fools nobody and as a result all exporters from countries that allow this practice suffer. It should be realized that mangoes are available from many countries, many of them developing countries similar to Pakistan, but whose exporters wish to build up a long term export industry so they Supply the importer honestly with what he requires.

The quality of fruit grown in many countries is not comparable with that grown in Pakistan for taste and flavour, but it is supplied uniformly graded in Containers that importers required and state ripeness that permits the importer a reasonable amount of time to market successfully. ;

Domestic Marketing

In order to maximize crops returns the following procedures must be carried out.

Identification of Markets

It is essential to research the market before starting production. In the past crops have been grown and then a market sought. Apples and apricots have been grown in areas that are inaccessible for transporting to market. Strawberries and Asparagus have been grown for processing only to find that there is no trade for the processed products.

Growing Right Variety

When researching markets it is important to see which variety are selling at a premium price. Persimmons is a classic example of the wrong variety being grown. The world market require a non-Astringent variety, the main variety grown in Pakistan is an astringent seedless variety. Kinno which is one of the most widely grown varieties of citrus (and individual to Pakistan) would have far more export potential if a seedless strain could be developed.

Crop Management

Once a cropping programme has been planned, it is essential that good crop management should be enforced at all stages of production. This includes seed selection, propagation, irrigation and pest and 'disease control. Better crop management will result in the production of a higher percentage of good quality fruit and vegetables.

Harvesting

The major post harvest operation is harvesting at the right time. The time of harvest is critical when fruit is going into store. The fruit going into store should be fully developed, having reached the climacteric point when developments ceases and maturity starts. Fruit and vegetables can be damaged by bad harvesting techniques, the damage only becomes evident at a later stage when bruising and breakdown become evident.

Handling

The handling of fruit and vegetables, from the field or orchard, to the packing point should be carefully carried out. Too many time fruit is carefully picked by experienced pickers only to be damaged by unskilled labour emptying the harvesting containers on to a heap of fruit at the headland or packing area. The transporting of fruit and vegetables to packing areas should be supervised. Fruit and vegetables with the field heat in them are more liable to damage than pre-cooled and correctly packed produce. (*Field heat* -Is the temperature of the flesh of the produce at the time of harvest). As with harvesting, any damage at this time may only become evident at a later stage.

Cooling (Removing of Field Heat)

All produce has correct storage and transporting temperature in order to maximize the shelf life of fresh produce. (*Shelf Life* -Is the time that produce remains in Good" condition after it has been harvested). There is very little cooling carried out in Pakistan, except for some vegetables which are washed in the canals and rivers. It is important to realize that for everyone degree produce is above its recommended temperature it looses one hour of it's shelf life every twenty four hours. There are many methods of cooling fruit and vegetables.

HYDRO-COLLING method is where the fruit or vegetables are passed through a tank of water, or sprayed with cooled water. Carrots and apples are two crops that can be successfully cooled by this method.

BLAST AIR COOLING is where cold air is blown over the produce. Melons, mangoes and citrus can be cooled using this method.

CRUSHED ICE can be used for cooling vegetables that have a low storage temperature.

COLD STORES can be used to pre-cool and store short and long term any crops. Onions, potatoes, apples and citrus could be cooled in pre-cooling chambers prior to loading into store. With all pre-cooling it is important that not only temperature be correct but also the percentage of humidity.

Grading into Cold Stores

It should always be remembered that only good quality produce should be loaded into cold stores. The produce should also be harvested at the correct time to maximise the storage life. No damaged, bruised or diseased produce should go into cold stores. Damaged fruit with the skin broken is very liable to secondary infection, with rot resulting. It is important with onions that the necks should be dried and sealed. All thick necked onions should be excluded from storage as they are liable to breakdown internally when stored. Produce not suitable for storage should be marketed locally.

Grading for quality and Size

The three factors of grading are for quality, size and continuity within the pack. First grade produce should be uniformly mature with consideration given to the time spent in distribution. It should be, free from pest, mechanical damage, disease and blemish. Produce should be of the same variety or type. Size should be uniform throughout the pack.

Packing and Packaging

It is important that great care should be taken when packing the produce. The major problem seen whilst in Pakistan has been over packing resulting in all produce within the container being bruised and damaged. Wrapping material should be used to protect fruit from the rough wooden containers. Protection should also be included between the layers of fruit and the top and bottom of the box. The purpose of the packaging is to protect the produce whilst in transit. Internationally and on the domestic markets in many countries packaging is used to promote the produce.

When using fibreboard it is essential to make certain the board is water resistant. Pakistan board tends to be soft and very absorbant with the result that it does not stand changes in temperature and high humidity conditions. The jute sacks used for distribution of potatoes and onions are too large and often over packed with the result that vegetables are damaged within the sacks.

It is not possible for the buyer to see the contents of the sacks many countries have started using plastic nets which enables the buyer to see the contents. These nets are produced in Pakistan for export throughout the world. '

Transportation

Many forms of transport are used to move produce from the farm to markets. Very little consideration is given to the damage caused by the use of incorrect methods of transport.

Another major cause of damage is the overloading of vehicles resulting in the produce o at the bottom of the vehicle being badly bruised or crushed The loads are poor for the transportation of fresh produce and these conditions are not improved by the frequent use of sleeping policemen

Both shipping and air freighting need to be modernized and the latest techniques used in order that produce arrives in good condition. The facilities at airports and docks are not satisfactory for the transportation of fresh produce.

Produce is sometimes left in the sun for many hours prior to loading into hot metal containers prior to air freighting.

Marketing

The wholesale markets throughout Pakistan are in urgent need of modernization.

Produce is damaged because of poor facilities available at wholesale level.

The produce is often stored in the open and subject to prevailing weather conditions which may be extreme hot or wet.

Growers should send produce to markets that have a large turnover so that the time spent on the wholesale market is kept to a minimum.

Cooling, Storage and Transportation

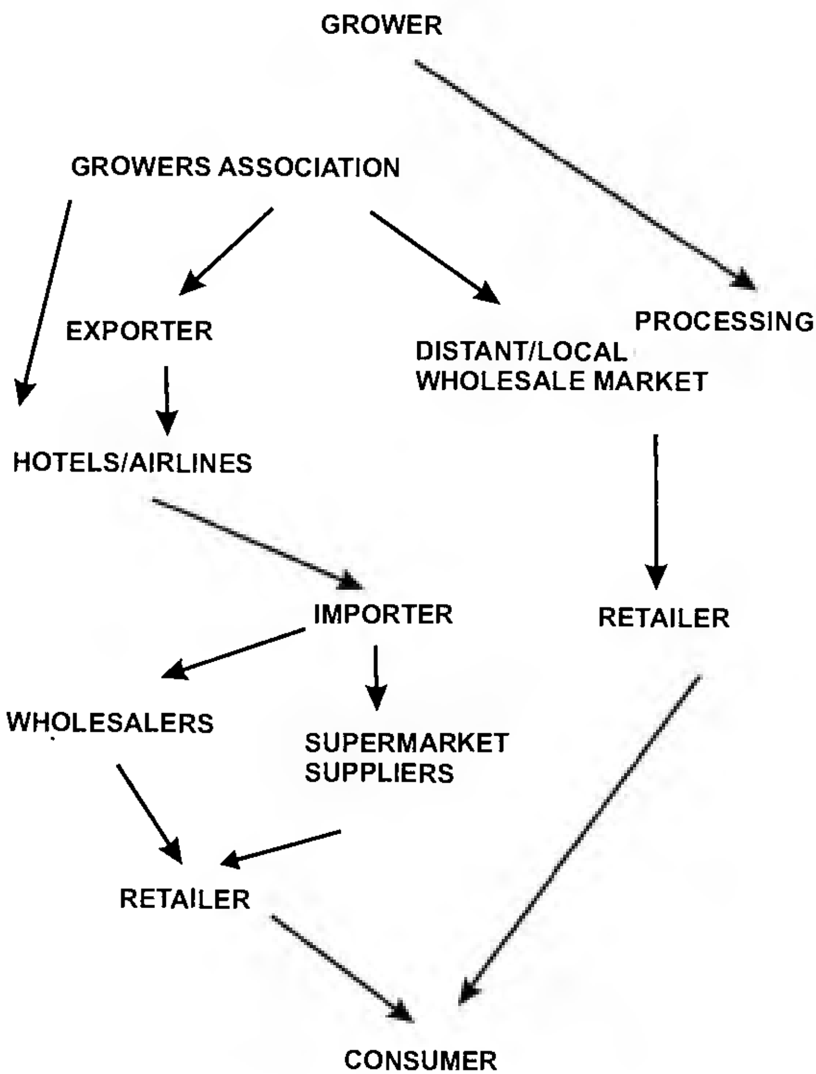
It should be pointed out that many world markets are supplied by mango growers who ship mangoes in correct conditions.

