JULIE MANGO
IN THE EASTERN CARIBBEAN

A comprehensive manual

Caribbean Agricultural Research and Development Institute (CARDI)

The Technical Centre for Agricultural and Rural Cooperation (CTA)

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The IPM concept

Integrated Pest Management (IPM) is a pest management system that encourages natural control of pest populations by anticipating pest problems and preventing pests from reaching economically damaging levels. Control is achieved using a combination of techniques, including enhancement of natural enemies, introduction of exotic enemies, cultivation of resistant species and cultural management, with pesticides used as the last resource.

In agricultural systems, the reduction of the damage by insects and mites is increasingly being guided by the philosophy of IPM rather than complete reliance on pesticides. By definition, in order for appropriate IPM techniques to be developed for a particular crop or pest, information is required on the following.

- the nature of the environment: climatic and weather conditions, cropping history, cropping system, socio-economic factors
- the population dynamics of the pest: population density and fluctuations, rate of population increase, nature and impact of mortality factors
- available control methods: cultural and biological methods, selection and use of pesticides, postharvest treatments
- economic injury levels: value of crop loss, cost of treatment operations.

The primary aim of IPM is to maintain crop yield while reducing the negative impact of indiscriminate pesticide use on human health and the environment.

IPM technology therefore concentrates on manipulating the processes and factors which regulate pest populations and uses pesticides only when it is biologically and economically justified.

Agro-ecological zones

The ideal agro-ecological zones for mango are usually defined with respect to the soil properties, weather and other environmental conditions which are favorable for crop production. The impact of pest organisms on the crop can also be very different depending on the prevailing environmental conditions. Some pests prefer wet, humid conditions while others thrive in a hot, dry environment.

Therefore in determining the suitability of a zone for mango production, attention should also be paid to the distribution of key pests present in the country. It is, of course, most desirable if zones, which are agronomically suitable, are at the same time undesirable for the development of key pests. This is not always the case, as many important pests of mango thrive best in conditions which are otherwise well suited for mango cultivation.

Economic threshold

The economic threshold of a pest on a crop is that population density which causes damage, the value of which is equal to the cost of controlling the population. In order to base pest management decisions on the economic threshold, information is required on the relationship between the population density and yield loss, and also on the cost of control options.

At present there is insufficient data on mango to derive economic thresholds for most pests, so decisions are usually based on rule of thumb rather than on actual population counts. Nevertheless, regular monitoring of orchards is a prerequisite to effective pest management, as it provides early warning of an impending pest infestation and is an indicator of the effectiveness of control measures.

Cultural practices

The cultural practices employed in the orchard can promote or retard the effects of various pests.

Overgrown trees with a very dense canopy provide ideal conditions for infestation by many pests. Pruning, including the regular removal of dead limbs and branches, discourages infestation by many important pests. Well pruned trees allow for closer inspection and monitoring as well as for more efficient spraying operations.

Other cultural practices including weed control, fertilizer application and supplemental irrigation, promote plant growth and vigour, thereby enabling the plant to withstand pest attacks.

The timely implementation of cultural practices will usually pay off in the long run by preventing pest outbreaks, thus reducing the need for costly interventions when infestations occur.

Efficiency and spraying operations

Many mango orchards in the Eastern Caribbean are established on hilly terrains and steep slopes. Spraying efficiency measured in terms of man hours/tree is directly related to these topographical features. In addition, trees may be overgrown with dense canopies, thereby reducing spraying efficiency. It is often difficult to justify the cost of spraying under these conditions.

