CHAPTER III ANTHRACNOSE

THE DEVELOPMENT AND ADAPTATION OF METHODS FOR CONTROL OF ANTHRACNOSE

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INTRODUCTION

Anthracnose is the most important disease of mangoes throughout the world and is caused as a result of infections by the fungus Colletotrichum gloeosporioides (Penz.) Sacc. There are two recognized forms of the conidial (asexual) stage of the fungus, C. gloeosporioides variety gloeosporioides and C. gloeosporioides variety minor. The latter is regarded as the pathogen of mangoes (29). The sexual state of the organism, Glomerula cingulata has not been shown to contribute to the infection cycle for anthracnose. The fungus attacks flowers, twigs, leaves and fruit, which results in typical dark brown necrotic irregular shaped spots on leaves which may also develop a curled margin. Infected twigs may die back and become cankerous while flowers turn black and are shed leaving a bare panicle stalk. Fruit which are affected in early stages of development will usually turn black and fall to the ground. Infections of more mature fruit can show as black, slightly sunken spots from pinhead size to blotches covering most of the fruit surface. Fruit which are apparently free from the disease at harvest may have latent infections in the form of subcuticular hyphae and appressoria which may cause subsequent development of lesions as the fruit ripens. Latent infections may also occur in lenticals. These lesions can coalesce and may cause the fruit to become completely rotten.

CONTROL OF ANTHRACNOSE IN THE FIELD

Orchard hygiene may help to reduce levels of infection and dead and discarded material should be removed and burnt. The development of the disease in the field is encouraged by damp conditions. It is, therefore, a more serious problem where trees are planted in humid valleys or away from prevailing winds or where there is a high rainfall or high ambient humidity. The spores can be spread by rain, particularly from infected upper branches of tall trees which are difficult to spray effectively.

It is, therefore, essential in areas where anthracnose is a problem to have an effective spray programme in order to maximize fruit yield and minimize subsequent post-harvest fruit losses. In comparison between copper fungicides in Florida (18) it was found that either cupric hydroxide at 2.4 g per litre or tribasic copper sulphate at 3.6 g per litre were the most effective treatments when applied with the organic sticker Nu-Film-17 at 0.125%. The sprays were applied at monthly intervals at about 57 litres per tree starting when the flower panicle was 4 to 5 cm long, which involved 12 sprays in total. Subsequently, McMillan (19) found that benomyl at 0.3 g per litre with Triton B1956 at 0.15 ml per litre gave very good anthracnose control. This was also applied at 57 litres per tree beginning when the flower panicles were 4 to 5 cm long at monthly intervals until 30 days before harvest.

Barmore et al (3) found that benomyl at 0.3 g per litre plus Vapour-Gard was the more effective treatment for anthracnose control, than either benomyl plus Nu-Film-17 or benomyl plus Triton. In Australia Grattidge (12) recommended mancozeb (800 g per kg) at 2 g per litre sprayed weekly during flowering then monthly until harvest to control anthracnose on mangoes in the field. He also found that in a wet season this spray programme increased fruit set many times. In experiments in Mexico (11) it was found that cupric hydroxide or captafol gave good control of mango anthracnose giving 62% and 43% healthy fruit respectively at harvest compared to only 7% on untreated. The spray programme was every 12 days throughout the season starting one month before flowering. In Brazil, Donadio (9) recommended 15 sprays starting one month before flowering and continuing until harvest. Fungicides recommended were copper, mancozeb, ferbam, captafol, benomyl, maneb and thiabendazole. Medcalf (20) in Sao Paulo recommended mancozeb at 0.15 to 0.25% and dinocap at 0.03% applied 45 to 60 days before flowering and continuing to November with 10 applications in total. Fruit from this treatment had 66% of exportable quality compared to only 2% for untreated. In Florida Mitchell (21) recommended 25 applications of benomyl starting just before flowering and continuing right up to harvest. Mancozeb, chlorothalonil and ferbam were shown to be equally effective as field sprays against mango anthracnose in Florida (38). Zineb, maneb or captan applied at weekly intervals during flowering, then at monthly intervals, gave adequate anthracnose control (29). In studies in the Philippines field sprays with mancozeb or copper were superior to either captan or zineb (31).