The transport and storage conditions are as follows:

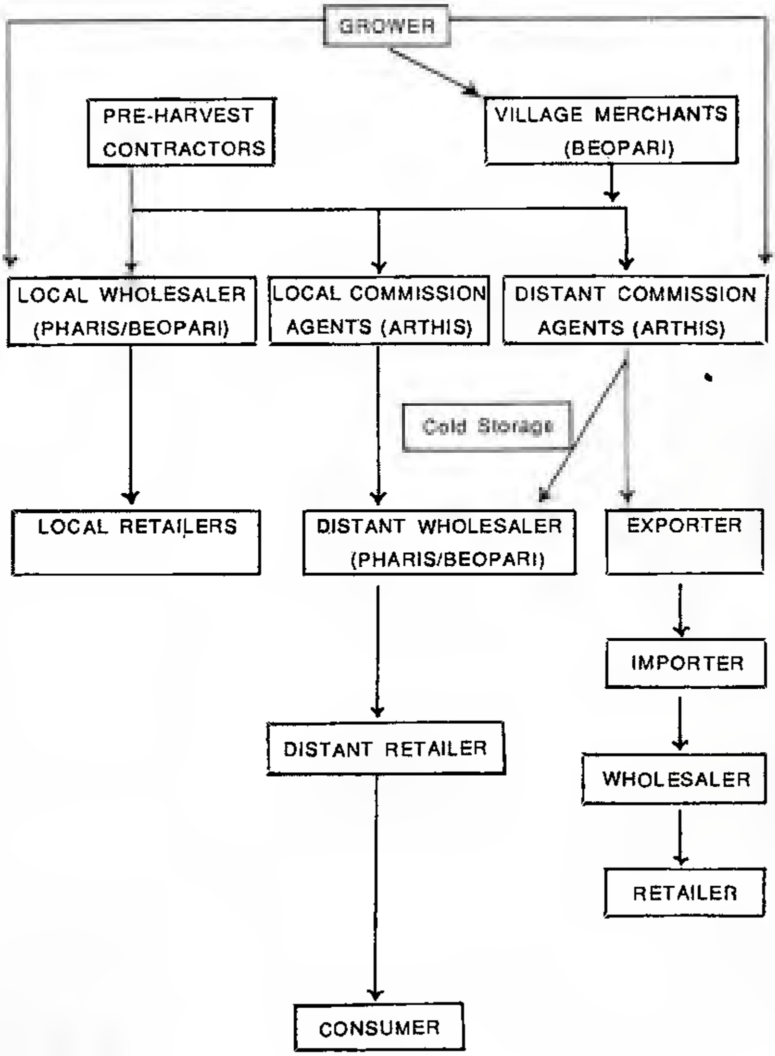
Variety	Degree C	Degree F	Humidity	Storage Period
Alphonso, India	7 – 9	45 – 48	90	7 Weeks
U.S.A.	13	55	90	2-3 "
Banglore, Safeda	5.5 – 7	42 – 45	90	7 "
Haden	12 – 14	54 – 57	90	2 "
Julie	11 – 12	52 – 54	90	2 "
Keitt	12 – 14	54 – 57	90	2 "
Neelum, Raspuri	5.5 – 9	42 – 48	90	5 – 6 "
Zill	10	50	90	3 "

Advantage of Growers Marketing Associations

IDEAL MARKETING CHAIN



DISTRIBUTION OF FRESH PRODUCE IN PAKISTAN



10.4. PREHARVEST CONDITIONS AND POSTHARVEST TREATMENTS AFFECTING THE INCIDENCE OF DECAY IN MANGO FRUITS DURING STORAGE

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10.4.1. Abstract

The quiescent infected area (QIA) by *Alternaria alternata*, cause of black spot, on mango fruit at harvest was closely related to the number of hours with RH 80% during a 52-day-period of fruit development. At least 350 h of RH 80% over 320 increased. A map of average daily maximum RH during fruit growth can be used as a basis for predicting the incidence of black spot in Israel.

The presence of the preformed, antifungal, 5-substituted resorcinols in fruit peel was reported in the past to affect the quiescent infection by *Alternaria alternata*. Treatments with 35% CO_2 for 24 hours at 20°C enhanced the level of antifungal compounds and delayed decay development.

10.4.2. Introduction

Alternaria alternata (Fr.) Keissler *(Alternaria* N ees) is the causal organism of the black spot disease of mango fruit *(Magifera indica* L.). The pathogen infects the fruit during the growing period and becomes quiescent soon after the initial stages of infection are completed (Droby *et al.*, 1986; Prusky *et al.*, 1980). *Mter* harvest, and as the fruit continue to ripen, the pathogen resumes growth, resulting in an active decay lesion (Droby *et al.* 1986). The presence of the mixture ofpreformed,'5-substituted resorcinols has been shown to be a critical factor affecting fruit resistance. The enhanced concentration of preformed compounds was already reported in other subtropical fruits. This approach represents a new possibility for the control of postharvest diseases.

Prusky *et al.* (1980) developed a quantitative assessment method for quiescent infections by *A. alternata* before harvest as a basis for the prediction of the incidence of postharvest decay during storage. They could quantify the quiescent infected area (QIA) by determining the percentage of infection by *A. alternata* of the sampled tissue and the area covered by the infection. The efficiency of this method was tested in two ways: (i) establishing different levels of QIA in one single grove with different regimes of preharvest fungicide Acta Horticulturae 341, 1993 Mango IV 307 treatment, and (ii) by collecting fruit from different groves with natural 'differences in QIA. In both cases, a significant correlation was observed between the QIA of the fruit at harvest and the incidence of decay during': storage (Prusky *et al.* 1983).

A. alternata is an ubiquitous pathogen present in all mango groves in Israel. It develops saprophytically in the grove on non-living organic matter; and in soil (Joly, 1967). Differences in the natural incidence of black spot in Israel can vary by a factor of almost 10 from stored mangoes in different: regions of Israel seems not to be directly related to topography and cultural practices. Different climatic parameters related to wetness or humidity regime affecting fruit in the grove may account for the differences in the QIA. These parameters include: relative humidity (RH), surface wetness duration and rainfall (World Meteorological Organization (W.M.O.) 1988). Rainfall has been reported to affect the incidence of quiescent infections by *Colletotrichum gloeosporioides* Penz in mango (Dodds *et al.* 1991). In Israel, however, mango fruit grow during a period of no rainfall. Dew is not a standard parameter for moisture determination (Rotem, J981), but it has been positively correlated with the development of epidemics caused by *A. solani* Sorauer in the desert region of Israel (Rotem, 1964). Measurements of surface wetness duration made at meteorological stations generally do not suffice for management of plant diseases. Surface wetness is difficult to measure well and has considerable spatial variability (Rotem, 1981); regular measurements of this parameter are not conducted in Israel. The most commonly used climatic parameter which reflects moisture is RH, especially the duration (in hours) at a range of RH or a above certain percentage of RH.

The present research was conducted to develop ways for the prevention of postharvest diseases. One way is by uncovering the relationship between the RH at critical periods during fruit development and the QIA of the fruit at harvest at different locations where mango is grown. The second way is to modulate the level of natural preformed antifungal compounds involved in resistance. Both approaches represent new ways for the prevention of postharvest diseases.

10.4.3. Materials and methods

Haden mango fruit were used in all the experiments. In experiments with CO_2 treatment, cv. Tommy Atkins was also used. Mango is grown in the southern desert, the southern coastal plain, the coastal plain, and the inland valleys in Israel (Table 10-1).

Table 10-1. Mango production regions in Israel and the corresponding meteorological stations

Region	Meteorological Station	Site of Mango Groves
Southern desert	Yotvata	Semer, Elot, Qetura
Southern Coastal plain	Havat haBesor	Gevulot, Nir Yizhaq, Zeelim, Mivtahim
Coastal plain	En haHoresh	Mishmar haSharon, M'barot, Bet Herut Kefar Yona, Kefar Hess
	Bet Dagan	Gan Rashel, Kefar haYaroq
	Lod	Nir Eliyyahu
Inland valleys	Mas'ada	En Gev
	Tirat Zevi	Kefar Ruppin

10.4.4. QIA and RH determinations

Quiescent infections by *A. alternata* in naturally infected mango fruit were assessed 7-10 days before the commercial harvest, according to the method described by Prusky *et al.* (1980). Ten fruit, each from different trees, were selected arbitrarily from orchards 0.3 hain size. The harvested fruit were washed thoroughly and discs of peel and flesh (5 mm diam, 4-6mm thick) were sampled. Discs were removed from six circular zones around the fruit at different distances from the stem end. The discs were surface-sterilized together. Discs from each fruit were arbitrarily placed, peel side down, in a petri dish containing potato dextrose agar with thiabendazole (20 ug a.i. ml^{-1}) and incubated at 25°C for 4 days. The QIA was estimated by calculating the product of the percent of infected discs of the fruit and $W^{2/3}$. The percent was expressed by values ranging from 0 to 1; $W^{2/3}$ weight of a single fruit, W, transformed into values proportional to its surface. (Monsenin, 1970)

The RH during the fruit growth period was recorded at regional agrometeorological stations, each representative of one to five experimental groves (Table 10-1). At each station the number of hours at a range of RH values or above a specific value was determined during 52 days of fruit growth, from 14 June to 7 August of each of three years. These dates represent the main growing period common to most groves in the various localities in Israel. The analysis was based on weekly charts of thermohygrographs (Lambrecht, FRG). The hourly RH data were assigned to five groups: RH-75%-79%, RH 80%-84%, RH $\geq$ 75%, RH $\geq$ 80%, and RH $\geq$ 75%. The length of the period with RH 75-79%, 80-85%, $\geq$75%, $\geq$80% and $\geq$85% at each meteorological station, was compared to the average QIA of fruit from groves located close to the station of that region utilizing Minitab analysis systems. Linear regression analyses for the average QIA of fruits from orchards close to the meteorological station, of the region were also performed to determine the effect of RH on the severity of infection. The level of significance reported herein is 0.05; probabilities >0.05 were considered to be not significant.

The average daily maximum RH for the month of July based on the last 20 yr was plotted on a map of Israel in order to identify the highly humid regions during the key month of mango fruit development. This climatic parameter was selected since these observations are routinely checked, processed and analyzed (I.M.S., 1983). Over 20 years, "normals" have been calculated for all stations. These values, have been used in this map. Data were available from stations and regions that represent the different agricultural locations of the country. Isolines representing 70,75,80,85 and 90% RH were superimposed on the map.

10.4.5. Antifungal compound extracts and CO_2 treatments

The 5-substituted resorcinols were isolated from crude extracts by flash chromatography. The mixture was further purified and assayed quantitatively by high performance liquid chromatography on a Varian model 5000 liquid chromatograph with a 25x1cm column, 7 mm RP-18 (Merck), as described by Droby *et al.* (1986). Concentrations of the substituted resorcinol mixtures were calculated on a relative concentration basis.