In order to maximize returns from spraying, careful attention must be paid to the following aspects:

- select the appropriate pesticide for the pest
- mix and prepare pesticide according to the label directions or recommendation from the extension service
- calibrate spraying machine to determine the volume of liquid to be applied per tree and the time required to spray
- prepare orchards for spraying by clearing weeds, vines etc. that may impede sprayman, pruning trees if necessary
- sprayman should transverse across the slope rather than up and down, on sloping land
- avoid the use of excessive amounts of water. Avoid spraying to 'run off', since this wastes pesticides and contaminates the soil. Finer droplets provides a better coverage of the target but are more easily lost through drift, particularly in windy conditions
- ensure that the target is reached. Many pests are harbored on the underside of leaves and in these cases, care must be taken to direct the application towards them
- disturb the leaves so as to achieve an even deposition of

the droplets within the canopy. For large trees this is best achieved with a mistblower which moves the largest volume of air at the lowest velocity. Knapsack sprayers can be used for trees up to 1.5 m (5 ft) tall

- spot spraying may be more appropriate in many cases than a full coverage spray of the orchard. Individual trees or parts of trees may be sprayed. An extensible/telescopic lance attached to a knapsack sprayer may be used to deliver pesticides directly to a selected target within individual trees. In addition, lures may be incorporated with the pesticide mix to attract the target pest to the spray area, thereby saving application costs
- various adjuvants (spreaders, stickers etc.) may be required in some conditions. Advice should be sought from the local extension service.

Biological control

In natural ecosystems, insect populations are regulated by various natural enemies, primarily other insects which are predators or parasites. Lady bugs are among the most common and important predators, while wasps are by far the most important parasites. Adults and immature predators feed directly on their prey while the adult parasitic wasps lay their eggs in or on their host. Their larvae consume the internal organs of their host and kill them before continuing their development to adulthood.

IPM strategies seek to conserve natural enemies and to establish and maintain conditions suitable for their survival. In some cases, it may be possible to augment the predator/parasite population by laboratory rearing for release into the field. Also, natural enemies may be introduced from their natural habitat into infested areas where they do not readily occur.

Most of the major pests of mango are subjected to attack by various natural enemies, although they may not be sufficient to reduce the pest population below economically injurious levels.

Population regulation by parasites and predators is most successful when there is opportunity for a longterm dynamic equilibrium to be established between the natural enemies and the host. The relative stability of a mango orchard provides such an opportunity and natural enemies will usually be active in most mango orchards. Therefore care must be taken to ascertain the status of natural enemies in orchards, and to prevent their destruction by indiscriminate use of pesticides.

Other biological agents – bacteria, fungi, viruses, and nematodes – have been transformed into commercial products, which can be used as pest controls in much the same way that conventional pesticides are used.

Biologically active chemicals such as insect hormones (pheromones) and their synthetic analogues, can be used to control some insect pests by disrupting their growth and reproduction processes.

Quarantine

Plant quarantine systems are established by national authorities to regulate the movement of plants and plant parts within and across their borders. These systems are designed to prevent the spread of exotic pests to geographical areas where they do not occur. Plant quarantine regulations provide for inspection and certification as well as prohibition of entry, treatment, and destruction of plants or plant parts.

While there is little restriction on the international movement of mango plants, many countries impose strict prohibitions and regulations to control the importation of mango fruits and seeds, particularly from countries where certain pests are endemic. These are especially strict in the case of pests which cannot be detected by normal visual inspection and for which there are no approved treatments.

Mango fruits are notorious for being among the main host of fruit flies, which are among the most destructive pest in modern agriculture. As a consequence, mangoes are subject to some of the most stringent quarantine measures in international trade.

Mangoes from the OECS (except Grenada and St Vincent) are prohibited entry into the USA and some other countries, due to the occurrence of various fruit fly species and also the mango seed weevil. Grenada and St Vincent have been extensively surveyed and shown to be free of all fruit flies. However recent findings have shown the occurence of mango seed weevil in Grenada.

Fruits from countries infested only with fruit fly can enter the USA provided that they are given approved treatment. However, fruits from seed weevil-infested countries are denied entry altogether, since no completely effective treatment has yet been devised for this pest. No similar quarantines are imposed by Canadian or European authorities, because the pests of concern are unlikely to survive even if introduced into these countries.

Similarly, mangoes may be prohibited entry into the Caribbean from various countries where pests (especially fruit flies) not found in the region are known to occur.

