

# PAPAYA

## Post-harvest Operations

 INPhO - Post-harvest Compendium



Food and Agriculture Organization  
of the United Nations

# PAWPAW: Post-harvest Operation

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## 1 Introduction

The pawpaw (*Carica papaya* L.) is the most economically important fruit in the *Caricaceae* Family. In some parts of the world, specially Australia and some islands of the West Indies, it is known as papaw, or pawpaw, names which are better limited to the very different, mainly wild *Asimina triloba* Dunal, belonging to the Annonaceae. While the name pawpaw is widely recognized, it has been corrupted to kapaya, kepaya, lapaya or tapaya in southern Asia and the East Indies. In French, it is *papaye* (the fruit) and *papayer* (the plant), or sometimes *figuier des Iles*. Spanish-speaking people employ the names melón zapote, lechosa, payaya (fruit), papayo or papayero (the plant), fruta bomba, mamón or mamona, depending on the country. In Brazil, the usual name is mamao. When first encountered by Europeans it was

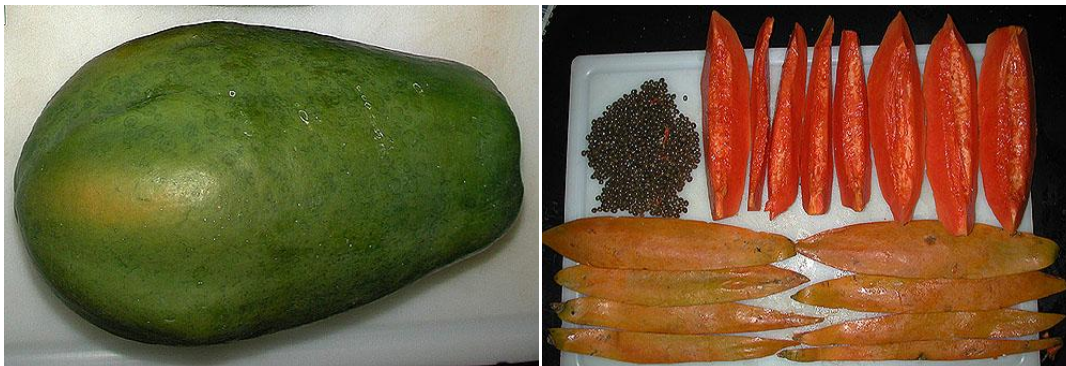
quite naturally nicknamed "tree melon". (Morton, 1987).

Production areas are located in most tropical and sub-tropical countries (CRFG, 1998) (Fig. 1 Pawpaw mayor producing countries).



**Fig. 1 Pawpaw mayor producing countries**

The percentage composition of typical pawpaw is: seed (8.5 %), skin (12 %) and pulp (79.5 %) (Fig. 2 Typical pawpaw, maradol variety; and Fig. 3 pawpaw maradol variety % composition). As a dual- or multi-purpose, early-bearing, space-conserving, herbaceous crop, it is widely acclaimed, despite its susceptibility to natural enemies.



**Fig. 2 Typical pawpaw maradol variety Fig. 3 Pawpaw Maradol variety % composition**

Component	%
Skin	25.3
Pulp	69.3

**a) Origin**

The pawpaw is believed to be native to southern Mexico and neighboring Central America. It is currently cultivated in Florida, Hawaii, Eastern British Africa, South Africa, Sri-Lanka, India, Canary Islands, Malaysia and Australia. It is now present in every tropical and subtropical country. Pawpaw was first described in 1526 by the Spanish chronicler Oviedo, who found it first on Panamanian and Colombian coasts. The fruit was rapidly propagated in the tropics, most likely due to the abundant and highly viable seeds. The crop has adapted quite well to tropical areas with fertile soils and abundant rainfall. The history of pawpaw spread was initiated approximately in 1500, when the Spanish conquerors carried seeds to Panama and Dominican Republic. During the following century Spanish and Portuguese sailors took the seeds to the Phillipines, Malaysia and India. For 1600 the fruit had been produced in warm regions of South and Central America, Southern Mexico, the Antilles, Bahamas, Bermuda y Florida. In the same century pawpaw seeds were taken from India to Naples in Italy. The crop reached Hawaii between 1800 and 1820. Until 1900, pawpaw seeds were taken to Florida, probably from Bahamas' plantations. The *Solo* variety has been cultivated in Hawaii since 1911, probably brought from Barbados and Jamaica. The first seeds of the *Maradol* variety were introduced into Mexico in 1978, through CONAFRUT, in Xalapa, Veracruz (CRFG, 1998).

