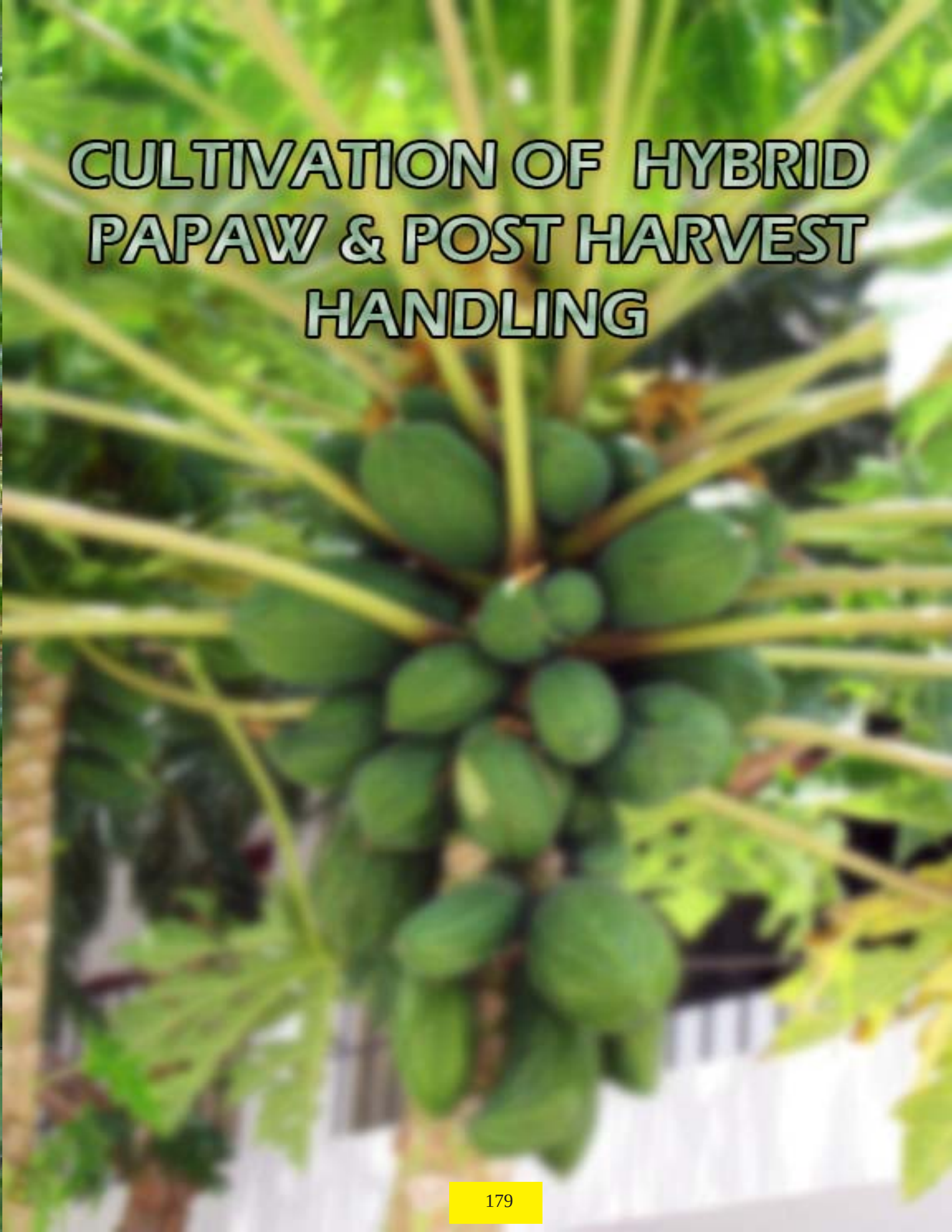
CULTIVATION OF HYBRID
PAPAW & POST HARVEST
HANDLING

PAPAYA

Introduction

Papaya *(Carica papaya)* is a quick growing perennial tree-like plant that is fast becoming a major crop in Guyana with huge potentials for export.. It is a popular fruit in Guyana available throughout the year. Hybrid papaya trees begin to produce fruits within nine months after transplanting depending on the cultivar, production practices and weather conditions.

Varieties

There are two types of papayas, Hawaiian and Mexican. The Hawaiian varieties are the papayas commonly found in supermarkets internationally. These pear-shaped fruit generally weigh about 1 pound and have yellow skin when ripe. The flesh is bright orange or pinkish, depending on variety, with small black seeds clustered in the center. Hawaiian papayas are easier to harvest because the plants seldom grow taller than 8 feet. Mexican papayas are much larger the the Hawaiian types and may weigh up to 10 pounds and be more than 15 inches long. The flesh may be yellow, orange or pink. The flavour is less intense than that the Hawaiian papaya but still is delicious and extremely enjoyable. They are slightly easier to grow than Hawaiian papayas. A properly ripened papaya is juicy, sweetish and somewhat like a cantaloupe in flavour, although musky in some types. The fruit (and leaves) contain papain which helps digestion and is used to tenderize meat.