The pink mealybug, which found its way to the Caribbean in 1993 has only been prevented from spreading to all countries of the region by the strict imposition of quarantine regulations, which have sometimes led to the complete cessation of trade in agricultural produce, including mangoes.

Postharvest disinfestation

Postharvest operations are geared towards enhancement of the quality attributes of produce. One major goal is to ensure that the produce present in the marketplace is free of pest infestation.

In mango, some superficial pests, e.g. scale insect, or blemishes, e.g. sooty mould, can be physically removed by postharvest washing and brushing.

For quarantine security (particularly fruit flies) postharvest fumigation against internal feeders, was previously required. This practice was banned in 1987 and replaced by hot water treatment, in which the fruits were kept in hot water at specific temperatures and durations to kill any fruit fly eggs and larvae within the fruit. Different treatment regimes are required for different varieties, sizes, and maturity grades of mango, and these regimes must be approved by the appropriate regulators in the importing countries.

Other postharvest treatments under investigation include the use of vapour heat and the control of storage atmospheres. None of these techniques however, is effective against the seed weevil.

Even where it is not necessary to treat for quarantine purposes, it may still be advisable to treat fruits destined for extraregional markets purely for quality enhancement. Hot water treatment will ensure that fruits are not infested with live fruit fly larvae in the market place.

The inclusion of insecticides in postharvest dips and washes should be avoided unless specifically recommended or required, as this presents the risk of contaminating the fruit with unacceptable residues.

Main mango pests

Pink Hibiscus Mealybug *Maconellicoccus hirsutus* (Green) Pseudococcidae

Description and lifecycle: The pink mealybug was first detected in the Western Hemisphere in Grenada in October 1994. It has since spread to a number of countries throughout the Caribbean, as well as to Guyana. Pest colonies can easily be identified on a host plant species. Infested plants are covered with a white cottony mass of wax, which is produced by mealybug colonies. All parts of the plant may be covered with wax - stems and shoots, leaves, fruits, and inflorescences.

Distribution: Pink mealybug has been identified in 22 Caribbean countries, including Guyana. It is also found in Africa, Asia, Australia and islands of the Pacific.

Biology: The adult is a small, white soft-bodied insect with a non-flying female and a flying male. The life cycle is from egg to active crawler to nymph to adult. The life cycle is temperature dependent and can be as little as 24 days. Adult females lay eggs from which extremely mobile crawlers (first instar nymphs) emerge. The male has four instars, while the female has three instars. Male and female nymphs are distinguishable by the end of the second instar.

This is one of the few mealybug species to have toxic saliva, which stunts and kills young shoots. Curled leaves resemble viral damage and even if treated, growth is less than in non-infested plants.

Control: Initially pesticide application, and cut and burn techniques were favoured. However these were soon deemed impractical and replaced with containment and control programmes, centred around reproduction and release of biological control agents, which have proved to be very successful. The two most widely used are the parasitic wasp, *Angyrus kamali,* and the ladybird beetle *Cryptolaemus montrouzieri.*

West Indian Fruit Fly *Anastrepha obliqua* Tephritidae

Description and life cycle: The West Indian Fruit Fly is found in Mexico, Central America, and the Caribbean (except Grenada and St Vincent).

The adults are about 10 mm (0.4 in) long and yellowish brown in colour. The wings have distinct brown bands.

The female lays eggs under the skin of fruits. The eggs hatch into larvae after about 3 days. The larvae live and feed inside the fruits. When fully grown, after about 10 days, they pierce the skin, and exit the fruit. They fall to the ground for pupation.

The pupae are enclosed in a brown puparium which is shaped like a capsule. After 10-14 days adults emerge from the pupae.

The main hosts of the fuit fly in Dominica are hog plum and other plums, guava, mango, and carambola. Other host fruits are pomerac, golden apple, gooseberry, and cherry. Some common fruits which are not fruit fly hosts include citrus, avocado, passion fruit, soursop and papaya.

All varieties of mango can be infested by the fruit fly but some varieties are less preferred, e.g. those with bitter skin. (Long mango is a preferred variety.) Levels of fruit fly infestation depend on the agro-ecological conditions and surrounding host plants.