**b) Taxonomy****Morphology and taxonomy**

**Family:** *Caricacea*.

**Order:** *Parietals*.

**Species:** *Carica papaya*.

SCIENTIFIC NAME: *Carica papaya* L.

**c) Botanical description**

**Plant:** It is a fast growing arborescent herb, with short life, it has single straight or sometimes branched stem reaching 2-10 m height (Fig. 4 Pawpaw tree), the stem is cylindrical spongy-fibrous, loose, hollow, gray or gray-brown colour, 10-30 cm diameter and toughened by large and protuberant scars caused by fallen leaves and flowers.



**Fig. 4 Pawpaw tree**

The pawpaw is a polygamous species. The plants may be classified into three primary sex types: 1) male (staminate), 2) hermaphroditic (bisexual), and 3) female (pistillate). In addition, some plants can produce, at the same time, more than one kind of flower. Also, some produce flowers that are not of these basic forms, but exhibit different degrees of maleness and femaleness. This tendency to change in sexual expression seems to be triggered by climatic factors, such as drought and variable temperatures. The tendency to produce male flowers seems to increase at high temperatures. Since male trees are unfruitful and fruit from bisexual plants is preferred in some markets, it is very important to select seed which will give a maximum number of fruitful trees of the desired type. This can't be do by simply saving seed from productive open-pollinated plants, but one can predict fairly accurately the progeny by knowing the source of pollen and the kind of flower the fruit came from. Accordingly, the grower must hand pollinate to obtain the desired combination of flower types. This is done covering an unopened flower, either bisexual or pistillate, with a paper bag until it opens and then transferring the desired pollen onto the receptive pistil. Pollination studies have shown that: 1) pistillate flowers pollinated by staminate flowers give equal numbers of male and female progeny; 2) pistillate flowers pollinated by pollen from bisexual flowers give an equal number of female and bisexual progeny, 3) bisexual flowers either self or crossed-pollinated with other bisexuals give a ratio of one female to 2 bisexual, 4) bisexual flowers pollinated by staminate ones produce equal numbers of female, male and bisexual progeny. It is evident that the second and third combinations will produce the maximum number of fruit-bearing plants (Malo, 2001).

***Radicular system:*** Highly superficial, which conditions soil work.

***Leaves:*** Alternate, bundled at the apex between stem and branches, long petioles; widely evident, 25-75 cm diameter, smooth, moderately palm shape with thick middle irradiant veins, the base is deeply string shape with overimposed lobes; from 7-11 large lobed, each with a wide base or slightly constrained and sharp-pointed, and sharp apex. The bundle of leaves is dark green to yellow-green, bright, visibly marked by the off-white nerves embedded and reticulated veins; the underneath surface is pale green-yellow and opaque with visibly prominent vascular structures; the petioles are round and yellow-green, with sporadic purple or violet stains, fistulous form, fragile, 25-100 cm length and 0.5-1.5 cm thick. (Fig. 5 Pawpaw leaves).





**Fig. 5 Pawpaw leaves**

**Flowers:** Six types of flowers are known in pawpaw plant.

**a) Typical female flower.** It is a rather large flower of conical shape when closed, when open, its five petals spread from the base. The ovary is large with circular and smooth or slightly undulated. Fruits produced by this flower are spherical or ovoid in shape. (Fig. 6 Typical female flower, De Los Santos, *et al.*, 2000).



**Fig. 6 Pawpaw typical female flower**

**b) Similar to the above when closed**, but this type has five short anthers, which correspond in their orientation with the five petals that also spread from the base. The ovary has five deep longitudinal grooves that remain until maturity. Fruit develop a form from globular to egg-shaped.

**c) Hermaphrodite intermediate flower.** The organization is undefined, petals may be fused up to two thirds of their length or free from the base. The number of anthers ranges from two to ten; the carpels range from five to ten, with different degrees of fusion. This type of flower produces irregularly-shaped fruit known as carpelodic (cat face), with little commercial value. These flowers appear more frequently when ambient temperatures are 24.5 °C during the day and 15.5 °C at night.

**d) Hermaphrodite elongated flower.** Petals of this type of flower are fused from one fourth to three fourths of their total length; ten anthers are observed, five long and five short (Fig. 7 Hermaphrodite elongated flower, (De Los Santos, *et al.*, 2000). The ovary is long and when it contains five or more carpels, the form of the fruit varies from cylindrical to pear-shape. From the different types of hermaphrodite flowers, this is the most commercially important. (Fig. 7 Pawpaw hermaphrodite elongated flower, De Los Santos, *et al.*, 2000).