Several types of Papayas are grown in Guyana ranging from the large elongated to the smaller pear like shaped types. Some of the common varieties include: known –You No1, Red Lady, Sun Rise, Tainung No. 1 and Tainung No. 2. The following entails a brief description of the various types grown in Guyana.

Known-You No.1

This hybrid is tolerant to papaya ring spot virus. Plants are thick, sturdy, early and heavy yielding. Fruit is large, weighing about 1.6-3 kg, with yellow flesh, sweet and good taste.

Red Lady

Early, vigorous, productive, and tolerant to papaya ring spot virus. Plants begin to bear fruit at 60-80 cm height and have over 30 fruits per plant in each fruit-setting season. Fruits are short oblong on female plants and rather long-shaped on bisexual plants, weighing about 1.5-2 kg. Flesh is thick, red, with 13% sugar content, and aromatic. Good shipper.

PAPAYA

Sunrise

Fruit is small, pear-shaped, red-fleshed, with very high sugar content and aromatic. Weighs about 400 g.

Tainung No.1

Plants are vigorous, prolific, and easy to grow. Fruit weighs about 1.1kg with red flesh and good aroma.

Tainung No.2

Large fruit with pointed blossom end, weighs about 1.1 kg. Flesh is orange-red, tender with good taste and quality.

Site Selection

If the land is low and accumulate water, ridges should be built about 45-60cm high and 60-90cm wide. If the land is high no ridges are needed. Papaya does not tolerate waterlogged conditions as such good drainage is a necessity.

Land Preparation

Planting holes should be dug 45cm wide by 45cm long and 30cm deep at a distance of 2.4m x2.4m. The first 15cm of top soil should be set aside and there organic matter is added to improve the soil structure. The lower 15cm of soil is discarded. TSP is added at 225g to the mixture along with about 450g of limestone for every rise in pH. Papaya requires a pH near neutral. The mixture is then added to the planting holes and built up into a mound, for best results this should be done about 6-8 weeks before planting. Planting should be done at the beginning or middle of the rainy season.

Planting

Seedlings should be about 6-8 weeks old at time of transplant. A planting hole the size of the planting bag should be dug on the pre-prepared site. The soil should then be treated for phytophthora with alliete or Ridomil at recommended rate. Before extracting the plants from the bags, make sure that the bags are properly watered; this will prevent the soil from loosening from the roots. The bag is then cut down the sides and the plant with the soil attached to the roots are taken out and placed in the planting holes and the soil around it gently firmed.

After Care

Irrigation: If the plants are planted in the rainy reason little or no irrigation is needed. If planted in the dry season about 4litres of water per day is needed for establishment up to about 2 weeks after transplanting, after which, irrigation can be done twice/week at the same amount.

Fertilizing:

Soil test should be done to determine the amount of fertiliser needed. In the absence of a soil test the following regime should be followed.

Two weeks after planting urea is applied at a rate of 125g/plant once every month until flowering, which should occur in the third month after transplanting.

After the third month limestone should be added in a circle around the plant about 60cm from the base of the tree and incorporated into the soil; since the feeding roots may be out of the previously treated area.

Fertilizing at flowering should be done with 12:12:17:2 at a rate of 225g per plant once per month.

Fertilizer rate should be increased to 450g per plant by the end of six months, and can be changed to 15:15:15 fertilizer.

Papaya bears in flushes, as such, fertilizing should be restricted when a flush is about to finish and restarted at the first indication of a new flush.

Papaya plants should be staked when they are about 1 year old so as to prevent lodging, this is done by planting two stakes into the ground and using canvas rope to bind the trees.

SYMPTOMS OF BORON DEFICIENCY

Bumpy fruit of papaya is associated with boron deficiency. It is known to occur in many of the papaya growing areas of the world and is observed in Guyana.

Symptoms

Deformity begins early but symptoms appear to become more severe as the fruit gets older. The bumpy appearance is a result of localized areas of the fruit being affected by the deficiency and cease to increase in size. Adjacent unaffected tissue continues to increase and result in a misshapen, bumpy appearance. The earliest symptoms usually occur in the young, developing fruits where bleeding of latex and initial deformation becomes evident (Figure 1). Seeds in affected fruit are often aborted or poorly developed and vascular bundles are often darkened. Under severe deficiency situations, height growth of trees may be affected causing a slight rosette effect and an associated stunting.

Fig 1. Symptom of Boron Deficiency

PESTS OF PAPAYA

Papaya mealybug *(Paracoccus marginatus)*

Damage Symptoms

There is a general reduction in leaf size and surface, curling, crinkling, twisting and general leaf distortion. Premature aging, chlorosis and leaf drop are also observed (Figure 2).

Sooty mould may cover the entire plant contributing to generally poor appearance and weakness of the plant.