Approximately 12-24 h after harvest, fruits were placed in 15-1 sealed jars through which passed a stream of air containing different CO_2 concentrations at a flow rate of 100 ml min for 24 h. CO_2 and air were obtained from commercial high pressure cylinders. The outlet of the jars passed to the outside of the storeroom, which was maintained at 20 C. Control fruits were stored in similar jars under a stream of air. 5-substituted resorcinols were assessed on removal of fruit from the jars and at daily intervals until the fruits were fully ripe.

CO_2 treatments were compared with the commercial fungicide threatment of 1500 μg ml^{-1} a.i. Prochloraz (0.2%). CO_2 and O_2 concentrations were monitored by gas chromatography (GC) using a thermal conductivity detector after passage through a Poropak Q molecular sieve column. Helium served as the carrier gas.

10.4.6. Results

The effect of RH on QIA

Relationship between the duration of RH above specific values and the quiescent Alternaria-infected area. The regression equation for an RH of 75-79% was y=55.5-0.399x (R^2=0.12); for an RH 80-84% was y=18.1-0.007x (R2=0.001);'for an RH $\geq$75% was y=-

34.5+0.0876x, (R2=0.69*); for an RH -80% was y=27 .3+0.09x, (R^2=0. 74*) and for an RH ≥85% was y=-10.1+0.078x (R^2=0.65) where x represents hours of RH and y=AIA. (P-0.05). Based on these results, values of RH 80 were used to predict QIA.

Relation between number of hours with ≥80% and the incidence of quiescent alternaria infections : The incidence of QIA was closely related to the number of hours with RH ≥80% (Table 10-2). QIA was not recorded on fruit from the southern desert's Yotvata meteorological station during the 3 yr of observation; the number of hours with RH ≥80% during the period of fruit growth ranged between 12 and 17. When the number of hours with RH ≥80% reached 350, QIA was not observed on fruit from groves located close to the meteorological stations of Mas'ada and Tirat Zevi. QIA was initially observed in fruits in other groves with at least 350 h of RH ≥80%. As the number of hours ≥80% increased above 350, the incidence of QIA increased as well, except the groves of the southern coastal plain located close to the Havat haBesor meteorological station. The incidence of QIA in this region is very high considering the intermediate level of hours with RH ≥80%, 354 h. When the groves of the southern coastal plain were included in the correlation analysis, the correlation coefficient was only r=0.55 (n= 18). This coefficient is lower than that obtained when the correlation excluded groves located close to the Havat haBesor meteorological .I , station (r=0.87, n= 15) (Figure 10-1).

Relation between the average daily maximum RH in July and the incidence of QIA : The standard deviation of the maximal RH values during 20 summers was less than 1-2% (data not shown). The quiescent infections were significantly affected by areas with ≥85% RH and, specifically, ≥90% RH, (Figure. 10-2). Areas covered by isolines of 80% RH and below did not show any incidence of QIA.

Figure 10-1. Correlations between the number of hours during the period of mango fruit development with RH ≥80% and quiescent infected area (QIA) at harvest. ______, indicates the data obtained from groves in the vicinity of the meteorological stations at ., En haHoresh; o Bet Dagan; ;Δ Lod ♣AMa'sada; Tirat Zevi; ▌Havat haBesor. n=18. ----- Indicates the same data but excluding groves located close to the Havat baBesor meteorological station (Gevulot, Nir Yizhag, Ze'elim and Mivtahim). Plain symbols indicate results obtained during 1983; ---over symbols indicates results obtained during 1984; and / indicates results obtained during 1985

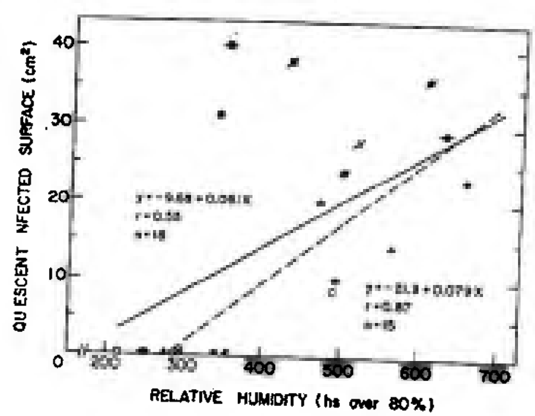
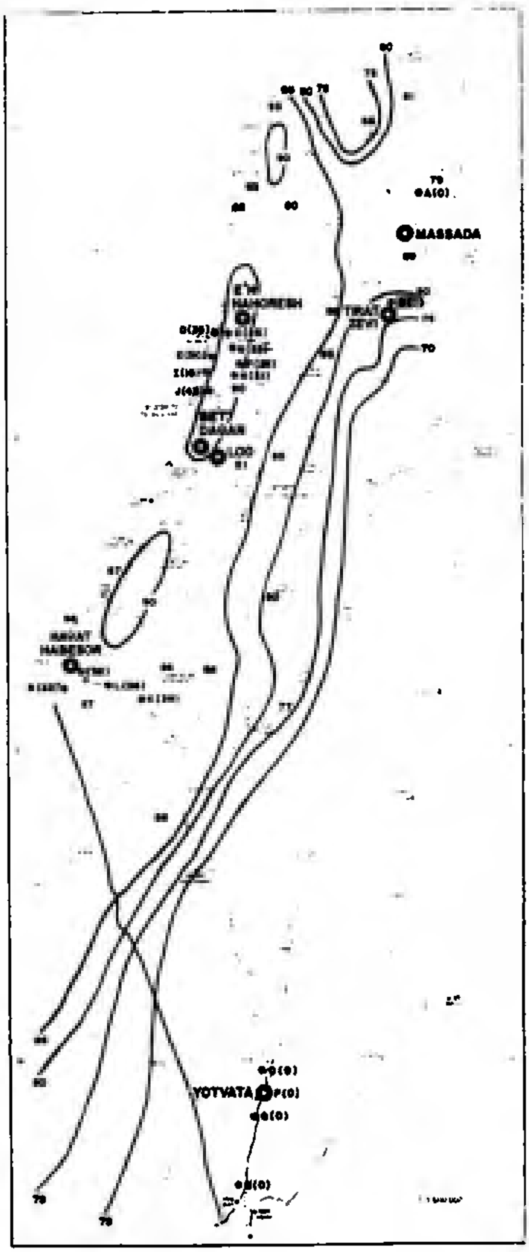


Figure 10-2. Isolines of average (20 yr) daily maximum RH in July (and average (3 yr) QIA of *Alternaria alternata* at harvest in various groves) throughout Israel. A, En Gedi; B, Kefar Ruppin; C. Mishmar haSharon; D, Bet Herut; E, Ma'barot; F, Kefar Hess; G, Kefar Yona; H, Nir Eliyyahu; I, Gan Rashel; J, Kefar haYaroq; K, Ze'elim; L, Gevulot; M, Mivtahim; N, Nir Yizhag; 0, Qetura; P, Yotvata; Q, Semer; R, Elot.



10.5. EFFECT OF POSTHARVEST CO_2 TREATMENTS ON FRUIT RESISTANCE

Exposure of Haden mangos to 35% CO_2 enhanced the level of the 5-substituted resorcinols almost ten folds compared to the integration area present in ripe fruits. This effect was observed between the 3[rd] and 4[th] day after treatment and delayed the development of black spot during storage (Figure. 10-3). Decay development on cv. Tommy Atkins was also prevented by a treatment with 35% CO_2 (data not shown). But when more mature fruits were harvested 7 days later from the same orchard there was a reduction in the efficiency of the CO_2 treatment for decay prevention. None of these treatments affected the taste of ripened fruits.

A dip treatment in the fungicide prochloraz delayed the appearance of the black spot disease more significantly than did the CO_2 treatment (Figure. 10-4).

Figure 10-3. Relative concentration of the antifungal 5-substituted resorcinols and decay development by *Alternaria alternata* in mango fruits cv. Haden. CO_2 was applied during 24 hrs at a concentration of 35%.

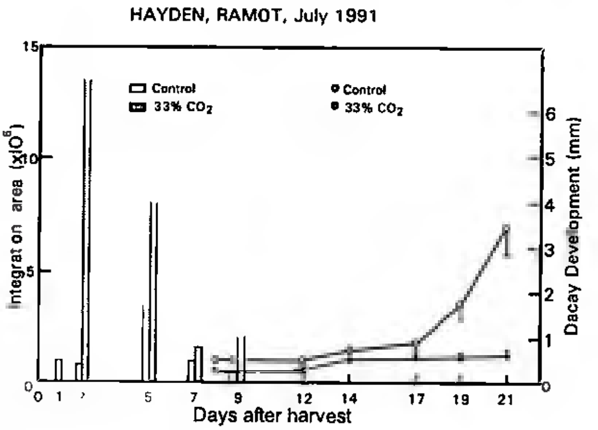
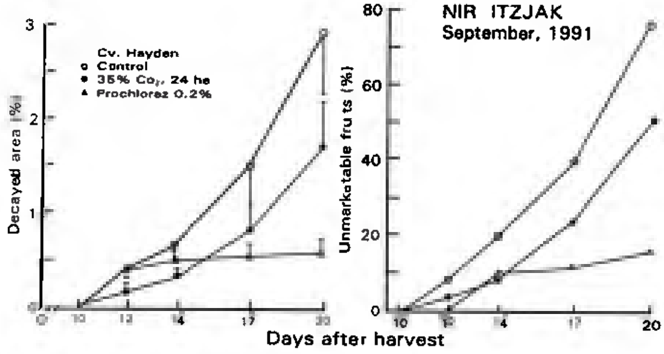


Figure 10-4. Decay development of *Alternaria alternata* in mango fruits cv. Haden after threated with either 35% CO_2 or the fungicide Prochloraz.