**Fig. 7 Pawpaw hermaphrodite elongated flower**

**e) Hermaphrodite sterile flower.** It is a flower that resembles the former, but does not develop an ovary and hence it is sterile, warm temperatures or water stress. Due to the fact that it produces pollen only, it may be considered a functional male flower (Fig. 8 Pawpaw hermaphrodite sterile flower, De Los Santos, *et al.*, 2000).



**Fig. 8 Pawpaw hermaphrodite sterile flower**



**f) Typical male flower.** This type of flower have a long and thin corolla contain anthers in two series of five; one series longer than the other. They have a rudimentary pistil no stigma and are non-functional. (De Los Santos *et. al.* 2000).

The leaves are spirally arranged in a terminal cluster, simple, on petioles 30-70 cm long. The leaves are rounded in outline, 60-90 cm in diameter, palmately 7-9 lobed. The margins of the lobes are very variable, and range from entire to undulate to deeply lobed (University of Cornell, 2000).

In nature, these plants are dioecious: male and female flowers are found on separate plants. Male flowers are morphologically distinct from female flowers. Male inflorescences are borne in many-flowered panicles of cymes on horizontal or pendent stalks to 1 m long. The flowers are yellowish, 2-4 cm long. The petals are fused into a long tube, have 10 fertile stamens, and a rudimentary, non-functional ovary. Female inflorescences are much shorter -- only 3-4 cm long-- and have fewer flowers. Female flowers are larger, usually white or cream in colour, with five free petals. There are no stamens, but a large ovary with 5 fan-shaped stigmas.

In cultivation, there are many intermediate forms, including bisexual flowers. At least 15 different flower forms have been named (e.g. Pentandria--5 stamens and a functional ovary) and, because they are correlated with different fruit characteristics, some forms, have been selected by breeders. Environmental factors may also influence sexual expression, and the sexuality of a plant may change seasonally or over the course of its lifetime. Thus the sexuality of any one plant in cultivation depends on a complex mix of genetic, developmental, and environmental factors (University of Cornell, 2000).

Female flowers have a calyx formed by a crown or five-pointed star easy to differentiate. On top of the calyx, the ovary is located by five yellowish sepals (when young, they show a purple coloration and are lose. There are five round-shaped yellow stigmas. Fruits from this flower are usually large and balloon-like.

Hermaphroditic flowers have both sexes and the tree bearing these has three different types of flowers. One is called *pentandria*, resembling a female flower, but when petals are taken apart 5 anthers are seen and the ovary is lobed. Fruit are balloon-shaped and lobed. A second type of flower is called *elongata* and bears 10 anthers, arranged in two sets, the flower is elongated and cylindrical as the ovary and produce elongated fruits. The last type is *intermedia* or *irregular*, which is not a well-constituted flower and produces malformed fruit.



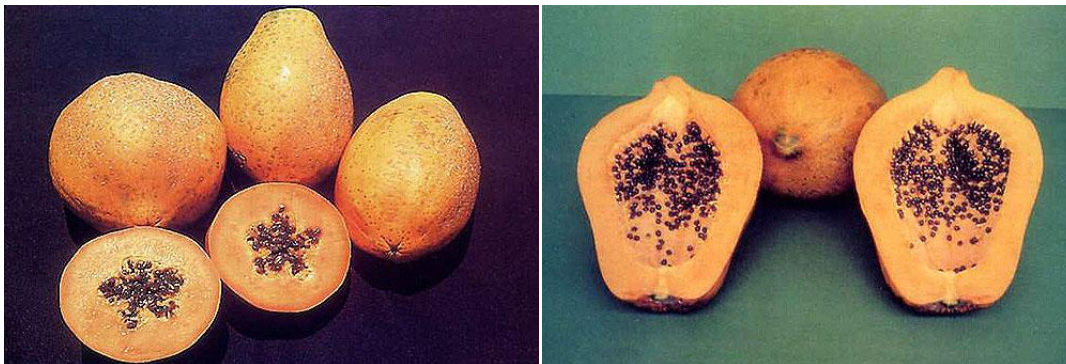
**Fig. 9 Pawpaw hermaphrodite flower**

Male flowers grow along peduncles measuring over half a meter length and at the end there are bundles formed by 15-20 small flowers. These flowers are constituted by a long tube formed by fused petals, inside which there are 10 anthers, arranged in two sets of five. The flower has a small rudimentary pistil and has no stigmas. No fruit are usually produced, or if formed these are elongated and of low quality.