Fig 2. Symptoms of papaya mealybug

Management and Control

The crawler stage of the papaya mealybug can be easily blown about by the wind and all stages can be washed off by rain or transported by birds and animals. Ants attracted to the honeydew can carry mealy bugs from plant to plant. However, humans are the main means to which the pest is spread .

Chemical Control

A number of insecticides have been reported to have some control e.g. Diazinon, Perfekthion, Malathion and, Admire. However, the effectiveness appears to be short lived.

Biological Control

This method has been recorded as the most effective weapon for the control of this pest as a result of the successful biological control of the Pink Hibiscus Mealybug. Four natural enemies are used for the biological control. These are:

Anagyrus sp.
Apoanagyrus sp.
Pseudophycus sp.
Acerophagus sp.

2. Mites (Brevipalpus californicus)

Symptoms

Mites suck the plant sap, leading to poor plant growth and blemishes on the fruit. Predatory mites generally provide adequate control, an additional reason for restraint in the use of acaricides or insecticides with miticidal action.

Cultural Control:

- Cultivation method such as controlling the amount and quality of water a plant receives is important not only from the aspect of plant growth, but also to prevent mite infestation;
- Crop rotation;
- Weed control may reduce mite infestations;
- When an Integrated Pest Management programme is evaluated, the use of predatory mites, cultivation methods, limiting doses of fertilizer, weed and chemical control are usually acknowledged as the main tools of such a programme.

Chemical Control:

- Many acaricides are available for the control of B. californicus.
- Dinobuton and cyhexatin gave good results against B. californicus.

3. Aphid

(Aphis gossypii, Myzus persicae)

Aphid infestation weakens the plants and aphids also transmit viral diseases.

Cultural Control:

Removing alternative hosts and the presence of natural predators can effectively reduce aphid populations.

Chemical Control:

Spraying of insecticides such as: Fastac, Decis or Karate on the undersides of the leaves is also an effective control measure.

4. Rootknot

(Meloidogyne incognita) **and reniform** *(Rotylenchulus reniformis)* nematodes infest papaya. Feeding nematodes cause root swellings or root galls (Figure 3), resulting in yellowing and premature abscission of the leaves.

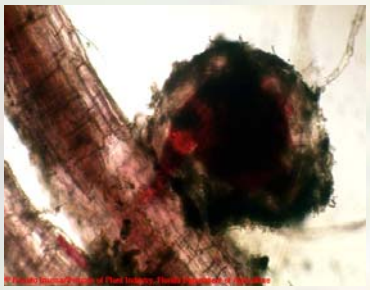

Fig 3. Symptoms of rootknot nematode

Cultural Control:

Since nematicide treatments are expensive, it is important to use clean land, not replanting papaya in the same field.

- Crop Rotation
- Integrated crop management(ICM)
- Minimum of six months of flood fallow.

Slugs

Slugs, which are present during the wet period, suck the leaves at the point of attachment of the leaves and stem, causing damage, which restricts the flow of nutrients resulting in fruit drop and death of leaves. This is controlled by slug bait

Fig. 4: Fruits affects by powdery mildew

DISEASES OF PAPAYA

Powdery Mildew in Papaya (Oidium caricae, fungus)

Symptoms

This common disease generally causes little damage or yield loss to bearing trees where lesions are usually found on senescent leaves (Figure 4). However, powdery mildew may severely damage young plants in environments with moderate rainfall and temperatures.

Diffuse mats of white mycelium commonly develop on the lower leaf surface, especially in areas adjacent to the leaf veins, but can occur occasionally on the upper surface of leaves. Initially, infected areas become light green and chlorotic and lesions may be surrounded by a dark green margin. Stems, flower pedicels, and fruits as well as leaves can become infected.

Although leaves of all ages are considered susceptible, infection is largely confined to the older leaves approaching senescence. Seedling plants are especially susceptible to attack and may be seriously affected (Figure 5). Defoliation, stem and fruit lesions on young plants may lead to measurable yield losses.

Affect leaf

Affected seedlings

Fig 5. Leaves and Seedling affected by powdery mildew

MANAGEMENT

1. Non-Chemical Control

Although control measures are generally not needed applications of wettable sulfur, sulfur dust, or lime sulfur have proved helpful in controlling this disease. However, wettable sulfur may be toxic to the plant during hot weather and is not very effective during periods when the disease is severe.

CHEMICAL CONTROL

Fungicides effective in controlling powdery mildew on other crops have generally been effective in controlling papaya powdery mildew. Benomyl, bupirimate, carbendazim, mancozeb, thiophanate-methyl, and triadimefon have demonstrated efficacy in the field.

2. Foot Rot of Papaya (Pythium aphanidermatum)

It is a severe disease of papaya. It is characterized by the appearance of water-soaked patches on the stem near the ground level. These patches enlarge rapidly and girdle the stem, causing rotting of the tissues, which then turn dark brown or black. Such affected plants withstand strong wind and topple over and die. If the disease attack is mild, only one side of the stem rots and the plants remain stunted. Fruit if formed are shriveled and malformed. Gradually the plant dies.