Damage: Some damage can be caused when the female 'stings' the fruit to lay her eggs. When this occurs, latex oozes from the wounds and can be observed on the skin. Females usually select only maturing or mature fruits to lay their eggs. However, in the case of Julie, some immature fruits are also attacked. These young fruits may fall from the tree.

The more serious damage is caused by the larvae feeding on the pulp of the fruit. When they emerge from the fruit to pupate they make exit holes in the skin. Fungi and bacteria then enter the fruit through these holes and cause rotting.

Quarantine: Many countries impose quarantine restrictions against mango imports from countries infested with fruit fly. Even where there are no quarantine restrictions, no country wants to sell infested fruit in international markets.

Conrol: Fruit flies thrive in dark, humid conditions. Prune trees and ensure adequate drainage.

Wild hosts, such as guava, hog plum and wild mango, are a source of infestation for commercial orchards, and nearby trees should be removed in the immediate vicinity.

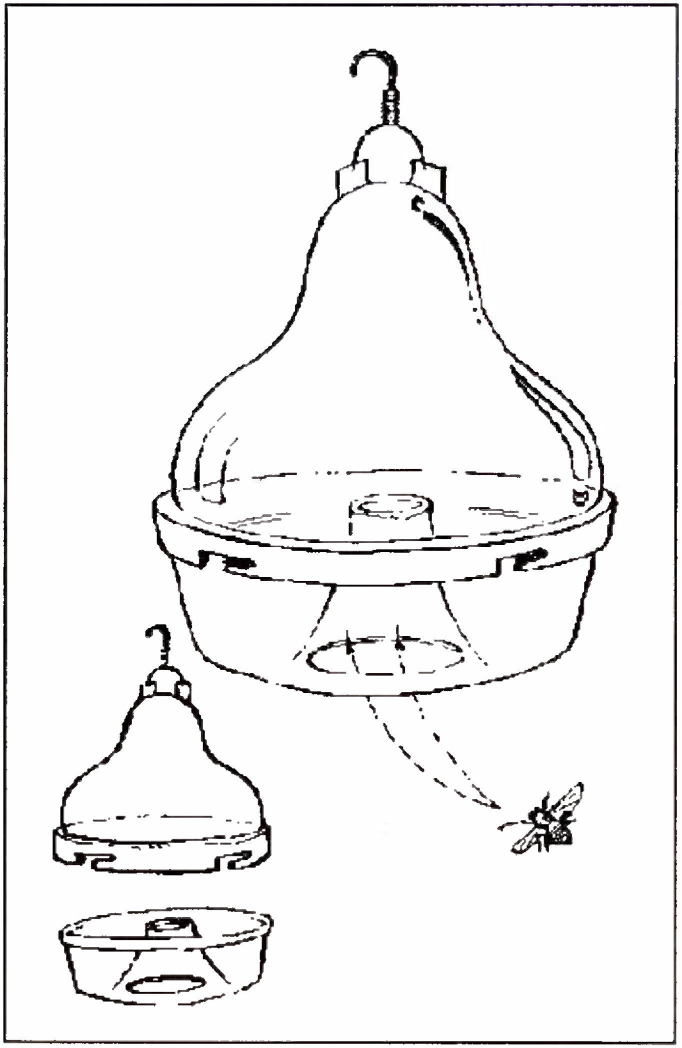
Remove and destroy fallen fruit.

Bait sprays can be applied to protect the fruit.

Fruit flies are attracted to various baits and lures. These baits can be placed in traps to capture flies.

Trapping: 30–40 traps/ha (12–15/ac) are required, based on 125 trees/ha (50/ac). Put 5 tortula yeast pellets in the base of each trap. Add 500 ml (about 1 pint) of water to the pellets.