**Fruit:** Generally, the fruit is melon-like, oval to nearly round, somewhat pyriform, or elongated club-shaped, 6 to 20 in (15-50 cm) long and 4 to 8 in (10-20 cm) thick; weighing up to 20 lbs (9 kg). Semi-wild (naturalized) plants bear miniature fruits 1 to 6 in (2.5-15 cm) long. The skin is waxy and thin but fairly tough. When the fruit is green and hard it is rich in white latex. As it ripens, it becomes light- or deep-yellow externally and the thick wall of succulent flesh becomes aromatic, yellow, orange or various shades of salmon or red. It is then juicy, sweetish and somewhat like a cantaloupe in flavor; in some types quite musky. Attached lightly to the wall by soft, white, fibrous tissue, are usually numerous small, black, ovoid, corrugated, peppery seeds about 3/16 in (5 mm) long, each coated with a transparent, gelatinous aril (Morton, 1987). (Fig. 10. a) Typical maradol, b) wax and c) sunrise "solo" pawpaw varieties, De Los Santos, *et al.*, 2000).



**Fig. 10a Typical pawpaw maradol variety**



**Fig. 10b Wax pawpaw variety**

**Fig. 10c Sunrise "solo" pawpaw variety**

An ovoid-oblong berry pyriform or almost cylindrical, large, fleshy, juicy, grooved along the upper longer side, green yellow to yellow or yellow-orange colour when ripen, single cell of orange or redish internal colour with many parietal seeds and a length of 10-25 cm or longer and 7-15 cm or more of diameter. Seeds are black, round or ovoidal shaped and enclosed inside a transparent aryl; subacid, cotyls are ovoid-oblong, flattened and white (Infoagro, 2002).

#### **d) Cultivars**

There are many strains and varieties of this melon-like fruit and the variation in size, form and colour is great.

Because of its complex genetic make-up, there are few, if any, true cultivars of pawpaw which are as uniform in horticultural characters as the cultivars of other herbaceous crops. When seed results from open pollination, it is impossible, in most cases, to obtain selections, which are reasonably uniform in flower type and fruit characteristics. Despite the lack of recognized cultivars, growers can maintain satisfactory strains by controlled pollination of selected plants as described under Propagation. Parent plants should be carefully selected for early and heavy fruit production and should have fruit of desirable shape and size.

A group of Hawaiian pawpaw s referred to as Solo comes closer to deserving cultivar rank than any other types. Originally from Barbados (W. I.), Solo owes its constancy in character expression to a high degree of natural self pollination of its bisexual flowers. This, in addition to continuous selection of pear-shaped fruit produced by bi-sexual plants, has maintained Solo relatively unchanged over the years. Improved selections, such as Sunrise Solo, have resulted from rigorous breeding work. Unfortunately, the Solo group is not well adapted to Florida conditions (Malo, 2001).

The mountain pawpaw (*C. candamarcensis* Hook. f.), is native to Andean regions from Venezuela to Chile at elevation between 6,000 and 10,000 ft (1,800-3,000 m). The plant is stout and tall but bears a small, yellow, conical, 5-angled fruit of sweet flavor. It is cultivated in climates too cold for the pawpaw, including northern Chile where it thrives mainly in and around the towns of Coquimbo and La Serena at near-sea-level. The fruit (borne all year) is too rich in papain for eating raw but is popular cooked, and is canned for domestic consumption and for export. The plant grows on mountains in Srilanka and South India; does well at 1800 ft (549 m) in Puerto Rico. Its high resistance to pawpaw viruses is of great interest to plant breeders there and elsewhere.

The babaco, or *chamburo* (*C. pentagona* Heilborn), is commonly cultivated in mountain valleys of Ecuador. The plant is slender and no more than 10 ft (3 m) high, but the 5-angled fruits reach a foot (30 cm) in length. Usually seedless, or with only a few seeds at most, the fruits are locally eaten only after cooking. The plant is not known in the wild and botanists have suggested that it may be a hybrid. It is propagated by cuttings and is grown on a small scale in Australia and New Zealand primarily for export (Morton, 1987).