Control : Application of Trichoderma viride (15 g/plant) mixed in well-decomposed FYM should be applied around the root zone of the plants at the time of planting. The crop should be irrigated by adopting the ring method of irrigation so that the water does not come in direct contact with the stem.

In the case of new plantings, preventing water logging of the soil may control the disease. The soil should be drenched with 2-3 litres of Copper Oxychloride (3 g per litre of water). The application should be carried out regularly at 15 days interval from the time of planting. During fruit formation, the plant should be sprayed with the same solution at the same time interval. Alternately, Mancozeb (2.5 g/ litre of water) may also be applied.

In the case of disease attack in existing crops, the rotted portion of the plant should be scraped and Copper Oxychloride or Bordeaux paste should be applied. The paste can be prepared by dissolving one kg of Copper Sulphate and lime separately in ten litres of water each. The two solutions should be mixed and shaken to form a paste.

The base of the plant should be drenched with three litres of Copper Oxychloride (3g/litre). The plant should be drenched during fruit formation with Copper Oxychloride or Mancozeb at the earlier mentioned concentrations twice at 15 days interval.

3. Leaf Curl of Papaya :

The disease is transmitted by the vector white fly (Bemisia tabaci). Severe curling, crinkling and deformation of the leaves characterize the disease. Mostly the young leaves are affected. Apart from curling the leaves also exhibit vein clearing and thickening of the veins. Sometimes the petioles are twisted. In severe cases complete defoliation of the affected plant is observed. The affected plants show a stunted growth with reduce fruit yield.

Control : Removal and destruction of the affected plants is the only control measure to reduce the spread of the disease. Checking the population of white flies also can reduce the infection severity. Soil application of Carbofuran (1 kg a.i./ha) at the time of sowing and 4-5 foliar sprays of Dimethoate (0.05%) or Metasystox (0.02%) or Nuvacron (0.05%) at an interval of 10 days effectively controls the whitefly population.

4. PAPAYA RINGSPOT

Causal Agent

The papaya ringspot disease is caused by the papaya ringspot virus (PRSV). This virus belongs to the potyvirus group of viruses. It is a flexuous rod shaped particle that is about 800-900 nm long. Two types of PRSV have been recognized-PRSV-p, which can infect both papaya and cucurbits, and PRSV-w (W- for watermelon) which infects cucurbits only. These two types of viruses are closely related, except for the inability of the PRSV-w to infect papaya.

Symptoms

Several types of symptoms are associated with this disease. The earliest symptoms on papaya plants infected with the virus are yellowing and vein clearing of the young leaves. This is followed by a yellow mosaic pattern on older leaves. Development of a shoestring appearance on new leaves followed by severe reduction in leaf canopy and in stunting of young plants is frequently observed (Fig.6). Several 'oily' streaks on the stem of young diseased plants are also common (Fig.7).

The disease derives its name from the symptoms that are observed on the fruits of infected plants. These conspicuous symptoms are dark green, slightly sunken concentric rings and C- shaped patterns that persist on ripe fruits (Fig 8 & 9) are diagnostic of the disease.

Fig 6. Shoestring symptom on leaves of infected papaya plant in Parika.

Fig.7. Oily streak on a papaya plant infected with PRSV.

Fig 8. Typical ringspot patterns on a fruit produced by a diseased plant at Parika

Fig 10. Severely distorted fruit produced on a plant infected with PRSV.

Fig 9. Severe ringspot patterns on the fruit of a plant infected with PRSV.

Young fruits produced after infection can be severely distorted and indented with the indented areas being pale green to white in colour (Fig.9). This is especially prominent at the stem–end of the fruit where typical ring spots are also observed.
Fruit quality, particularly flavour, is adversely affected. Plants infected before flowering may not produce fruits or will only produce severely distorted fruits. Plant yield and fruit quality are severely affected. The entire plant may be destroyed in 4-6 months after initial symptoms are observed.

isolates of this pathogen will cause severe reduction in fruit production but will rarely cause death other isolates can cause wilting and death. Papaya plants at all stages in development are susceptible and will start expressing symptoms within three weeks of infection.

Disease Spread

This virus is transmitted from diseased plants to healthy plants by several aphid species in a non-persistent manner. Reports also indicate that the virus can be carried by aphids from infected cucurbits to papaya. The virus is not considered to be seed transmissible although there is one report of seed transmission in the Philippines. The movement of infected plants into disease free areas can also result in the spread of this virus. The PRSV cannot be transmitted by air, movement of soil or water, and dead plant materials will not serve as a source of inoculum. Once a plant has become infected the disease cannot be cured by spraying with pesticides or by the removal of the plant part showing symptoms. An entire orchard can become infected in 2-3 months especially when there is a high population of winged aphids.