Disease control programmes used on mango farms in Sao Paulo in Brazil were generally to start spraying about a month before flowering with one or two sprays, then continuing spraying through the flowering period; commonly every 15 days. After flowering, spraying was continued to just before harvesting. Different growers had different spraying frequencies, but mostly they were every 20 days. However, the intervals depended on weather conditions and growers inspected the crop at frequent intervals and decided subjectively when to spray depending on the condition of the crop and the weather. The fungicides used were benomyl, thiophenate methyl, zineb, maneb and various copper formulations (41). Copper has both insecticidal and phytotoxic properties and, therefore, if applied during flowering can reduce fruit set. The pre-harvest application of benomyl besides controlling anthracnose disease can enhance the colour of some cultivars which are not normally highly coloured (6).

VARIETAL RESISTANCE OF MANGOES TO ANTHRACNOSE

In a review (29) the varieties Carrie, Carabao, Florigon, Tommy Atkins and Saigon were listed as resistant to anthracnose, Kensington Pride as moderately resistant and Willard, Neelum Manoranijan as very susceptible. Some of the varieties listed above as resistant are listed elsewhere as susceptible (29, 38).

Akamine (1) stated that although there is some varietal difference in susceptibility to anthracnose disease in mangoes, all varieties are attacked. Hatton and Reeder (14) compared the percentage of fruit which developed anthracnose in 9 mango varieties in Florida. The study was only during one season, but there is some indication that levels on Zill and Tommy Aktins were less than the other varieties and that Sensation was particularly susceptible (Table 1).

Campbell (7) observed that Tommy Atkins appeared resistant to anthracnose. These observations were not confirmed by Evans and Thompson (10) who found that hot water fungicide treated Tommy Atkins had no anthracnose compared with 17% for untreated fruit after transport between Jamaica and Britain for 15 days at 13°C.

Table 1: **Percentage of ripe fruit with anthracnose.** Comparison between untreated or dipping for 5 minutes at 55°C after Hatton and Reeder (14).

Variety	Treated	Untreated
Irwin	4	34
Keitt	1	28
Kent	3	39
Lippens	1	47
Palmer	1	37
Sensation	28	62
Smith	15	46
Tommy Atkins	13	15
Zill	0	13

Murthy and Rao (27) described an interaction between mango varieties and fungicide treatment. Post-harvest fungicide treatments which significantly reduced anthracnose levels in Alphonso had no effects on levels on Totopari.

POST-HARVEST CONTROL OF ANTHRACNOSE

Post-harvest control of anthracnose disease usually refers to treatments which can kill the latent fungal infection without damaging the fruit. These infections are in the form of spores which germinate in moisture on the fruit surface during their development in the field. Appressoria are formed at the end of the germ tube within several hours of germination. These appressoria adhere strongly to the fruit surface and are much more resistant than spores. Some of them remain in this form, while others produce slender hyphae which grow through the cuticle and outer wall of the epidermal cells to form a mass of hyphae. Further development of the pathogen may be prevented by the resistance of the immature fruit. At this stage there may be no external symptoms of the infection. These latent infections usually remain viable for several months and give rise to anthracnose disease symptoms when the fruit begins to ripen (13).

Methods which have been successful in controlling these latent infections are chemical treatments, hot water treatment and gamma irradiation. Some of these treatments have been found to be most effective when applied in combination with others. Their use may be governed by legislation with maximum tolerance levels for chemical residues. Some treatments are banned entirely in certain countries.