<b>Table 1 Fruit characteristics of pawpaw cultivars in major producing countries.</b>		
<b>Cultivar</b>	<b>Country of origin</b>	<b>Fruit Characteristics</b>
Kamiya	Hawaii	Small to medium-sized fruit. Distinct, blocky shape, very short neck. Deep yellow-orange skin and flesh, firm, juicy, very sweet. Dwarf, high-yielding plant.
Mexican Red	Mexico	A rose-fleshed pawpaw that is lighter in flavor than Mexican Yellow. Medium to very large fruit. Generally not as sweet as Hawaiian types.
Mexican Yellow	Mexico	A very sweet and flavorful, yellow-fleshed pawpaw. Medium to large fruit can grow up to 10 pounds. Generally not as sweet as Hawaiian types.
Maradol Roja	Cuba	Small to medium-sized fruit. A very sweet and flavorful
Vista Solo	USA	Medium to large fruit depending on climate, 5 inches wide, up to 18 inches long. Skin yellow, flesh orange to yellow-orange. Hardy, compact Solo type producing high quality fruit. Needs fairly hot weather to develop sweetness
Waimanalo	Hawaii	Fruit round with a short neck, average weight 16 to 39 ounces. Skin smooth, and glossy, cavity star-shaped. Flesh thick, firm, orange-yellow in colour, flavor and quality high, keeps well. Recommended for fresh market and processing. Fruits of female plants rough in appearance. Average height to the first flower is 32 inches.
Sunrise solo	Hawaii	Pear-shaped fruit with a slight neck. Averages 22 to 26 ounces depending on location. Skin smooth, flesh firm, reddish-orange, sweet, sugar content high. Quality similar to Solo. Seed cavity not as deeply indented as other Solo strains, making seed removal easier. Plant precocious, maturing fruit about 9 months after transplanting, at a height of about 3 feet.
Sunset	Hawaii	Solo type. Small to medium-sized, pear-shaped fruit. Orange-red skin and flesh. Very sweet. Dwarf, high yielding plant.

Source: De Los Santos *et al.*, 2000

**e) Growth habit**

Pawpaw are well adapted to many soil types (Fig. 11 Soil type for Pawpaw), like to be warm with both sunshine and reflected heat, so the hottest place against the house where nothing else seems happy is an ideal location. They also like to be as free from wind as possible, although this is not as critical as their need for sun. Pawpaw can be grown successfully in shade, but the fruit is rarely sweet. They are best planted in mounds or against the foundation of a building where water can be controlled (CRFG, 1998).



Pawpaw need a light, well-drained soil. They are easily killed by excess moisture. The soil needs to be moist in hot weather and dry in cold weather. Since this is the opposite of California's rain pattern, in addition to good drainage, plastic coverings to prevent over-wetting in winter may also be worthwhile. Pawpaw do not tolerate salty water or soil (CRFG, 1998).

Requires a well drained soil with high organic matter. Does not tolerate flooding even for short duration. Recommended in regions with well distribution rainfall throughout the year without flash floods, water-logging and strong winds (Agrolink, 2002).

While doing best in light, porous soils rich in organic matter, the plant will grow in scarified limestone, marl, or various other soils if it is given adequate care. Optimum pH ranges from 5.5 to 6.7. Overly acid soils are corrected by working in lime at the rate of 1-2 tons/acre (2.4-4.8 tons/ha). On rich organic soils the pawpaw makes lush growth and bears heavily but the fruits are of low quality (Morton, 1987).

It is recommended that no herbicides used due to the little woodyness of the pawpaw tree stem which may end up damaged.

Usually weeding is performed manually or mechanically-aided, deep soil disturbances can damage the root system. It is advisable to use black polyethylene film on the surface to avoid weed growth (Infoagro, 2002).



**Fig. 11 Soil type for Pawpaw**

#### **f) Cultural practices**

Seeds retain their viability for 2-3 years when kept air-dry in airtight containers. Seeds may be sown in cold frames or boxes during January or in the open in March. Early planting is much to be desired to make a vigorous plant before the beginning of following winter. Seeds germinate in 2-3 weeks. When 2 or 3 true leaves have formed, seedlings should be

transplanted, spacing them 5-7.5 cm apart in seedbed. When plants are 7.5-10 m tall, they can be set in their permanent places in the field. Usual planting distance is about 3-4 m apart each way, giving about 1750 trees to the hectare. In selecting plants for field planting, the more vigorous growing plants are usually the males and may be safely discarded except for a few. By planting 2 or 3 plants in a hill, there is a chance for further selection and elimination of excessive males when first flowers appear, about one male plant to each 25 or so females is sufficient. Transplants must be watered and shaded. Mulch gives much better results than clean culture, keeping down weeds, preserving moisture, shading the soil from hot summer sun, and preventing the burning out of humus and nitrates in the top soil layer. Heavy applications of stable manure or commercial fertilizers can often be used with profit. Attempts at grafting and rooting shoots have not been successful on a commercial scale (Morton, 1987).