Management

This disease cannot be controlled using chemicals. Once a plant has become infected it cannot be cured of the disease. A number of different methods have been employed in the management of this disease with varying degrees of success.

The following are some of the strategies that can be used in the management of this disease.

1. Geographic isolation combined with diligent surveillance and roughing of infected plants can delay the spread of this disease to other areas.
2. The use of papaya seedlings that are certified free of PRSV.
3. Situate new orchards as far away as possible from infected fields.
4. The use of resistant or tolerant cultivars where possible. Resistance is the only sustainable means of effectively managing this disease. The cultivars Red Lady, Know You #1 and the Cariflora have all been reported to be tolerant to this disease. The Solo Sunrise, Tainung #1 and Tainung # 2 varieties have all shown to be susceptible to this disease locally. Two new cultivars of the solo type – ‘UH SunUp’ and ‘UH Rainbow’- are reported to be resistant to PRSV based on field trials conducted in Hawaii. These are transgenic cultivars that were derived by transforming the Solo ‘Sunset’ cultivar using the coat protein gene of an isolate of PRSV from Hawaii.

1. Use of cross protection in disease management. Some successes have been reported in Taiwan and Hawaii using this method. In this method plants are inoculated with a mild strain of PRSV that protect them against economic losses resulting from infection from the more severe strains of this virus.
2. Planting of a non-host crop such as corn around papaya orchards has also been used in disease management. The strategy here is for the aphid vectors transmitting the virus, in a non-persistent manner, to feed first on the non-host plants thereby reducing the chance of them infecting papaya plants.
3. Insecticides may also be used as part of disease management. Insecticides are used primarily in controlling the aphid vector and thus, the spread of the papaya ringspot disease. Data available has so far indicated that the use of insecticides has only been effective in delaying the spread of this disease.

The papaya ringspot disease has been positively identified in Guyana and has so far only been diagnosed on papaya plants in Parika in Region 3. This disease has caused widespread destruction to papaya industries in a number of countries and has the potential of causing similar destruction in Guyana. It is therefore imperative that this disease be isolated within the identified area in order to prevent its spread to other papaya growing areas in the country. The movement of plants from this area to other parts of the country will result in rapid spread of this disease to disease free areas. It is therefore essential that quarantine measures be put in place to restrict the movement of papaya plants from this region to other parts of the country. Additionally, research into the use of available resistance to this disease is critical if the papaya industry is to survive and continue to grow. The National Agricultural Research Institute has started to conduct research on the PRSV including those aimed at identifying and evaluating resistant cultivars to this disease.

5. DAMPING-OFF *(PHYTOPHTHORA PARASITICA* OR *P. PALMIVORA)*

Whole plant

Seedlings usually display damping-off or blight symptoms, often resulting in death of the plants. Infected plants may be cut at the stem base and show early senescence.

Leaves

Wilting is the most common symptom. Some leaves may be chlorotic, yellowing, developing lesions and then rot, resulting in death and defoliation.

Stem

Brownish-black discoloration occurs at or near the soil level, gradually girdling the stem, leading to plant death. Affected tissues are soft and water-soaked. Secondary adventitious roots often emerge above the lesions.

Roots

The roots of affected plants blacken, decay and become entirely rotted. Affected tissues are soft and water-soaked.

Growing Point

The growing point of infected plants may rot and dieback and mycelium may be present.

Cultural Control:

The control of plant diseases caused by soil-borne pathogens is difficult.

- Good aeration, drainage, and hygiene are important to curb these fungi in the orchard as well as in the nursery.
- Crop rotation

Chemical Control:
In general, fungicidal control is the normal practice using primarily narrow-spectrum systemic fungicides.

Anthracnose
(Glomerella cingulata)

Symptoms occur on leaves, stems and fruits. Where seedlings have grown from infected seeds, lesions are more obvious on the upper parts of the stem and on the older leaves. Lesions on the leaves are usually circular and dark brown. Prominent, dark pycnidia develop within the lesions, particularly as the leaves age and conditions are moist. The pycnidia can vary in abundance from sparse to numerous and are sometimes concentrically arranged. On the stems, the lesions are usually smaller at the early stages of infection, but they elongate up the stem and become markedly sunken. The lesions are usually darker than those on leaves and contain scattered pycnidia. When the lesions are deeply sunken, the stems of the plants may break at the point of infection, either causing the crop to lodge before harvest or, if the infection occurs at an early stage, the stems may bend upwards producing a kink where the stems re-grow vertically.

At the seedling stage, where infection originates from the seedborne source, the combination of stem and leaf infection may result in the death of the plant.

Cultural Control:

- Plant only certified seed

Chemical Control:

- Fungicidal sprays can control this disease.

Cornysporium papaye is a new disease of papaya identified in Guyana by R. Persaud, NARI, 2002. This disease affects the veins of the leaves causing it to become dark brown, this infection restricts nutrient flow to all parts of the leaves resulting in necrosis of leaves, fruit drop and finally death of the tree. The disease is spread by rain splash and wind. Control is done by good farm sanitation, including removal and burning of all infected plant parts. Spray with a chemical fungicide such as Benlate.