Figure 8.1 McPhail trap for fruit flies



Secure the top and bottom of the trap and swirl to dissolve the pellets. Ensure that no bait spills in the orchard or contaminates the outside of the trap. Hang traps about half-way up the canopy and about two-thirds of the way along the branch. Ensure that the entrance of the trap is not blocked by leaves, etc. Place traps approximately 12 m (40 ft) apart, i.e. a spacing of 2 trees between traps. Service the traps once per week, removing the captured flies and changing the bait. Store the captured flies in a bottle filled with alcohol for collection and assessment by the plant protection unit.

Termite *Nasutitermus costalis* (Isoptera: Termitidae) Neotermis sp.

Distribution: Throughout the Caribbean
Description and life cycle: Termites are soil insects and generally live in large colonies. These colonies construct galleries on the ground as well as in living and dead trees. Termite nests or mounds comprise a maze of galleries covered by a hard coating of mud, organic material, and spittle-like secretions. Termites usually construct covered trails leading from the nest to various food sources.

A termite mound may contain several million individuals. The population is divided into various castes, including winged reproductive males and females, and wingless soldiers and workers. During specific periods, e.g. on rainy evenings, the winged reproductives leave the nest, mate and establish new colonies.
Damage: Termites attack living or dead plant tissue, including roots, stems and branches. They destroy the wood, making the affected parts susceptible to breakage during strong winds or under heavy fruit loads.
Management: Dead branches are the usual focal points for termite attack. Old tree stumps, pruned limbs etc. should be removed from the orchard and burnt. Dead branches should be promptly pruned and pruned surfaces sealed.

The mound must be destroyed to prevent re-infestation. Destruction can be effected by burning, or by pouring insecticide into a hole made in the mound with a sharp stick or cutlass. Severe termite infestation is rare in well-managed orchards.

Broad mite, Yellow tea mite *Polyphagotarsonemus latus* (Banks) (Acarina: Tarsonemidae).

Distribution: Throughout the Caribbean and worldwide. Mainly on tea and cotton, also on coffee, tomato, pepper, bean, citrus, avocado, (50 hosts).
Description and life cycle: Eggs are laid singly on the undersides of leaf flushes. The lower section of the eggs are flattened onto the leaf surface, but the upperside is covered with 5–6 white tubercles which gives a characteristic bumpy appearance.

Eggs hatch into minute larvae which become quiescent pupae (nymphs) after 2–3 days. A generation may be completed in 5–7 days. Female pupae are carried by adult males to leaves which have just emerged from the bud stage.

On emerging from the pupae, adult males migrate to young leaves on their own. Adult females are broad, oval and yellowish or dark green in colour depending on the host plant on which they feed. Males are shorter and more tapered than females and are always yellowish.
Damage: Broad mite populations are most numerous in damp, shady places so infestation of mango occurs mainly

in nurseries during propagation and where these conditions prevail in orchards.

The mite feeds on the lower leaf surface. The leaves may become bronzed or otherwise discoloured. Infested leaves become curled and crinkled, stiff, narrow and twisted and may fail to elongate. Severely infested leaves may split and become ragged or may dry up and die.

Monitoring: Leaves which are suspected to be infested with broad mite should be examined microscopically. The ornamented eggs attached to the leaves are highly definitive. Flush leaves in particular should be regularly examined, since the population readily move from mature leaves to newly emerged leaves.

Management: Reduction in shade and humidity levels are unfavourable for the development of the broad mite. Damage therefore tends to subside during the hardening of the plants especially in the absence of flush leaves.

Application of sulphur dust or specific acaricides will control severe infestations.

Mango Bud Mite *Eriophyes mangiferae* (Sayed) (Acarina: Eriophydae)

Distribution: Throughout the Caribbean and in all mango growing areas in the world.

Description and life cycle: The mites are white and worm like, about 225 micrometer long, invisible to the naked eye. They are commonly known as gall mites or nest mites. A few species feed on leaves from a pouch-like gall on the leaves. The majority feed on leaves without producing galls, instead they cause a nesting of the leaves.

They are elongated and worm-like with no body setae, and have only two pairs of legs. The mouth parts are also highly modified.

Dispersal is by wind and they insert themselves in the protected micro-environment under the bud scales which provide food and cover. These mites have no trachea and absorb oxygen through their epidermis.