**Culture:** Seeds may be planted directly in the field, or seedlings raised in beds or pots may be transplanted when 6 weeks old or even up to 6 months of age, though there must be great care in handling and the longer the delay the greater the risk of dehydrated or twisted roots; also, transplanting often results in trunk-curvature in windy locations.

Small bottom perforated plastic containers can be used for seed germination (Fig. 12 Perforated plastic seed germination containers).

The small holes in the bottom of plastic containers avoid the humidity inside of the containers.

The fertilizer is added to the containers with pawpaw seeds in order to obtain the germination. This kind of containers offers advantages like: easy handling, easy release of the plant and recycle containers.



**Fig. 12 Perforated plastic seed germination containers**

**Soil preparation and fumigation for seed germination.** This operation consists of mixing 4 parts of ground, 2 of dry manure and one of sand. The mixture must be disinfested from fungi, weeds or insect larvae. A bed of 1 m width for 20-25 cm height and depth is prepared and its length is varied according to the number of plants needed. Chemicals that can be used are methyl bromide or sodium methane (Vapam); before their application the bed must be watered during three consecutive days to promote weed germination and hence the small plants may be destroyed by the chemicals.

**Seed germination:**

**a) Seeding:** This is the traditional method for pawpaw seeding and although some producers have found alternative methods, it is still been used in several producing areas. In the bed described above, grooves are marked with separations of 10-12 cm; then each groove receives from six to eight seeds every 10 cm. Seeds are placed 1-1.5 cm deep and covered with dirt. After seeding profuse watering must be made.

Frequency of further watering are dependent on moisture conditions of the seeding daily or every other day watering may be needed. It is advisable to cover the seeding with mulch during the period of seeding and plantule emergence, in order to avoid excessive water loss by evaporation produced by the sun (Fig. 13 Pawpaw seeding establishment). The mulch is removed when the pawpaw plantules bloom and five plantules are left per site. (De Los Santos, *et al.*, 2000).



**Fig. 13 Pawpaw seeding establishment**

Experiments in Hawaii indicate that direct seeding results in deeper tap-roots, erect and more vigorous growth, earlier flowering and larger yields. In Puerto Rico, it is customary to set 2 plants per hole. In El Salvador planters place 5 to 6 seeds, separated from each other, in each hole at a depth of  $\frac{3}{8}$  in (1 cm). When the plants bloom, 90% of the males are removed, preferably by cutting off at ground level. Pulling up disturbs the roots of the remaining plants. If the plantation is isolated and there is no chance of cross-pollination by males, all the seed will become female or hermaphrodite plants. Fruits should mature 5 to 8 months later.



In India, seeds are usually treated with fungicide and planted in beds 6 in (15 cm) above ground level that have been organically enriched and fumigated. The seeds are sown 2 in (5 cm) apart and 3/4 to 1 1/8 in (2-3 cm) deep in rows 6 in (15 cm) apart. They are watered daily and transplanted in 2 1/2 months when 6 to 8 in (15-20 cm) high. Transplanting is more successful if polyethylene bags of enriched soil are used instead of raised beds. Two seeds are planted in each bag but only the stronger seedling is maintained. Transplanting is best done in the evening or on cloudy, damp days. On hot, dry days, each plant must be protected with a leafy branch or palm leaf stuck in the soil. After flowering, one female or hermaphrodite plant is retained, the other two removed. But one male is kept for every 10 females. 'Coorg Honey Dew' and 'Solo' are planted one to a pit and no males are necessary. Watering is done every day until the plants are well established, but over watering is detrimental to young plants. Double rows of *Sesbania aegyptiaca* are planted as a windbreak.

The installation of constant drip irrigation (12 gal per day) has made possible pawpaw cultivation on mountain slopes on the relatively dry island of Maui, which averages 10 in (25 cm) of rain annually.

Pawpaw plants require frequent fertilization for satisfactory production. In India, best results have been obtained by giving 9 oz (250 g) of nitrogen, 9 oz (250 g) of phosphorus, and 18 oz (500 g) potassium to each plant each year, divided into 6 applications.

Because of the need to expedite growth and production before the onslaught of diseases, Puerto Rican agronomists recommend treating the predominantly clay soil with a nematicide before planting, giving each plant 4 oz (113 g) of 15-15-15 fertilizer at the end of the first week, and each month thereafter increasing the dose by 1 oz (28 g) until the beginning of flowering, then applying 227 g per plant as a final treatment. In trials, this program has permitted 6 harvests of green fruits for processing, each over 1 lb (1/2 kg) in weight, spanning a period of 13 months. The roots usually extend out beyond the leaves and it is advisable to spread fertilizer over the entire root area.