10.5.1. . Discussion

Black spot of mango caused by *A. alternata* has been increasingly reported as a postharvest disease during fruit storage. The fungus causes symptoms similar to those produced by C. *gloeosporioides* (Dodds *et al.* 1991.). Differences in disease incidence of stored mangoes in various regions of Israel reflect the incidence of QIA on fruit from those locations (Prusky *et al.*, 1983).

Infection by Alternaria is heavily dependent on moisture (Rotem, 1964 and 1978). Except for powdery mildews and some wound pathogens, a film of free moisture on the host surface is essential for infection by most pathogens (Rotem, 1978). In this study the RH obtained at regional meteorological stations was compared with the level of QIA by *A. alternaria* in adjacent mango orchards. The exact relationship between both parameters under field conditions was not determined since RH was measured at a meteurological station and not at the fruit surface. However, a significant correlation exists between the maximum RH in the orchards and at the meteorological station (Lomas *et al.*,. 1971). Measurements of the maximum RH at a meteorological t station and in an adjacent orchard in the coastal plain, differed only, by 1-4%. When the number of hours with RH 75-79%, 80-84%, ≥75%, and ≥85% from., groves in Israel was compared with the QIA of fruits, an RH over 80% gave the highest correlation with an R^2 of 0.74. It is not clear why the of hours at this; later RH gave a better correlation with QIA than did the number of hours with RH over 85%. Night temperatures during mango growth are sufficiently high for infection to occur (20-25 C) (Israel Meteorological Service, 1983). Under these conditions, several hours of marginal RH at 80-85% RH may facilitate' the development of the epidemic (Rotem, 1978). *Alternaria alternata* with spores extremely resistant to heat and desiccation is able to utilize dew for infection. *Alternaria* needs at least 350 h of RH ≥80% during the fruit-growing period to achieve a significant disease incidence on mango. As the number of hours increased over 350, there was a concomitant increase in the QIA. In the most humid locations, with 620 h of RH , the average QIA was 29 cm^2. Less humid locations in the same region, with only 493 humid hours, had a QIA of 14 cm^2. In the inland valleys, with 326 h of RH 80%, disease was not detected.

The southern coastal plain, represented by the meteorological station of Havat haBesor, had only 375 h with RH ≥80%, but groves had 30% more QIA. In that region an additional parameter seems to affect disease incidence. In this region, *A. alternata* infections could be significantly enhanced by winds and sand storms coming from the desert. The groves in the southern coastal plain are located only 10-40 km from the desert. Rotem (1965) reported that tomato plants exposed to sand storms had double the amount of wounds on the leaves, compared with non-exposed plants. The observations of Rotem and co- workers on disease epidemics of *Alternaria* in potato plant suggest that pathogen infection is enhanced by the presence of wounds caused by winds which occur during the afternoon in the southern coastal plain (Rotem, 1964, 1965 and 1981).

The average daily maximum RH is a standard measurement in meteorological stations. The duration of a certain RH values is not, however, routinely measured. Our intention was to develop a simple index that might correlate with the disease incidence of mango fruit at harvest. For that reason, a map of the daily average maximum RH of July regions was used to determine its effect on disease development. The regions with the greatest potential for disease are located close to the isolines of 85% to 90%; no risk regions (low potential) in the dry area with <70% RH; and intermediate regions at between 75% and 80% RH. The availability of such a map, together with a local QIA evaluation prior to harvest, should be of help in determining the need for postharvest treatment of the fruit and for locating potential new sites for mango production.

The usual method for control of postharvest disease in ripening mango is dip in Prochloraz (Prusky *et al* (1983). Droby and co-workers (1986) have Suggested that the endogenous was 5-substituted resorcinols are involved in the resistance of unripe mango fruits. The inhibition of the antifungal compound decrease during ripening and the development of the inhibited pathogen is resumed. In avocado fruits, where other antifungal compounds were observed, it was possible to enhance the concentration of the antifungal diene and the degree of fruit resistance to *Colletotrichum gloeosporioides* with CO_2 treatments (Prusky *et al.*, 1992). In mango fruits CO_2 treatment affected the level of the 5-substituted resorcinols and delayed decay development. The efficacy of this treatment seems to be dependent on concentration of CO_2, the duration of the treatment and the degree of maturity of the fruit. Through understanding and affecting the degree of resistance of ripening fruits, to postharvest pathogens, a new avenue for the control of postharvest diseases may be possible.

10.5.2. References

Dodds, J. C., Estrada, A. B., Matcham, J., Jeffries, P., and Jeger, M. J. 1991. The effect of climatic factors on *Colletotrichum gloeosporioides,* causal agent of mango anthracnose, in the Philippines. Plant Pathology 40: 568-575.

Droby, S., Prusky, D., Jacoby, B., and Goldman, A. 1986. Presence of an antifungal compound and its relation to the latency of *Alternaria alternata* in unripe peel of mango fruits. Physiol. Molec. Plant Pathol. 29:173-183.

Israel Meteorological Service, 1983. Averages of temperatures and relative humidity, 1964-1979. 41: 1-84. Bet Dagan, Israel.

Joly, P. 1967. Les pourritures noires des agrumes provoquees par les Alternaria. Fruits 22:89-95.

Lomas, J., Zilka, M., Gaat, Z., Stettiener, M. and Schleisinger, E. 1971. Macroclimate and microclimate, their measurement and relation to disease development. Mildews and Allied Fungi in an Arid Climate, With and Without the Aid of Irrigation. J. Rotem, J. Palti and J. Lomas, eds. Agric. Res. Org., Volcani Center.

Monsenin, N. 1970. Physical Properties of Plant and Animal Materials. Vol. 1. New York: Gordon and Breach Scientific Publishers. 734 pp.

Prusky, D., Fuchs, Y., and Yanko, U. 1983. Assessment of latent infections as a basis for the control of .pC1stharvest disease of mango. Plant Dis. 67:816-818.

Prusky, D., Fuchs, Y., and Zauberman, G. 1980. A method for preharvest assessment of latent infection in fruits. Ann. Appl. Biol. 98:79-85.

Prusky, D., Plumbley, R., and Kobiler, I. 1992. Modulation of natural resistance of avocado fruit by CO_2 treatments. Physiol. Mol. Plant Pathology. 39: 325-334.

Rotem, J. 1978. Climatic and weather influences on epidemics. In Plant Disease Academic Press, In NY., pp 317-337.

Rotem, J. 1964. The effect of weather on dispersal of Alternaria spores in a semi-arid region of Israel. Phytopathology 54:628-629.

Rotem, J. 1965. Sand and dust storms as factors leading to Alternaria blight epid.emics on potatoes and tomatoes. Agric. Meteorol. 2:281-288.

Rotem, J. 1981. fungal diseases of potato and tomato in the Negev Desert. Plant Dis. 65:315-318.

Sutton, J. C., Gillespie, T. J., and Hilderbrand, P. D. 1984. Monitoring weather factors in relation to plant disease. Plant Dis. 68:78-84.

World Meteorological Organization. 1988.

Agrometeorological aspects for operation of crop protection. (WMO- No. 687). Technical Note No. 192-1-165.

10.6. PACKAGING OF MANGOES FOR EXPORT

Tanwir Ahmad Khan, RD&C Department, Lahore

Mango (Mangifera Indica) is home-grown to Southern Asia probably originating in the Indo-Burma area thousands of years ago. It is said that more people eat mangoes than any other fruit in the: world as it grows abundantly in the parts of the world most heavily populated. The oblong shaped mango fruit varies in size among varieties, some fruits weighing as much as half kilogram. The fat, elliptical seed may comprise 7-20 % of the weight of the whole fruit. There has been a lot of emphasis to improve foreign exchange earning through export of agricultural products including fruits and vegetable. The share from the fresh produce up till now has not been very significant.

The changes that can take place between harvesting and consuming fresh produce are many. Some of these changes include:

1. Loss of water which result in wilting;
2. Ripening which results in changes (often desirable) of color, flavor and texture;
3. Ageing which results in excess softening;
4. The growth of shoots (e.g., sprouting in potatoes);
5. Spoilage due to microorganisms on the external surfaces.

Mangoes are often gathered before they are fully ripe. In the handling of fresh produce the temperature should be held as low as possible since this is the surest way of slowing the ageing processes and giving maximum shelf life.

Mangoes should be cooled as soon as possible after harvesting particularly if they are required to undergo long distance sea transport. The optimum storage temperature for most varieties is 13°C. A few varieties can tolerate 10°C or lower. The temperature should never fall below the figures stated, as this may result in chilling injuries. Mango has a moderate ethylene production rate but is very sensitive to it. Ethylene is a gas that triggers the ripening process. Due to the short shelf life, 2-3 weeks, mangoes are transported by air, ISO has issued an International Standard **"ISO 6660 Mango-storage 1 guide"** in this regard.

Packaging for mangoes should be constructed to allow for good ventilation. There is a market preference for the units that are around 2, 3 and 5 kg net, and contain variable count of fruit depending upon size. Fruit can be tightly packed without inserts or cushioning, provided the stacking strength of the package is sufficient. Where inserts are used they should be full height in order to obtain increased stacking strength at a moderate cost. Cushioning such as tissue paper underneath the fruits is an advantage. The mangoes are placed on the face in the corrugated boxes according to size. They should be packed one layer only. Five kilogram of mangoes requires approximately 8.5 to 9.5 L of internal space when packed without inserts, and approximately 11 to 13 L when packed in cell pack form. A recommendation for mangoes has been issued by UN/ECE:AGRI/WP.1/R.1

Handling and Storage of Mangoes

Packaging is an essential element in the' distribution of mangoes. Cultural practices, climates, seasons and areas Influence the quality and behavior of mangoes. Proper handling of mangoes requires knowledge in areas of harvesting, grading, packing, transport techniques, storage and shelf life etc. Mangoes have to be exported to targeted markets and diversified requirements of these perishables passing through a chain of complex distribution systems must be well understood to encounter the competitive market.