There are four stages in the development of the mango bud mite: eggs, two nymphal stages and adult. All stages are passed beneath the bud scales.

Damage: The mite stunts or distorts young buds, causing proliferation or `brooming'. Buds may become dried up and in severe cases twigs may be killed. However this is not a pest of major economic importance in the Caribbean.

Monitoring: Brown or black spots on the bracts of buds is a sign of mite activity. Since the mites are not visible to the naked eye, their presence should be confirmed by microscopic examination.

Management: Pruning at the end of the production cycle will significantly reduce the number of mites available to infest newly initiated buds. In severe cases where treatment is necessary, the use of sulphur should be considered as this is relatively nontoxic and environmentally benign. However, crop damage may result from application during hot weather. Application of recommended acaricides will generally give adequate control.

Red banded thrips or cocoa thrips *Selenothrips rubrocinctus* (Giard) (Thysanoptera: Thripidae)

Distribution: Throughout the Caribbean and worldwide in tropical and sub-tropical areas. Other host plants include avocado, cocoa, cashew, guava.

Description and life cycle: Adults are dark brown to black. The immature stages are black with a bright red band across the middle of the abdomen. Adults and nymphs are about 1 mm long.

The red banded thrips reproduces parthenogenetically, that is without being fertilized by males. Males are rare. Eggs are deposited beneath the epidermis on the underside of the leaves and nymphs emerge in about two weeks. After 6–10 days, nymphs pass into a so-called pupal stage which does not feed, but is morphologically similar to the nymph except for the presence of wing pads. Adults emerge from pupae in about 5 days.

Damage: Both nymphs and adults feed together on the underside of infested leaves. Initial feeding damage causes a reddening and/or bronzing of effected leaves. The thrips carry a faecal droplet at the end of the abdomen, which when deposited on the leaf surface appear as shining tar-like spots.

Severe infestations produce a scorched appearance and defoliation may result, especially in dry conditions. Fruits may also be attacked in severe cases with similar symptoms of silver or bronze discolouration and the presence of faecal droplets. Nutritional deficiencies exacerbate the damage.

Monitoring: Thrip colonies can be observed by examining the underside of the leaves through a x10 magnifying hand lens. The black tar-like faecal spots and associated leaf discolouration are visible to the naked eye.

Management: Application of a systemic insecticide or a contact insecticide directly to the underside of the leaves is usually required to control this pest.

Mango seed weevil *Sternochaetus mangifera* (F) (Coleoptra: Curculionidae)

Distribution: Caribbean: Barbados, Dominica, French Guiana, Guadeloupe, St Lucia, Martinique and Grenada. World: Australia, India and South Asia, Hawaii and Oceania, Africa.

Description and life cycle: Adult weevils are short and compact about 1cm long and 4mm wide. The colour varies from grey to reddish brown with a pattern of lighter patches. They are nocturnal, hiding during the day under the bark of mango trees, in branch forks or in debris at the base of the trees. When disturbed, the adults feign death.

Although capable of flight, the main method of dispersal is through the movement of infested fruit. Adults may live for up to two years. They enter into a period of quiescence (diapause/hibernation) when mango fruits are not available.

Egg laying commences in young mango fruits and may continue until fruits are almost mature. Eggs are laid singly on the skin of the fruit and covered by the female with a brown exudate. Several eggs may be laid on one fruit. The eggs are about 2–3 mm (0.1 in) long and are creamish-white in colour. On hatching, the larvae tunnel through the fruit where pupation and adult emergence occur.

Larvae are white and legless, growing to a length of about 1 cm. Adults remain within the seed and emerge four months after fruit fall or after the fruit has been consumed or decayed.

Damage: The direct damage to the fruit is minor. Tunneling through the flesh into the seed is discernable in mature fruits. Adults may exit the seed of the late maturing varieties and cause damage to the flesh. Larvae may damage the cotyledons within the seed, thereby reducing the germination of seeds to be used in propagation.