In late fertilizer applications of a crop destined for canning, nitrogen should be omitted because it renders the fruit undesirable for processing. High nitrate content in canned pawpaw (as with several common vegetables) removes the tin from the can. To avoid nitrogen deficiency at the beginning of flowering for the next crop, 1 or 2% urea sprays can be applied.

In southern Florida, on oolitic limestone, experts have prescribed liquid fertilizer weekly for the first 10 weeks and then 1 lb (1/2 kg) of 4-8-6 dry fertilizer mixture (with added minor elements) per plant weekly until flowering. Here, a heavy organic mulch is desirable to conserve moisture, control weeds, keep the soil cool, and help repel nematodes.

Mechanical cultivation between rows is apt to disturb the shallow roots. Judicious use of herbicides is preferable.

Overcrowded fruits should be thinned out when young to provide room for good form development and avoid pressure injury. Cold weather may interfere with pollination and cause shedding of unfertilized female flowers. Spraying the inflorescence with growth regulators stops flower drop and significantly enhances fruit set. After the first crop, the terminal growth may be nipped off to induce branching, which tends to dwarf the plant and



facilitates harvesting. However, unless the plants are strong growers, fruiting branches may need to be propped to avoid collapse (Morton, 1987).

It is better to seed manually when two year old trees are been substituted, since older trees are too high and make fruit harvest or latex collection more expensive; in addition fruit production is diminished.

Female trees are better for latex production, because fruit are bigger. Fruit intended for fresh consumption are better produced from hermaphroditic trees because fruit are smaller and suitable for commercial handling.

It is necessary to perform self-pollination or cross-pollination between female and hermaphroditic plants or between hermaphroditic plants, since the male plants are no productive and represent an economic burden for commercial pawpaw production. Both female and hermaphroditic trees are selected, which flowers are well developed. With the help of a brush or a feather the pollen is carried to the stigmas. Later the pollinized flowers are covered with a bag until the fruit is set. With this practice more seeds are produced that will induce female and hermaphroditic plants avoiding male plants (Infoagro, 2002).

**Cultivation:** To grow pawpaw successfully, the grower should make sure that the following requirements are met.

1. The seed should preferably come from controlled crosses (female x bisexual or bisexual selfed), or from bisexual trees known to have a high degree of self-pollination under field conditions. The type of seed used is most important since it determines production potential and thus restricts or enhances the value of other cultural methods (Fig. 14 Pawpaw seed).



**Fig. 14 Pawpaw seed**

2. The soil should have good drainage. Pawpaws are very sensitive to even short periods of flooding. If not killed, they lose their vigor and regain it very slowly. (Fig. 15 Cultural practices of Pawpaw).
3. Irrigation should be provided during dry spells because a fluctuating water supply may cause growth retardation, flower abortion, and dropping of young fruits.
4. Pawpaws are fast growing plants, which require an abundant supply of nutrients if they are to be highly productive. Supplemental fertilization is particularly important in infertile soils. Nitrogen and phosphorus are especially important. In Florida, young plants should be started with 1/2 lb of a 10-10-10-5 mixture (with 30% of the nitrogen from natural organic sources) at planting time or shortly after. This amount of fertilizer is applied every 2 weeks and should be increased gradually to 1 1/2 lb until the plants are 7 to 8 months old. Thereafter, monthly applications should be sufficient, unless unusually hard rains occur. Fertilizer should be reapplied under these conditions.



**Fig. 15 Cultural practices of Pawpaw**

**Cultivars :** Because of its complex genetic make-up, there are few, if any, true cultivars of pawpaw, which are as uniform in horticultural characters as the cultivars of other herbaceous crops. When seed results from open pollination, it is impossible, in most cases, to obtain selections, which are reasonably uniform in flower type and fruit characteristics. Despite the lack of recognized cultivars, growers can maintain satisfactory strains by controlled pollination of selected plants as described under Propagation. Parent plants should be carefully selected for early and heavy fruit production and should have fruit of desirable shape and size. A group of Hawaiian pawpaws referred to as Solo comes closer to deserving cultivar rank than any other types. Originally from Barbados (W. I.), Solo owes its constancy in character expression to a high degree of natural self pollination of its bisexual flowers. This, in addition to continuous selection of pear-shaped fruit produced by bi-sexual plants, has maintained Solo relatively unchanged over the years. Improved selections, such as

Sunrise Solo, have resulted from rigorous breeding work. Unfortunately, the Solo group is not well adapted to Florida conditions (Malo, 2001).