In many cases, it is observed that nearl half of the perishables produced on the farm are lost by the time these reach the market due to spoilage, inadequate storage and transport facilities. Quality products compete and sell in the export market exclusively. All the efforts, therefore, should be focused in achieving produce, which would be:

1. Of prime quality at the time of picking and stored properly .
2. Well packed and adheres to the quality standards.

Packaging has been defined as "The art of and the operations involved in the preparation of articles or commodities for carriage, storage and delivery to the consumer. A more simple but quite adequate definition is "A package must sell what it protects as well as Mango 'protect what it sells". A food package provides three basic functions: It protects the food, supplies it in convenient quantity for handling and stimulates sales.

To make a package marketable and stimulate sales it must be provided with a distinctive variable graphic image so that the type of food, its brand name and any special features could be emphasized.

The goods, which are not packed properly, can not be sold. Packaging materials must be of acceptable standards with regard to strength properties, protection and resistance to weather ability. It is very likely that one combination of material may not be suitable under different storage conditions. When considering for export purposes, tests have to be carried out to assess the conditions of handling and transportation,

Corrugated Packing

One of the constraints faced by Pakistani exporters is the mode of packaging acceptable to international markets and it is here that the corrugated packaging plays a predominant role. The corrugated box is by far the most common form of distribution packaging. It is considered to be one of the most widely used packaging materials. It provides structural protections as the erected boxes are self-supporting and also provide scuff or scratch protection.

Corrugated packaging, designed to conform to international standards of strength and performance, has contributed significantly to the exports especially in the fields of fruits & vegetables. In the years to come corrugated packaging will be a vital factor in ensuring Pakistan's increasing share in the world market.

Corrugated board is made from a variety of paper thickness or basis weight and can be classified by the fluting type. The fluting types that are normally used are B, C and E. As the height of flute changes, properties like compression strength and flat crush strength also change and in opposite direction. The types A, C, B & E are differentiated from each other on the basis of flute height as shown in the table given below.

- Corrugated board

Fluting Top of back Liners

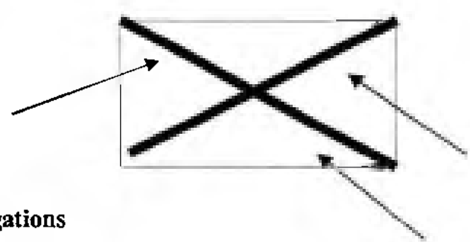


Table. Types of Corrugations

Flute	Flute height, mm	Average No. of flutes/meter	Average Medium take up factor	Top to bottom compression %	Flat crusb %
A	4.7	110	1.54	100	100
C	3.61	129	1.45	85	125
B	2.46	154	1.33	75	150
E	1.14	295	1.26	60	350

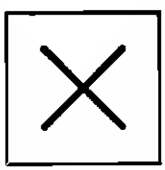
The role of fluting as spacer in corrugated board is important for its contribution' to flat crush-resistance, edge compression and bulge resistance. The thicker walled "A" flute makes containers with better top to bottom compression strength than "C" or "B" flutes but ,the thinner "B" flute makes board with better flat crush than either "A" "C". B is a: compromise having good compression strength with reasonable flat crush strength. The "E" flute is mainly used in the manufacture of heavy-duty folding cartons and display board.

Corrugated board can also be differentiated from one another on the basis of the number of liners and flutes that are used to make board. On this basis corrugated board generally divided into three categories .namely: single, double and triple wall. A single-wall board is produced using two liners and one fluting. A double-wall board consists of three liners and two flutings and a triple-wall board with four liners and three flutings.

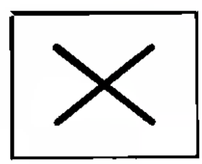
Strength properties are not only governed by the type of corrugated board and flute but are also influenced by the properties of paperboard used in the construction of corrugated containers. Laboratory tests are available for paperboard, corrugated board and corrugated boxes to predict the predominance of corrugated boxes in real life situations. , One of the major contributors to corrugated board's versatility is the ease with which flat sheets of corrugated board can be cut into immense range of package styles.

There are many box styles available, some have highly specialized features, and some vary in their application. The most common styles of box fall into category of slotted styles" a general term used to describe corrugated boxes made from a single sheet of board and delivered flat to end users. Slotted styles are easily set up, filled and closed, require a minimum of storage space, are suitable for a wide range of products. Of the slotted styles, the most widely used is one in which the major or long flaps meet at the centre. This box is still most commonly referred to as an R.S.C., which stands for regular slotted container. Some of the types of corrugated hoxes generally used are shown below. The dividers are some times used to physically separate items to be packed in one box from one another. Box dividers when properly designed also increase the stacking strength of corrugated boxes.

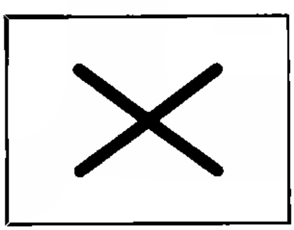
Stitched RSC



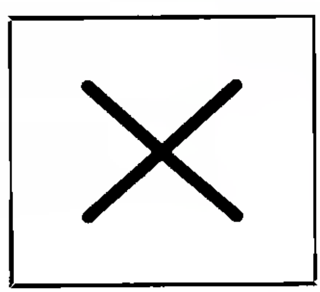
Corrugated box with lid



Telescoping to and bottom box



Box Dividers



The carton must withstand various types of external loading and handling, and must protect the contents and reach the consumer without damage. During transport and storage, cartons are usually stacked and suhjected to compression loading. The box compression strength requirement depends upon a number of factors:

1. The structural designs of carton, i.e., size and dimensions, supporting elements in the carton design, flap design, and loading direction.
2. Whether the contents support the package or not (fresh produce does not support).
3. Types of secondary packaging.
4. Transport storage methods and conditions (palletisation, stacking, climatic conditions).
5. Material properties such as stiffness and compression strength of the paperboard. - t When corrugated boxes are stacked, the maximum load occurs in the bottom layer: This" is the layer, which is most likely to collapse under the load. Fortunately risk of collapse can be estimated. The most important property of the material in this respect is the compression strength of corrugated board, which 'can be measured by using an "Edge Crush Tester".

Holes are frequently put in the side and end panels of corrugated board boxes for fresh fruits and vegetables to facilitate ventilation and handling. Such holes reduce the stacking strength of a box. The location of hole is critical with respect to the drop in strength associated with it. It has been shown that reduction in stacking strength is a maximum when material is removed from areas of concentrated stress, usually extending diagonally from the comers and from areas close to the horizontal and vertical edges of the box. In one study it has been shown that same .prop in stacking strength was observed when 3.6 % of the panel area was removed in one case and 24.8 % in another case 2. This clearly 1 shows the importance of the location of wholes in corrugated containers.

Moisture also reduces the stacking strength of boxes. This effect of moisture on stacking strength has been reported by levans[2] as given in the Table 10-2.

Table 10-2. Effect of moisture content on stacking strength of palletized boxes

RH%	Moisture %	Load at standard condition, % of compression strength		
		90 days life	180 days life	360 days life
50	7.5	60	55	51
65	10	43	40	37
75	12.5	32	29	27
80	15	23	21	20
85	17.5	16	15	14
90	20	12	11	11

This factor must also be considered before developing a corruwall container specification for the transportation of fresh produce such as Mangoes. Corrugated containers may be waxed or extrusion coated from inner side or outer side to make it water-resistant.

The best stacking pattern from the standpoint of box compression strength is vertical columns. They are most effective if the boxes are properly aligned. Interlocked stacking patterns are popular because they are more stable than vertical patterns. In an interlocked pattern, each layer is arranged in opposing directions to the layer below. However, the comers are not aligned: in fact, three or all four comers rest on the side panels of the box below. This results in a loss of 45 % to 55% of the compressive strength 3. This indicates the importance -of stacking pattern for the stacking of corrugated boxes.

In this article we have tried to highlight some of the factors that should be considered before finalizing specification for corrugated containers. Making a corrugated container is easy but making it right is rather difficult. It involves quite a bit of theoretical knowledge as well as proper laboratory facilities. In case of packaging of fresh produce like mangoes, especially for export, it is very important that the exporter selects the right packaging material to ensure safe handling and transportation.

10.6.1. References

1. Food Industries Manual 20th edition: by Anthony Woollen 1969, PP 375
2. Performance and Evaluation of Shipping Containers, Ed. George G. Maltenfort, PP 156-159
3. Fiber Box Handbook by Fibre Box Association, U.S.A.

10.7. MANGO EXPORT FROM PAKISTAN AND WTO REGIME ON FOOD AND AGRICULTURE

Dr. Wajid Hussain Pirzada, PARC, Islamabad

Mango Exporters of Mexico have benefited from such a proactive approach. Mexico used to export till mid nineties mangoes without any quality control. For example, in 1995 [alone] Mexico exported 30 million boxes of mango without resorting to quality standards. The Export Mango Packing Association [EMEX], realizing the challenge ahead got engaged proactively, with Mexican Research Center in Food & Development, for purpose of [quality] standards setting. In progressive economies, like Singapore, standards setting is carried out in private sector. which assists Government in quality management. Private sector in Pakistan too should embark upon this strategy.