Infested mangoes may be marketed and consumed without any sign of infestation.

Mango seed weevil is however a pest of serious quarantine importance. The United States and Japan will not accept fruits from countries in which this pest occurs. There are no such quarantine restrictions in Europe, however.

Monitoring: Visual inspection of bark crevices, debris and other hiding places can detect adults during the day. During the early fruiting periods, adults can be collected by shaking limbs over a white cloth in the early mornings. At about 4 weeks before harvest a sample of 1 in 400 (0.25%) fruits is randomly selected and sliced in half for a visual examination of the seed.

Management: No specific control measures are recommended for seed weevil. Routine spray applications against other pests may kill adults.

Strict quarantine against the movement of mango fruits and seeds from infested countries is required.

9 Disease management

Major Diseases

Anthracnose *Colletotrichum gloeosporioides* (telemorph: *Glomerella cingulata* Stonem, Spauld and Schrenk) (Mordue 1971)

Mango anthracnose disease is the most prevalent and destructive disease of mango particularly in the humid tropics. This disease is also known in the Caribbean to attack and cause severe losses in other fruit crops including papaya, avocado, golden apple, and citrus.

All mango cultivars are susceptible to anthrancose, albeit in varying degrees. In mango, the causative agent of anthrancose disease, *C. gloeosporioides*, attacks young flush, flowers (blossoms) and fruit. Hence the fungus causes severe problems at critical stages of crop growth – blossom blight may lead to severe losses in fruit set as well as subsequent quiescent infection of mature fruit. Anthracnose exhibits the phenomenon of quiescence or latency, i.e. the fungal pathogen ceases advancing after it penetrates the cuticle, and progression of disease symptoms are seen only after the fruit matures and ripens.

Symptoms: Disease symptoms are not usually seen or fully developed at the time of harvest. Mango is a climateric fruit, i.e. the fruit matures and ripens after harvest. This is the time that the typical anthracnose symptoms become evident.

The fungus affects all parts of the plant – twig, leaf, flower and fruit, but because of the quiescent nature of the disease, symptoms are not usually seen nor fully developed at the time of harvest.

Research recently completed in Dominica on the epidemiology of anthracnose in Julie mango indicated that leaf symptoms are not as important as observed in other mango growing regions of the world. However anthracnose in young flush (leaf) is usually manifested as tiny necrotic spots which are sub-cuticular and angular in shape. Later, brown spots to black lesions with distinct margins are found on the leaf. Lesions may then enlarge or coalesce causing destruction of large areas, often beginning from the leaf margin.

Twigs of the current year's growth or of the previous year provide a source of the fungal infection.

When the disease is manifested on blossoms it is referred to as the blossom blight stage. The disease occurs at the base of the ovary rather than at the peduncle. Flower buds, opened blossoms, flower pedicels, and the main and secondary stalks of the flower panicle, develop tiny black necrotic spots. These spots later enlarge, coalesce and lead to blighting of clusters of flowers or the entire inflorescence, which becomes black and dried.

Later infections produce depressed lesions on young fruit, which usually result in fruit drop, as distinct from normal physiological fruit drop. On larger fruits infections develop further until ripening when dark sunken lesions appear. Eventually the fruit shrivels resulting in a black pulp.

In many cases the eruption of pink slimy spore masses can be seen in the centre of the lesion, and very often these spore masses are arranged in concentric rings in the necrotic tissues. The phenomenon of a concentric growth pattern can also be seen on agar culture in a petri dish, particularly after two weeks in culture.

The fungus also causes 'tear staining' which affects the appearance and reduces shelf-life of the fruit. Tear staining can be attributed to large masses of spores of the fungus being washed down by rain along the fruit surfaces.

Etiology: C. gloeosporioides and its telemorph *G. cingulata* were positively confirmed by CAB International Mycological Institute as the causal organism of mango anthracnose in Dominica.