Cercospora leafspot appears on leaves as small greenish-white circular spot, they soon enlarge, becoming grayish brown with brown borders and often coalesce to form large irregular spots. The spots are often covered with grayish powdery mass of conidia. Heavily infected leaves gradually turn yellow and fall off. The conidia are dispersed by rain splash and wind. Control is done by removal of infected leaves and burning, also chemical control such as maximo or Bravo has been effective.

Phytopthora Blight is a soil born fungus and is present in most soils of Guyana especially the wet areas. It appears as a water- soaked lesion on the trunk in heavy dew condition and rainy season, girdling the diseased trunk which later rot, then the whole tree dies after wilting (Figure 11). Similar lesions containing white latex exudet and white mold occur on ripening fruits on tree as well as fruits after harvesting. Control can be achieved by controlling soil moisture content, the use of chemical fungicides such as Alliete and Ridomil at recommended rate.

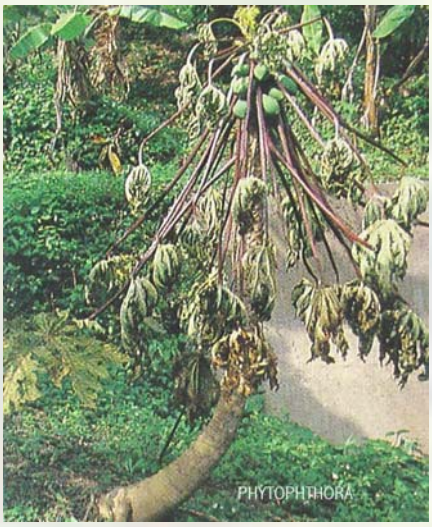

Fig 11. FRUIT AND TREE INFECTED WITHPHYTOPTHORA BLIGHT

Weed Control of Papaya (*Carica papaya L.*) **in Guyana**

- Effective use of Paraquat and Glyphosate in papaya is dependent on avoidance of spray contact to green bark and foliage.
- Pre-emergence herbicide tolerance is dependent on age, size and maturity of the crop, and soil type.
- Only Oryzalin can be tolerated by papaya immediately after transplanting.
- Herbicides with a broader spectrum of weed control, such as Diuron and Oxyfluorfen, generally injure young plants, but they can be effectively used later in development.

POST HARVEST TREATMENT

Anthracnose is a major post harvest disease occurring in Papaya resulting in severe losses of fruits. Work done by (R. Persaud , NARI, 2002) showed that Mertect give the best result in controlling post harvest infection than several other fungicides that were evaluated.

Use 6 ml of Mertect to 2 liters of water and dip harvested fruit into it. Allow fruits to air-dry, then wrap individually in newspaper, this will ensure uniform ripening and also act as a cushion from the other fruits. The fruit should now be ready for packaging and shipping. Package should be well cushioned to avoid impact damage.

Harvest Maturity Indices

Various non-destructive indices can be used to determine papaya harvest maturity, including the number of days from flowering, fruit size, and external color. It is important to harvest papaya fruit at the proper maturity stage, because they do not increase in sugar content after picking.

Papayas normally require about 3 months from flowering until fruit maturity. The smaller pearshaped Hawaiian type papaya fruit generally weigh between 350 to 500gm when mature. Native type fruit are significantly larger when mature, often weighing more than 1500 gm when mature. The most obvious index of fruit maturity is external skin color. As the fruit matures, the skin color will change from green to yellow/orange (Figure 12).

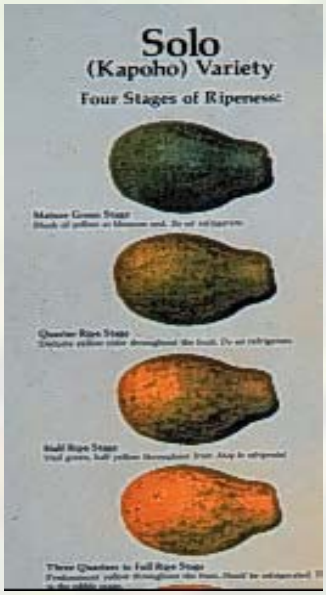

Fig 12. External skin color changes from green (top) to yellow-orange (bottom) during ripening .

Papayas for export should be harvested between the onestripe stage [one yellow stripe showing at the blossom end (Figure 13)] and the quarter-ripe stage [some yellow at the blossom end (Figure 14)]. Fruits harvested at these stages of maturity will withstand the rigors of shipping and transport to distant markets. Fruits harvested immature green will not ripen properly, will taste flat, and shrivel prematurely. For fruits to arrive in the importing country at the correct color stage, attention has to be paid to the maximum and minimum color stage on departure from Guyana, the length of transit, and the transit temperature. Many importers prefer fruits to arrive at the half-yellow color stage.