10.7.1. [Mango] Health& hygiene and safety management

Diseases & Quarantine Laws: number of diseases affect mangoes such as Powdery mildew. anthracnose, sooty mold, root rot & rot of mangoes malformation of inflorescence etc. Some 86+ species of insect pests alone have been recorded on mango. Fruit fly. scale insects. mealy bug & hoppers are important. The conditions laid down by importing countries. in terms of disease control measures; such as quarantine [SPS] laws need to be met. Most of these countries have regulations aiming at protection of life & health of flora, fauna and human being. For example. under Biosecurity Act 1993, of New Zealand, there have been provided [explicit] import health standards for fresh mango [Mangifera indica]. And until and unless these import health standards under section 22 of the Biosecurity Act are satisfied, entry in to New Zealand of [all] plants & plant products is prohibited. Plant Protection Department. Government of Pakistan needs to engage in [proactive] dialogue with countries like New Zealand & Australia to harmonize .plant [mango] Protection measures. New Zealand in-the recent past has also introduced legislation. under Hazardous Substances Act 1996 that regulates deliberate introduction of new organisms including *inter alia* Genetically Modified Organisms [GMOs]. Relevant agencies in Pakistan like Ministry of Environment and Ministry of Food. Agriculture & Livestock need to study these regulations and coordinate with Risk Management Authority, Government of New Zealand. This shall help formulate national strategy on GMOs. The [se] quarantine laws address the issue(s) related to Regulated Pests [Actionable] those organisms for which phyto-sanitary actions would be undertaken, if they were intercepted or detected. These pests have been categorized. under the Act, into different groups. based on [possible level] of risk associated with these organisms. These groups are. Quarantine: Risk Group 1, 2 & 3 Pests Regulated non- quarantine pests and Regulated non-plant pests. Similarly Vectors -associated Quarantine Pests, Vectored Organisms. Strains [variants] of pests, Unidentifiable Organisms; and unlisted Organisms have been dealt with under the category of Regulated Pests in the Act. Under Non-regulated Pests [Non- actionable]-those organisms for which Phyto-sanitary actions would not be undertaken. if they were intercepted/detected; categories like Non-regulated non-quarantine pests. Non-regulated non-plant pests and Contaminants such as soil. leaf litter etc have been addressed. For example, lots with more than 25 gms of soil per 600 unit samples shall he treated, reshipped or even destroyed. Each [mango] consignment thus has to carry Phyto-sanitary Certificate from mango exporting country, stating specifically *interalia* that the mangoes have been inspected in accordance with appropriate official procedures and found to be free of visually detectable Regulated Pests, as specified by the New Zealand Ministry of Agriculture & Forestry. The aforementioned conditions are specific to mangoes imported from Philippines. Other countries need to enter in to [similar] bilateral quarantine arrangement such as agreement & work plan (s), with their trading .partners.

In addition to the [aforementioned] requirement of Phyto-sanitary Certification, there are [pre] conditions specific to: protection, packaging & shipping. materials, which for example under the New Zealand Biosecurity Act 1993. need to be inert/synthetic. Other preconditions could [possibly] relate to transit requirements e.g. mango must be packed & shipped in a manner to prevent contamination by Regulated Pests. Needless to underline that [mango] consignments, destined for target market. are expected to carry mangoes in intact form. color and at required level of maturity. For this, mangoes must have been carefully picked and have an appropriate degree of development & ripeness in accordance to the criteria appropriate to the variety and to the area in which these are grown. The state of ripeness must be such as to allow the fruit to withstand transport& handling' pressures, and thus arrive in satisfactory condition at the place of destination. The importing country [in this case New Zealand] will only issue Biosecurity Clearance, if she is satisfied that Regulated Pests are not detected and consignment is free of Contaminants.

10.7.2. Capacity Building Initiatives:

- Following initiatives can help huild trade capacity in mango [sub] sector:

- Mobilization of mango growers & exporters as Associations! Chambers.
- Credit Program for value-added exports.
- Investment in Mango R &D.
- Gene Banks.
- Disease control/disease free zones.
- Development of quality infrastructure.
- Grading/Export Standards.
- Training in quality management.
- Packing, packaging & labelling facilities Specific initiatives are to be taken- in the following areas:

10.7.3. Monitoring & surveillance of contaminants

1. **Contamination:** Food. as we know, itself is a good indicator of environment, in which it is produced. Because of urbanization and concomitant industrialization phenomena. risk of food being contaminated with industrial and other potential pollutants has increased. Surveillance & monitoring of contaminants alone help identify and avoid problems.

2. **Infestation:** Constraints on trade resulting from fruit fly especially needs to be managed through appropriate scientific methods. Disinfestation with ethylene dibromide 20 g/m3 for 2 hr was earlier recommended as a [possible] treatment for disinfestation for fruit fly. With the discouraging trends and [consequent upon that] phasing out of this chemical world wide since 1984, it has become imperative to find better alternatives. such as dips and packing line flood treatments with dimethoate (400 mg/L) or fenthion (400 mg/L). and gamma irradiation at 75 Gy. Heat treatments, particularly vapor heat are yet other alternatives. Irradiation and heat treatments are preferred for these are free of chemical residues. Improper & unsanitary handling practices e.g. washing with contaminated water are the leading cause of food borne diseases. Irradiation can serve to decontaminate the surface of these commodities. without residual effects associated with chemicals. It also slows down the ripening process, and can thus facilitate safer transportation to destined markets. Doses range from 0.15-1 kGy can be applied without appreciable loss of food quality.

3. **Value Addition:** Some of the value added [mango] products. other than pickles, preserves etc are different types of juice products: .100% pure or 100% juice.

- Cocktail. Punch. Drink & Beverage- less than 100% juice with added sweeteners.
- Fresh Squeezed Juices- not
- From Concentrate-reconstituted from Concentrate.
- Not from Concentrate-never been concentrated
- Fresh Frozen-freshly squeezed, packaged & frozen.

- Juice on refrigerated shelves- shelf stable products.
- Canned Juice-Heated & sealed Juice industry can be promoted through value addition and by adopting Hazard Analysis & Critical Control Points [HACCP]. Recommendations:
- Multan be declared and developed as Mango Export Zone
- Mango Development Fund be established [as a share out of [EPB] available sources; and financialsupport e.g. up to 25.000 per acre of plantation & nature of crop. may be provided for 5 years, on lines with Konkan India.
- Establish VHT, Irradiation. Cold Chain and Laboratory facilities at Multan.
- Packaging facility and tax holiday for value-added processing & exports may be provided.
- The mango traders need to seek help of professionals in popularizing -in a creative and
- aggressive manner -their firms/ products.
- Establish an immediate marketing presence in the destined market [even] prior to physical presence.
- Strengthen their position! linkages with their trading partners/agents.
- Affiliate with trade group. before they [even] open the office.
- Acquire the critical marketing tools-product information representation in trade fairs. web sites; and for this they need to begin now and act strategically.

(The author is Director/National Coordinator WTO-FARM @PARC and National SPS/TBT Enquiry Point).

10.8. INTERNATIONAL TRANSPORTATION REQUIREMENTS

John Seymour

10.8.1. Abstract

Mangoes are picked and packed within the orchard not at proper set stage of ripeness and with packing material generating excessive heat resulting deterioration and shrivel of fruit.

It is important that the fruit should be cooled, graded and then packed in suitable market packs and shipped in refrigerated containers. The major quantity of exported fresh produce from Pakistan is of wide variation in maturity, from over-ripe to immature fruit within the same box. The PIA is using the worst type of containers. Proper post harvest technology has to be adopted for getting good price.

10.8.2. Introduction

Mangoes and all fruits are living organism, and when being transported this must be taken into account. It must be remembered that in Pakistan some wholesale markets are over two days travel away from the growing area.

10.8.3. Background

At present mangoes are harvested, and packed. In many cases orchards are cleared, and not picked at a set stage of ripeness. This means that mangoes on the outside of the tree, exposed to the most sun, are more mature than fruit on the shaded area of the tree.

The fruit is packed hot in boxes often with dried grass or straw; as a result the heat has no chance of escaping. It is a proven scientific fact that heat generates heat, and fruit packed the way it is in Pakistan will only deteriorate very rapidly.

One of the major factors on the quality of exported fresh produce from Pakistan is a wide variation in maturity, from overripe to immature fruit within the same box. The second biggest problem in shrivel, because fruit has lost its condition as a result of being transported too hot, and transpiration has caused fruit to shrivel. Another reason fruit shrivels is because some fruit is harvested before it reaches its climax point of development. Fruit harvested in this condition will never ripen correctly.

10.9. TRANSPORTATION REQUIREMENTS

It should be pointed out that cool-chain distributed will only maintain temperature. It is also important to remember that each variety of mangoes have a different storage and transportation temperatures.

The fruit shall be pre-cooled and then graded and packed in suitable market packs which allow the fruit to breathe and maintain good condition. It is important to pack the fruit in the type of container that the importer requires. In Europe fruit is packed flat, and mainly in single layer trays, approximately 5 kilos per box.

The Far East prefers its fruit packed on end with foam rubber top and bottom, and honeycomb pack. The cool-chain transport should be loaded to allow air to freely circulate. If it is overloaded too high, the boxes at the top will suffer cold store damage as a result.

Mangoes are shipped from South to Europe by refrigerated containers.

Airline companies have special refrigerated containers. The metal containers that PIA uses are the worst type of containers to use. If hot fruit is packed in them and they are left in the sun, the fruit will cook. At Heathrow, London, a container of fruit and vegetable were inspected and found to be cooked as a result of using a metal container. The container had to be left and 1.5 hours before it could be unloaded. The produce was all condemned as unsuitable.

Certain fruit on long journeys have ethosorb packed in the containers. It absorbs the Etholyene gas given by fruit. The gas is a natural ripening agent, and if removed the ripentac process is delayed.

The same gas is used as a rapid ripening agent by supermarkets that can ripen and controls shelf life by gas mixture and cool chain distribution right through to the consumer.