The following fungicides have been shown to be effective post harvest against anthracnose either alone or in combination with other treatments:

benomyl methyl 1 - (butylcarbamoyl) benzimidazol - 2 - ylcarbamate thiabendazole 2 - (thiazol - 4 yl) benzimidazole

thiophanate-methyl dimethyl 4, 4^1-(O-phenylylene) bis (3-thiophanate)

imazalil 1 -(allyloxy - 2, 4 - dichlorophenylethyl) imidazole

etaconazole 1 - [2-(2,4-dichorophenyl)-4-ethyl-1, 3-dioxolan-2-ylmethyl] - 1H - 1,2,4 - triazole. (CA).

iprodione 3 - (3,5 dichlorophenyl) - N - isopropyl - 2,4 - dioxoimidazoldidine - 1 - carboxamide

captan N - 4 - (trichloromethylthio) cyclohexene - 1,2 - dicarboximide

kasugamycin [5 - amino - 2 - methyl - 6 - (2,3,4,5,6 - pentahydroxycyclohexyloxy) pyran - 3 - yl] amino α-iminoacetic acid

Fungicides Alone

In the studies of mango anthracnose it was found that the disease could be reduced if fruit were dipped in benomyl at 600 or 1000 ppm plus a surfactant (31). The treatment was more effective if applied within 24 hours of infection. Bleinroth et al (4) also demonstrated good control of mango anthracnose by dipping fruit for 2 minutes in 2000 ppm benomyl plus a surfactant. Sohi et al (36) reported good control of anthracnose on mangoes dipped in either 500 ppm benomyl or 900 ppm thiabendazole. They found no difference in effect between a rapid dip or a ten minute soak. Dipping Alphonso mangoes in 500 ppm benomyl significantly reduced infections and hot water did not enhance this effect (27). Contrary to these results Spalding and Reeder (37) found no reduction in anthracnose levels when mangoes were dipped in 1000 ppm benomyl or 1000 ppm thiabendazole. Muirhead (22) also found no effect of cold water dips with benomyl on mango anthracnose. He suggested that it may be due to the inability of the fungicide to penetrate the thick cuticle of the fruit.

In recent studies of fungicides which would give good control of anthracnose in cold water, it was found that dipping in 0.55 ml per litre prochloraz for up to 2 minutes significantly reduced the level of anthracnose compared with untreated fruits, but had significantly higher levels than fruits dipped in 1000 ppm benomyl at 52°C for 5 minutes (25).

In a recent study of the effects of fungicides on *in vitro* control of *C. gloeosporioides*, tolerance to benomyl and cross tolerance to thiabendazole and thiophenate-methyl was found. No tolerance to either imazalil or etaconazole was found and the latter was the most effective in controlling *C. gloeosporioides*, both *in vitro* and *in vivo*, on Tommy Atkins and Keitt mangoes (34).

Hot Water and Fungicides

There is evidence that hot water treatment alone will give good control of anthracnose (14, 17, 28, 31, 33, 35, 37). In some cases the inclusion of a fungicide with the hot water enable lower water temperatures to be equally effective or the fungicide reduced the need for very precise temperature control (22, 33, 34). In commercial export trials from Jamaica to Britain taking 24 days at 13°C by reefer container almost all mangoes treated with hot water only (55°C for 5 minutes) had slight superficial anthracnose symptoms compared to untreated fruits which had much more severe symptoms giving a large proportion of wastage. The addition of benomyl (500 ppm) to the hot water resulted in fruits which developed no symptoms of anthracnose disease (40). In storage trials in Brazil using various hot water fungicide combinations it was found that hot water treatment at either 50°C for 30 minutes or 55°C for 10 minutes was required to give results comparable to 55°C for 5 minutes plus fungicide (33). Other workers have shown that gamma irradiation subsequent to a hot water fungicide treatment can enhance the control of anthracnose (15).

From the literature the general consensus would be that 55°C for 5 minutes with 500 ppm benomyl is effective in controlling anthracnose (Table 2). This, however, needs careful monitoring especially in view of the report of tolerance to benzimidazole fungicides (38). There are different strains of the fungus (22) and more detailed investigations into the epidemiology, life cycle and physiology of the fungus are required.