Fig 13. Export market destined papaya fruits harvested at the one-stripe stage

Fig 14. Slightly yellow (quarter-ripe) papaya fruits destined for export.

Flavor and edible quality generally improve with advanced ripeness stage. Fruits intended for domestic markets can be harvested at a more advanced stage of ripeness than export market fruit. Domestic marketed fruits should be harvested when the skin is partially yellow-orange in color (between one-quarter to half-ripe). A completely yellow-orange skin indicates full ripeness and generally a sweeter fruit. However, the postharvest life of this advanced maturity stage fruits will typically be less than a week (Figure 15).

Destructive indices used for determining harvest maturity include internal pulp color and % soluble solids content (sugar content). These indices are used to test randomly selected fruits in order to correlate fruit size with maturity. The internal pulp color of mature papaya fruit changes from cream to yelloworange as the external skin color changes from green to yellow-orange during ripening. The soluble solids content of mature fruits should be at least 11.5%, and can be determined by placing several drops of juice on a hand-held refractometer. Experienced growers use a combination of external and internal maturity indices to determine when to harvest.

Fig 15. Papaya fruits harvested at full ripeness (yellow-orange skin color) have a very short market life.

Principal Postharvest Diseases

Anthracnose

Anthracnose, caused by the fungus *Colletotrichum gloeosporiodes*, is a serious postharvest disease of papaya. The pathogen initially infects intact, non-wounded, immature green fruit in the field. However, symptom development generally occurs after harvest, especially when the fruit is ripe. Disease symptoms begin as small water-soaked spots on ripening fruits. As the spots develop, they become sunken and turn brown or black and may enlarge to 2 in. (5 cm) in diameter (Figure 16). The fungus may produce a pink mass of spores in the middle of these older spots. The pathogen can grow into the fruits, resulting in softening of the tissue and an off flavor of the pulp. The environmental conditions that favor the pathogen are high temperatures (optimal is 28°C) and high humidity. Disease spores must have free water to germinate and are spread by wind or rain. Anthracnose can be controlled by following an adequate fungicide spray program beginning at fruit set and continuing at regular intervals (usually every 10 to 14 days) while the plants are producing fruit. Postharvest application of the fungicide thiabendazole (1000 ppm spray or dip) is effective in reducing the amount of anthracnose decay. Also, a postharvest hot water dip at 48°C for 20 minutes will significantly reduce the amount of anthracnose. Specialized equipment is needed for circulating the water and maintaining a uniform temperature, as fluctuations in water temperature will reduce the effectiveness of the treatment and may damage the fruits. Although no known cultivar of papaya offers complete resistance to anthracnose, the Hawaiian cultivar Sunrise is more resistant than is Kapoho.

Fig 16. Anthracnose decay of mature green (left) and ripe (right) papaya fruit.

Black Rot

Black rot, caused by the fungus *Mycosphaerella caricae*, is another common postharvest disease of papayas. Fruits symptoms may appear in several different ways. Slightly sunken circular surface lesions may appear anywhere on the fruit, eventually enlarging up to 4 cm in diameter (Figure 17). The margin of the lesions are light brown and translucent. As the lesion surface dries and wrinkles with age, it turns black and becomes covered with fungal growth. The infected tissue usually remains firm. Another typical symptom of black rot is a dry, firm, dark rot extending into the fruit from the stem end (Figure 17).

Fig 17. Sunken lesion (left) and stem end decay (right) of black rot infected papaya.

The fungus colonizes senescing leaves and petioles that serve as the primary source of inoculum in the field. The disease is spread by rain and may remain dormant on the fruit surface for extended periods. Wounds created during harvest and postharvest handing may be quickly infected with the pathogen under ambient temperatures. The incidence of postharvest stem-end rot on fruit from non-sprayed fields is typically between 30 to 40% of the total harvest. A significant reduction in stem-end rot is obtained by biweekly fungicide sprays during fruit growth and development. A postharvest hot water treatment at 48°C for 20 minutes also significantly reduces stem-end rot. Fruits should be treated within a day after harvest.

Phytophthora Fruit Rot

Heavy fruit losses caused by the fungus *Phytophthora palmivora* frequently occur during rainy periods. When mature fruits are infected, circular translucent lesions develop on the skin and become covered with a whitish to gray fungal growth (Figure 18). Rain and wind are the two principal ways of spreading Phytophthora in the field. Temperature also influences disease severity, with pathogen growth being highest at 25°C. Phytophthora fruit rot can be controlled with bi-weekly preventive fungicides, such as mancozeb, basic copper sulfate, Ridomil, or Aliete during fruit growth. Cultural practices are also important in the management of Phytophthora. The disease incidence on mature trees during rainy periods can be greatly reduced by improving drainage in orchards. Infected fruit on trees and on the ground should be removed.