10.10. COOLING OF MANGOES AND MANGO PRODUCTS

Max Bayer

10.10.1. Abstract

Mango is really not a fruit which reacts well to refrigeration. It presents severe technological problems in connection with refrigeration.

It changes colour, odour/flavour and taste on different temperatures and relative humidity with special reference to its various strains. However, mango must be stored under refrigerated conditions in order to enable export of sizeable tonnage.

Study done in Florida revealed that

1. Langra and Dasheri mangoes can be kept for 35 to 45 days under 7 °C and 85 to 90% relative humidity.
2. Alfanso mango can be kept for 32 days under 5 °C to 10 °C, 15% CO2 concentration at a relative humidity of 85 to 90%.

Different mango products can be kept and cooled under different methods of cooling.

10.10.2. Effect of Cooling on Mango Storage

10.10.3. Introduction

When one speaks of cooling with reference to mango, the consequences and the necessity for cooling is completely different on scope from other fruits. Apples for example are kept in refrigerated storage for months as a means of preservation.

Mango is harvested when mature and subjected to ripening, i.e. between 22 °C and 40 and 65 relative humidity depending on the ambient temperature in the area. Mango will ripen in a week and the edible for a few days.

In order to extend the storage life the method commonly used is refrigeration.

Mango, however, presents severe technological problems in connection with refrigeration.

Early research reported positive results from refrigerated storage did not attack the negative effect of past storage ripening. Temperature is the critical control point may change with culture.

- 15 °C -Inferior flavor and colour to
- < 15 °C -Ripening
- < 28 °C -Develop off flavours; reduction in storage life

Mango is really not a fruit which reacts well to refrigeration.

A. Effect of cooling Discoloration Pitted regions on the skin Non- uniform ripening High acidity -low sugar content
B. A Jekyll and Hyde situation

C. Mango must be stored under refrigerated conditions in order to enable export of any sizeable tonnage.

Some exhaustive research done in Florida on the kent mango. Mature fruit freshly harvested was stored at: 8 °C, 10 °C, 13 °C; with a relative humidity of 85 -90% for10, 16, 22 days.

Chilling injury occurred at all temperatures regardless of length of storage. When subjected to ripening, flavour deterioration was evident.

The upshot of this study indicated that temperatures less than 13 °C were critical to the development of injury in the KENT mango.

A similar study done on the Manila mango yielded chilling damage at temperatures of 16 °C. But at 25 °C and 80 -90fi relative humidity, the Manila mango showed decent organoleptic quantities.

It appeared evident that storing mangoes under refrigeration with subsequent ripening required studies for each mango culture.

Studies done on most Florida mangoes indicate an optimum storage temperature of 13 °c and a ripening temperature of 21°C -24 °C.

Studies done on the Langra and Dashehari mangoes showed at:

7 °C -85 -90% relative humidity for	35 -45 days
9 °C	25 -35 days

Subsequently ripened to an acceptable palatability. However, lower carotene content in the ripe fruit was noted subsequent to cool storage.

Alphanso mango was stored in atmosphere of 5, 10, and 15% CO2 conc. in air at 11.1 to 12.2 °c, at a relative humidity of 85 to 90% for 32 days.

This and other studies to date do not indicate the feasibility of this approach.

Uses of Mango

Hot or sweet pickles -From young mangoes, 4-6 weeks maturity.

Mango slices in syrup Nectar
Squash Juice Jam
Pickles
Chutney
Fruit Bar
Mango wafer
Mango powder
Dehydrated mango slices Mango pulp and puree
Heat processed, chem. Preserved, and Frozen
Mango custard (Baby food)
Mango Puree

Thermal processing -Most comm. Developed

A. 1. Poor stability during storage
   2. Irreg. productivity

3. Loss of flavour during storage

B. 1. Inadequate procedures for pulp extraction

2. Peeling of fruit and removal of pulp by hand not commercially feasible

3. Some places use Lye/steam to peel Brush pulpers, centrifuges, paddle pulpers

C. Requires less labour and can be used to manufacture other products such as jams, jellies, beverages, dairy and bakery products using sucrose and high-conversion corn syrup as sweeteners.

D. *For canning* -Processing time 100 °C, for five minutes.

Freezing Mango Puree

1. Mangoes washed, seeds removed, peeled (mech. scraper).
2. Plate heat exchanger Heated to 90 °C, for 1 minute Cooled to 32 °C -38 °C Filled into 30# tins or Bag in Box, and frozen - 10 of.

Freeze Drying

1. Product frozen prior to placing in dryer
2. Frozen product cut and deposited in its final size onto trays that are placed on the shelves in the drier.
3. Doors are closed, vacuum system turned on 4. 1 to 4 mm, mercury absolute pressure
5. Ice in the product sublimes directly into vapor with no intermediate liquid phase.
6. To drive off moisture heating solution at 54 °C -121°C, circulated though hollow shelves.
7. 30 hours for a single load of 4 oz. fruit slices to dry. Discuss continuous system.

Freezing Mango

1. Fruit is peeled, pitted, sliced and frozen in sugar syrup 25 40 Balling.

Excellent quality maintained.

2. Another procedure

0.1 % ascorbic acid added to the syrup to inhibit polyphenoloxidase activity and 0.05% ascorbic acid to avoid browning. Product transferred to poly bags and vacuum closed.

Ratio of fruit to syrup 3:1
Frozen product kept at -20 °C up to four months.
Drying Mango

I. Preparation

Selection and sorting for size, soundness and maturity
Washing
Peeling
Cutting in various shapes
Blanching
Sulfuring
(0.2 -0.5% (as SOJ using sodium sulfite and sodium bisulfite in equal proportions)
(Discuss U.S. requirements on sulfite)

II. Sun Drying

Uniformity and high quality not expected. Limited shelf life. Moisture levels 15-20%.

III. Solar Drying

Black rays
Solar through
    Direct incident radiation
    Indirect reflected radiation
Use of mirrors.

IV. Dehydration

Application of artificial heat to vaporize water; then removing water vapor after its separation from the fruit tissues.

Peeled and diced green mangoes have been air dried to low moisture levels after sulfuring and osmotic treatment in sugar of salt solution.

Soaking in 1 % potassium metalosulfite solution 30 min, improved quality.

Pulverized mango powder has been used in the preparation of curry.

V. Osmovac Drying (Fruit Pieces, Slices)

Fresh fruit expnsed tn dry sugar to remove water by osmosis.

Over 50% of initial weight can thus be removed. The pieces are then further dried by other conventional methods (vacuum shelf drier)

Method advantages

1. Reduced time product exposed to high temps.
2. Minimized heat damage to cnlor and flavor.
3. Use of sugar as the osmotic agents reduced loss of fresh fruit flavor. 4 Some fruit acid is removed by osmosis.

10.11. COOLING AND COLD STORAGE

Max Bayer

The mango must be stored under the refrigerated conditions in order to meet the requirement nf nverseas markets. It is important that fruit is cooled to appropriate temperature for better ripening, colour, taste and nutritinnal value. Tbe studies done in Florida indicated the optimum storage temperature of 13°C and ripening temperature of 21°C to 24 °c.

When one speaks of cooling and cold storage in connection with fruit, what comes to mind is the necessity of prolonging the quality of the product.

Areas of our earth differ in temperature and length of growing season. In the United States for example fruit such as apples are a one-time crop whicb must be preserved; whicb brings into play the necessity of cooling and cold storage. Mango is a more complex fruit in so far as maintaining quality is concerned.

An analysis of most of the literature and research indicates that the determination of mango maturity is not exact; there are bound to be variatinns.

The fruit is harvested when mature, subjected to ripening between 22°C and 32°C and at a relative humidity of 40 and 65%.

Depending on the area, mango will ripen in a week and be edible for a few days.

This of course is a condition industry can't live with if its eye is on overseas markets; so in this circumstances we turn to refrigeration; since we have been taught that cooling and refrigeration slows dnwn biological processes; this is solution to our dilemma; one would think! But mango is a maverick and presents problems in connection with refrigeration which have kept researchers busy for years. To put it bluntly, temperature is the critical control point in connection with mango quality.

Although mango must be stored under refrigerated conditions in order to cope with overseas markets, it has been evident that the fruit does not react well to refrigeration.

Researchers report the following defects:

- Discoloration
- Pitted regions on the skin
- Non uniform ripening
- Poor color and flavor
- High acidity -low sugar content

When it became evident that concentrated research had to be done if the export of mango was to ever become a viable commercial possibility, some exhaustive studies were forthcoming. In 1977 there was published in the *Processing Florida State Horticultural Society* a paper entitled "Effect of refrigerated temperatures on the incidence of chilling injury and ripening quality of mango fruit" by Saucedo *et al*. The work was done on the kent mango.

Briefly -mature fruit, freshly harvested was stored at 8°C, 10°C and 13°C with relative humidity of 85 -90% for 10, 16 and 22 days. The fruit was then transferred to ripening chambers at 25 °C at 85 -90% relative humidity.

1. Chilling injury occurred at all temperatures regardless of length of storage.
2. When subjected to ripening, flavor deterioration was evident.

The bottom line indicator was that temperatures below 13 °C were critical to the development of injury in the kent mango.

A similar study done on the manila Mango by the same author entitled , "Effect of storage temperature on the ripening of mangoes -variety Manila" was published in 1977 in Chapingo, Nueva Epoca indicated chilling damage at 16 °C.

But at 25° C and 8 -9% relative humidity, Manila mango showed decent organoleptic qualities.

Studies done on most Florida mangoes indicate an optimum storage temperature of 13° C and a ripening temperature of 21°C to 24 °C.

Research done on the Langra and Dashhehari mangoes stored at 7 °C 35 - 45 days and 9 °C for 25-35 days indicated acceptable quality after subsequent ripening.

In summation, one cannot escape the conclusion that storing mangoes under refrigeration with subsequent ripening require study research for each, mango cultivar.