There are reports that hot water treatment can adversely affect the fruit. Pennock and Montaldo (28) reported that at 52°C and above there was a risk of scald. Other workers have shown some evidence of heat injury at 54.4°C for 5 minutes (37) and an acceleration in ripening at 53 - 55°C for 5 minutes (17).

Conversely, it was reported by Hatton and Reeder (14) that there was no evidence of heat injury at 55°C for 5 minutes. In an unpublished study of the effects of 55°C for 5 minutes it was found that chemical and physical changes which occurred during subsequent storage and ripening were similar in treated and untreated fruit. There was some indication that the climacteria peak of respiration could be slightly earlier in treated fruit compared to those not treated, but the difference would not be of commerical importance (42).

Commercial Application of Hot Water Treatment

Maintaining precise temperature for a precise time has been shown to be essential for effective control of anthracnose without damaging the fruit. Equipment used commercially for this purpose must provide these conditions with an adequate throughput often in the order of 2 tonnes per hour and more. In many countries growers have developed their own equipment (10, 12, 41), but usually these are for only a small throughput and often give inadequate temperature control.

A study was carried out on the design and development of equipment on a batch system for hot water treatment giving a throughput of 1 tonne of mangoes per hour (12, 40). This was successfully field-tested at a commercial packhouse in Jamaica over several years. Subsequent equipment was developed, based on the same design, by an exporter in Brazil with a 2 tonne per hour throughput. Some work has been done in Hawaii on a continuous system for application of hot water, and future equipment developments for mangoes may go in this direction.

Table 2: Recommended conditions for hot water treatments to control anthracnose post harvest on mangoes.

Ref.	Water temperature °C	Dipping time minutes	Fungicide ppm	Country
28	51 - 51.5	15	0	U.S.A.
35	54.4 - 55.8	5	0	U.S.A.
14	55	5	0	U.S.A.
37	54.4	5	0	U.S.A.
37	54.4	5	1000 benomyl	U.S.A.
37	54.4	5	1000 thiabendazole	U.S.A.
17	53 - 55	5	0	Mexico
15	55	5	1000 benomyl	South Africa
31	53	10	0	Philippines
23	55	5	0	Australia
23	51.5	5	500 benomyl	Australia
23	48.5	5	1000 benomyl	Australia
39	58 - 62	2	2000 benomyl	Zambia
12	52	4	500 benomyl	Australia
33	50	30	0	Brazil
33	55	5	1000 benomyl	Brazil
33	55	5	1000 thiabendazole	Brazil
33	55	5	1350 captan	Brazil
33	55	10	0	Brazil
5	55	5	1000 iprodione	South Africa
5	55	5	1000 benomyl plus 0.75 KGy irradiation	South Africa
34	55	5	2000 to 4000 Kasugamycin	Brazil
24	53.5	4	500 benomyl	Australia
25	52	5	500 benomyl	Australia

Discussion

Much of the information published on mango anthracnose disease is conflicting. Several reasons for this are possible including the fact that work has been done in several countries and differences in the environment and cultural practices may interact with control measures. There are known to be different strains of C. gloeosporioides which may respond differently to treatments. Evaluation methods vary with different research workers, as do the way observations are interpreted. Application of chemicals to tree crops can be difficult and, especially with large trees, it may not always be possible to ensure complete coverage. However, in spite of some anomalous reports all mango varieties currently grown commercially should be considered susceptible to anthracnose to some degree.

New sites for production should be selected which are least conducive to C. gloeosporioides. In sites where it is a problem a comprehensive field spray programme is essential based on experiments reported in the literature and the experience of the grower. Where fruits are to be marketed locally post-harvest control of anthracnose may not be necessary since the fruit may ripen quickly and disease symptoms remain superficial. However, effective post-harvest hot water/fungicide treatment will almost always be essential if fruits are to be held in storage for extended periods during marketing, e.g. when they are exported in refrigerated containers.

Cultural practices, growth regulation and varietal and root stock selections to enable the production of dwarf open trees may be an important way of reducing anthracnose. If carried out effectively it can not only create a microclimate which is less conducive to fungal development, but facilitate effective spray applications.

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