Fig 18. Whitish fungal growth on mature papaya fruit infected with Phytophthora rot.

Watery Soft Rot

Watery soft rot, caused by the fungus *Rhizopus stolonifer*, is a common postharvest disease of papayas. It is important only during fruit storage and transit and is rarely seen in the field. When Rhizopus infects fruit already packed for market, the watery leakage causes an unsightly mess. Watery soft rot is characterized by a soft and watery rot that quickly causes the collapse of the entire fruit but leaves the cuticle intact (Figure 19). The fungus can grow through any break in the cuticle and spread rapidly to adjacent fruit, often destroying the entire contents of a box within a few days. The infected fruit is often covered by a coarse gray to black hairy fungal mass. The affected fruits quickly becomes colonized by yeasts and bacteria and have a sour odor.

Fig 19. Typical symptoms of watery soft rot.

Rhizopus can enter the fruit tissue only through wounds and cannot penetrate uninjured fruit surfaces. Therefore, wounding that occurs during harvesting, transporting, or postharvest handling plays an important role in the development of the disease. The incidence of watery soft rot increases during rainy weather, in part because of higher inoculum levels, higher humidity, and an increase in the number of fruit lesions caused by other fungi. High humidity and temperatures of about 25°C during storage or transit are optimum for Rhizopus soft rot development. The most important control measure is sanitation in and around the packing plant. Rotting fruit in packing plants should be removed and destroyed. Bins and water tanks used for fruits should be chlorinated to prevent the buildup of this and other pathogens. Conveyor belts, rollers, and other equipment that touch the fruit should be regularly sanitized. Preventive field fungicide sprays control Rhizopus soft rot by reducing field inoculum levels.

Wet Fruit Rot

Wet fruit rot is caused by the fungus *Phomopsis*, and in its early stages resembles Rhizopus watery soft rot. It occurs most frequently as a stem-end rot, although any part of the fruit can be affected. Symptoms include a discoloration of the tissue around the stem end, which soon breaks down and becomes colonized by a whitish-gray mold (Figure 20). The fungus grows rapidly, causing lesions to expand very quickly and extend into the seed cavity. The cuticle over the infected area remains intact and develops a delicate, is soft, mushy, and wet but, unlike tissue affected by Rhizopus watery soft rot, does not usually leak liquids. Wounding of the fruits is required for infection. The disease usually develops on fully ripened fruit and is rare on green fruits in the field.

Control of wet fruit rot, like the control of many other postharvest diseases of papaya, must begin in the field. Regular field sprays with protective fungicides reduce inoculum levels and prevent infection through wounds that might occur in the field. Dead leaves should be removed from trees because they may become heavily infected with *Phomopsis* and interfere with spraying. The removal of leaves is best accomplished by periodically cutting the petioles that droop below horizontal about 30cm from the stem and removing them about a week later after the abscission zone forms but before the petiole stub has dried.

Fig 20. Phomopsis stem-end rot on ripe papaya fruit.

The prevention of mechanical wounds during and after harvest is important. Postharvest hot water treatment for 20 min at 48°C is also effective when used in conjunction with regular field preventive sprays.

Stemphylium Fruit Spot

Early symptoms of Stemphylium fruit spot are development of small, round, dark brown surface lesions. The lesions become sunken and develop reddish brown to purple margins as they enlarge. A velvety, dark green spore mass forms in the lesion center. White to gray fungal growth covers the lesion in advanced stages. Internally, the infected tissue is discolored from reddish brown to dark brown, appears dry, and may develop small air pockets.

The Stemphylium fungus is also capable of causing decay of the stem end. The characteristics of decay of the stem end are similar to those of the fruit spot, except infection begins on the broken-end surface or near the base of the stem and later spreads to the surrounding tissue.

Regular field sprays with protective fungicides help keep the inoculum level low in the field. The standard single hot water dip is effective in controlling this disease. Hot water exposure at 48°C for 20 min will kill more than 98% of the conidia. Wounding and prolonged cold storage should be avoided, and heat-treated fruit should be cooled immediately after treatment. Injury or stress, wounds, and chilling injury all increase the susceptibility to fruit spot. Ripe fruits are the most likely to be infected.

Alternaria Fruit Spot

Alternaria fruit spots are depressed, circular to oval lesions that eventually become black as a result of pathogen sporulation. Lesions are restricted to the surface of the fruit and do not cause extensive rotting of the flesh. However, lesions from multiple infection sites can coalesce as they expand and eventually cover the entire fruit surface.

Alternaria fruit spot rarely develops on fruits kept or ripened at room temperature. However, fruits that are kept in cold storage (< 10°C) for 10 to 14 days will suffer chilling injury and a high incidence of Alternaria.

The fungicides chlorothalonil or mancozeb will significantly reduce postharvest Alternaria development if sprayed biweekly during fruits growth. However, a preharvest spray program alone does not provide complete control of this disease. A single postharvest hot water dip of 20 min at 48°C also will reduce the disease.