As a point of departure however, for our purposes, based upon results reported with the Alphonso cultivar. It would be recommend an initial approach of 15 °C to 20 °C

10.12. MANGO BY PRODUCTS

Max Bayer

10.12.1. Ahstract

Mango has second rank after banana in terms of the world production. In the market the mango products are mango chunks in syrup, nectar, juices, jam, chuttany, baby food and ice cream, etc. For the production of the by-products various methods are used i.e. sun drying, osmovac drying, freeze drying, use of preservatives, thermal processes, cooling to various temperatures, etc.

Although mango ranks second only to the banana in terms of world production it has not yet attained the status and recognition in the economy with relation to tropical fruit. This state of affairs has been attributed to several factors.

1. Inadequate procedures for peeling and pulp extraction, although lye, steam, brush pulpier, and other methods are gradually coming into increased use.
2. Poor stability and loss of flavour during storage. 3. Irregular productivity.

Some mango products presently on the market include.-

1. Mango chunks in syrup, 2. Nector, 3. Juice, 4. Jam, 5. Chutney, 6. Dehydrated slices, 7. Frozen slices, 8. Baby food, 9. Ice cream

In order to produce these by-products, the raw fruit has to be converted into various forms. These include :-

1. Puree, 2. Frozen, 3. Dried

10.12.2. Puree

A. Thermal processing

One process consists of adjusting the pulp to pH 3.5, heating the pulp to 90 °C, filling into bulk containers and holding for two hours, then cooling and storing. These products can then be used to manufacture jams, jellies, beverages and ice cream, among others.

Puree can also be produced by conventional canning techniques and by processing at 100° c for five minutes. One advantage of the latter process is the adjustment of pH to 3.5 which results in increased microbiological control.

10.12.3. B. Freezing Puree

By far the predominant method in the United States is freezing puree.

Mangoes are washed, seeds removed. The fruit is peeled using mechanical scrapers. Processing is done by running the puree through a plate heat exchanger at 90 °C to 93 °C for one minute, then cooling to 32 °C to 38 °C.

The product is then filled into 30# tins or bag in a box and frozen at -10 °F.

One of the largest producers in the United States of frozen puree, Carlin Foods a division of Bunge oil Company, packages the puree in a nitrogen atmosphere. This product practically sterile; is used by dairies in ice cream, sorbet and yoghurt.

10.12.4. Mango Slices

10.12.5. Freezing

A. 1. Containers are filled with slices.

2. Syrup is added 25 -30 Brix.

3. Containers are sealed and frozen at -30 °C and kept at 0 °C.

B. Mangoes peeled, sliced washed and held in a receiving tank with a solution of 0.05% ascorbic acid (to avoid browing). Product is transferred to poly bags and vacum closed.

Ration of fruit to syrup 3:1.
Product kept -20 °C up to four months.

10.12.6. Drying

a. Sun Drying

This method of drying is still practiced in many parts of the world where the climate is hot and dry.

Fruit is simply spread and exposed to sun until dry with moisture levels running from 15-20%. Uniformity and high quality are not to be expected.

b. Dehydration

Involves the application of artificial heat to vaporize water; then removing water vapor after its separation from the fruit tissues.

Peeled and diced green mangoes have been air dried to low moisture levels after sulfuring and osmotic treatment in sugar or salt brine solution.

Pulverized mango powder prepared this way has been used in the preparation of curry.

c. Osmovac Drying

Fresh fruit is exposed to dry sugar to remove water by osmosis over 50% of the initial weight can thus be removed. Mango slices and pieces are then further dried by conventional methods such as vacum shelf driers. The advantage this method has is that by the use of sugar as the osmotic agent much of the fresh fruit flavour is retained.

IV. Freeze Drying

This method holds the most promise for a more successful utilization of mango, and has the potential of achieving a status second only to the banana. First, to describe the process:

1. Product is frozen prior to placing in the drier.
2. The frozen product is cut and deposited in its final size onto trays that are placed on the shelves in the drier.
3. Doors are closed, and the vacuum system is turned on at 1 to 24 mm mercury absolute pressure.
4. Ice in the product sublimes directly into vapor with no intermediate liquid phase.
5. To drive off the moisture, heating solution at 54 degree C -121 degree C is circulated through hollow shelves.
6. It takes 30 hours for a single load of 4 oz. Fruit slices to dry; but we have available continuous systems which perform more efficiently.

These are easily reconstituted with water and are used predominantly in military meals and in dehydrated soups.

One of the largest food industries today is the Breakfast Cereal Industry. I am circulating a carton of cereal which utilizes dried fruits such as dates and raisins and figs along with the grains.

The Natural foods merchandisers offer ready to eat Oat Bran Cereal called Granola Branana, Oat Bran Cereal containing freeze dried banana chips. It is expected that soon frozen dried mango chips would also their way to super food stores.

10.13. PLANT SANITATION

Max Bayer

10.13.1. ABSTRACT

Handling of the product under the sanitary condition is the utmost important. The premises of the building should be well cleaned and all syrup tanks be covered properly. There should be proper arrangements for ventilation, light, water supply and water disposal. The equipments utensils and food containers be maintained in sanitary condition.

The storage facilities and control of insects, dogs, cats, birds and rodents is also necessary. No person effected with any communicable disease or infected lesions on hands. arms or face should be permitted to have direct contact with the food or food products being processed.

It is of utmost importance that product be handled and produced under sanitary conditions. Not only are food companies subject to inspection by agencies of Government. They on their own also maintain inspection procedures as part of their quality assurance program.

The following is the guide-lines set up by the United States Department of Agriculture and does not differ significantly from those of other countries.

10.13.2. PREMISES

Premises shall be clean, well drained and free from any material or condition that creates rodent and insect harborage. all roadways and parking areas adjacent to the plant buildings creating dust or dirt problem shall be hard-surfaced or treated in a manner to prevent a possible source of product contamination.

10.13.3. BUILDINGS

Floors, walls and ceilings shall be constructed of such materials that they can be kept clean and maintained in a sanitary manner. All windows, doors and similar openings shall be protected by appropriate screening or other devices where flies, insects or birds are a problem.

10.13.4. SYRUP & BRINE ROOMS

All syrup tanks shall be adequately covered or syrup rooms shall be completely screened. Syrup, brine, sugar, salt or other ingredients used in food products shall be kept clean.

10.13.5. VENTILA TION

Ventilation shall be adequate for the operation that is to be performed

and sufficient to control excessive condensation, more growth and objectionable odours.

10.13.6. LIGHTING

Lighting in all buildings and specific areas shall be sufficient and adequate or the operation that is to be performed. Light bulbs and fixtures suspended over food tanks or inspection belts shall be of the safety type or otherwise constructed to prevent product contamination.

10.13.7. WATER SUPPLY

A sufficient quantity of potable water shall be readily accessible for processing and clean-up. The water supply shall be approved by the state or local health authority.

10.13.8. WATER DISPOSAL

Liquid waste from washing, processing, cooking, cooling and cleaning or from toilet or hand-washing facilities shall be conveyed to a public sewer or shall be disposed off by methods or systems that will not create unsanitary conditions. Solid waste, including garbage, trash, rubbish, paper, cartons, etc. shall be removed from the premises at regular intervals and at such frequencies as to preclude the development of insect-attracting or breeding conditions, odors, or other nuisances. Receptacles for wet waste collection within the plant shall be kept covered at all times and removed and cleaned at regular intervals.

10.13.9. EQUIPMENT, UTENSILS & FOOD CONTAINERS

Equipment shall be maintained in a sanitary condition regardless of type, construction or design and shall be kept in a proper state of repair. Containers, utensils, pans buckets used for the storage or transportation of partially processed food ingredients shall not be nested unless rewashed before each use; and containers that are used for holding partially processed food ingredients shall not be stacked in such manner as to permit contamination of the partially processed food ingredients. Containers in which the food is packed shall be clean.

10.13.10. GENERAL HOUSEKEEPING

Through cleaning of all equipment and facilities shall be accomplished at such frequencies as to keep the plant in a sanitary condition. Frequent cleaning of floors and rest rooms shall be conducted during plant operations and adequate waste receptacles shall be provided at all times.

Toilets Facilities

Toilets, washrooms and rest rooms shall be totally enclosed, well lighted and ventilated to the outside. They shall be adequately screened and ! equipped with self-closing doors. Toilet facilities shall be adequate, operational, conveniently located and in compliance with city and state codes. Hand-washing facilities with soap, running water, and drying facilities shall be provided in convenient locations.

10.13.11. Storage Facilities

Storage facilities for raw materials, packing and packaging materials and finished products shall be maintained in an orderly, clean, and sanitary manner.

10.13.12. Control of Insects, Birds and Animals

Every practical precaution shall be taken to exclude dogs, cats, birds, and vermin (including rodents and insects) from the plant. Insecticides and rodenticides, if used, shall be only those suitable for the purpose, shall be used in accordance with approved methods, and shall be handled and stored in a safe manner.

10.13.13. Plant Operation

All operations after the final washing operations shall be constructed so as to prevent contamination from the elements and other hazards. Methods used in the processing, manufacture, handling and storage of foods shall be such as to prevent contamination of the product.

10.13.14. Plant Personnel

No person affected with any communicable disease in a transmissible stage or infected lesions of the hands, arms, or face shall be permitted to have direct contact with the food or food products being processed. Employees having direct contact with food products or food components shall comply with the following:-

- Wear clean suitable outer garments
- Have adequate hair nets or head covering
- Refrain from spiting, gum chewing, and all uses of tobacco except in designated areas.
- Take all necessary precautions to prevent the contamination of processed products and ingredients thereof with any foreign substance (including but not limited to perspiration, hair, cosmetics, and medications).
- Wash hand immediately prior to starting work and each resumption of work after each absence.