Investigations in Dominica showed that high relative humidity (RH) of not less than 97% induces production of conidia on leaf flushes. Similar findings were reported on mango anthracnose in Australia and the Philippines. The number of wet days correlated significantly with conidia production on leaf. An empirical regression model was developed relating the percentage of conidia-forming appressoria (thread-like hyphae) to temperature and the duration of leaf wetness.

Optimum temperature for disease development was found to be 21°C and the average temperature during the period was 21.5°C.

During the blossom phase of the crop phenology, the studies in Dominica showed likewise high RH of 97% with a mean of 93% was favourable to conidial production. The optimum temperature for disease development on blossoms was 19°C. During the fruiting period average RH of 98% caused peaks in the production of conidia. The optimum temperature for disease development was 20°C with an average temperature of 23°C in Dominica.

The study also showed the difference in disease development in two different ecozones with low and high levels of relative humidity respectively.

Roger on the west coast with an average relative humidity of 70–80% is not conducive to severe anthracnose. The area has a low annual rainfall (1,500–2,000 mm), is 150 m above sea level, and is wind swept.

By contrast, Salisbury (heights) is known for severe

Table 9.1 Conditions favouring the development of anthracnose at different stages of plant growth, Dominica

Growth stage	*Relative humidity (%)*		*Temperature (°C)*	
	optimum for development	*average in Dominica*	*optimum for development*	*average in Dominica*
Leaf flush	≥97	≥97	21	21.5
Blossom	≥97	93	19	-
Fruiting		98	20	23

anthracnose. It is considered highly favourable for anthracnose because of the following ecological characteristics: an annual high rainfall of 2,400–2,500 mm, 360 m above sea level but land locked between forest trees, and an escarpment that prevents any significant free air movement. Critically, the relative humidity is 93–98% during the months of September to May of the next year, i.e. from leaf flush stage to fruit maturity and harvesting.

Epidemiology: Important differences in anthracnose epidemiological studies can be traced directly to location and mango cultivar. Dominica, for example, has distinct ecozones based on rainfall and humidity. Julie mango also has a distinctive growth pattern with several blossom sets and more than one period of leaf flushing.

Anthracnose is particularly severe in young leaf flush, flowers and floral parts, and fruit following the wet season. High rainfall with high relative humidity nearing 100% with temperature ranges of 19–23°C cause severe disease. The infective propagules of the pathogen *C. gloeosporioides* were shown to be water-borne conidia. Conidia production was shown to be highest during periods following rainfall for over 3–8 days with a period of high RH of 93–98%. The leaf flush period during September to November was shown to be very susceptible to anthracnose infection during days of high humidity. During December to March, blossoms and flowers are exposed to continuous infection by the pathogen during similar conditions of high relative humidity.

Young fruits and mature fruits alike are attacked between April–June and July–August respectively. Disease progress and severity depended on relative humidity of 93–97% and favourable temperature ranges of 19–23°C. It was observed that the disease inoculum (water-borne conidia) is always present throughout the crop cycle (and perhaps the entire year), i.e. from leaf flush, blossom set and fruiting until maturity and harvesting. The cycle was shown to start all over at the end of harvesting and the beginning of new flush in September.

Disease management: Our study showed that preharvest treatment is an integral part of any strategy to manage mango anthracnose, not only in the field but also during postharvest, just before reaching the consumer.

Preharvest: Any effective disease management of mango anthracnose should be based on the epidemiology of the disease, and more precisely on the epidemiology of the disease of a specific cultivar in a given location. The less humid areas within a country consistently produce fruits which are less infected with anthracnose. A strategy for limiting mango anthracnose should include the following elements of an integrated crop management (ICM) approach: location, cultivar, plant nutrition, method of cultivation, and crop protection practices. Research in Dominica for three years adopted the ICM approach and reported excellent results in the reduction of mango anthracnose. Therefore the following recommendations are based on empirical data and observations taken over five seasons in six orchards with a range of anthracnose disease indices.

Location: orchard should be located in elevation between 100–300 m. A gradual slope is also desirable for proper rooting, soil aeration, and also to prevent severe water run-off and soil erosion.

Cultivar: the choice of Julie by the farmer will be determined