### **g) Planting and Climate**

The pawpaw is a tropical and near-tropical species, very sensitive to frost and limited to the region between 32° north and 32° south of the Equator. It needs plentiful rainfall or irrigation but must have good drainage. Flooding for 48 hours is fatal. Brief exposure to 32 °F (-0.56 °C) is damaging; prolonged cold without overhead sprinkling will kill the plants.

### **h) Fertilization**

In late fertilizer applications of a crop destined for canning, nitrogen should be omitted because it renders the fruit undesirable for processing. High nitrate content in canned pawpaw (as with several common vegetables) removes the tin from the can. To avoid nitrogen deficiency at the beginning of flowering for the next crop, 1 or 2% urea sprays can be applied (Morton, 1987).

**Fertilization:** The fast-growing pawpaw requires regular applications of nitrogen fertilizers but the exact rates have not been established. Feed monthly and adjust according to the plant's response. They can take fairly hot organic fertilizing such as chicken manure if used with deep irrigation after warm weather has started. Phosphorus deficiency causes dark green foliage with a reddish-purple discoloration of leaf veins and stalks (CRFG, 1998).

**Fertilizer ( Dose):** For the first year, a compound fertilizer consisting of nitrogen, phosphate and potassium in the ratio of 15:15:15 can be given in three applications followed by ratio of 12:12:17:2 with some trace elements (:2) applied in the fertile period (Agrolink, 2002).

**Foliar fertilization.** It is recommended to fertilize plantations through the leaves to supplement the soil, if enough moisture was retained by the soil and the fertilizer may be taken up by the plant.

### **i) Soil improvement and fixing nutritional deficiencies**

**Acidity and alkalinity correction of the soil.** Yield of pawpaw decrease when the soil is too acid (pH values below 5.5) because this condition produces nutritional deficiencies in nitrogen, phosphorus, potassium, calcium and magnesium. To correct for this acidity, either calcium carbonate or lime is added to the soil.

On the other hand, if pH of the soil is on the alkali side (pH values above 8.0), deficiencies in magnesium, manganese, iron, zinc, copper and boron, occur that need to be corrected; in this case by addition of sulfur. The type and amount of product must be defined by a laboratory based on physical and chemical analyses of the soil to test for pH values, texture and Ca, Mg and S availability.

**Foliar diagnosis .** In order to evaluate the nutritional status of the plantation, a foliar analysis is performed. This analysis includes sampling of leaves at the beginning of the flowering period, the most recently matured petiole (usually the third or fourth counting downward) is cut off and the leave is discarded.

**Correction of Boron deficiency .** Boron deficiency is frequent in sandy soils. When this is detected, borax and sodium tetraborate may be applied. These two compounds are readily available boron sources. (De Los Santos *et al.*, 2000).

#### **j) Pollination**

If a pawpaw plant is inadequately pollinated, it will bear a light crop of fruits lacking uniformity in size and shape. Therefore, hand-pollination is advisable in commercial plantations that are not entirely bisexual.

Bags are tied over bisexual blossoms for several days to assure that they are self-pollinated. The progeny of self-pollinated bisexual flowers are 67% bisexual, the rest being female.

To cross-pollinate, one or 2 stamens from a bisexual flower are placed on the pistil of a female flower about to open and a bag is tied over the flower for a few days. Most of such cross-pollinated blooms should set fruit. Resulting seeds will produce 1/2 female and 1/2 bisexual plants.

By another method, all but the apical female flower bud are removed from a stalk and the apical bud is bagged 1-2 days before opening. At full opening, the stigma is dusted with pollen from a selected male bloom and the bag quickly resealed and it remains so for 7 days.

Plants from female flowers crossed with male flowers are 50-50 male and female. Bisexual flowers pollinated by males give rise to 1/3 female, 1/3 bisexual and 1/3 male plants.

South African growers have long been urged to practice hand-pollination in order to maintain a selected strain and, in breeding, to incorporate factors such as purple stem, yellow flowers and reddish flesh so that the improved selection will be distinguishable from ordinary strains with non-purple stems, white flowers and yellow flesh (Morton, 1987).

#### **k) Germplasm**

Reported from the Middle American Center of Diversity, pawpaw, is reported to tolerate drought, high pH, insects, mycobacteria, slope, and virus (Duke, 1978). Pawpaw trees differ from each other in that some are either male (staminate) or female (pistillate), whereas others are perfect, having both male and female flowers on same plant. When the sexes are separate, fruits set on the female plant only when pollen is carried from male plants. One male tree is needed for each 25 or so female plants, but one cannot determine the male trees until they flower, about 12 months after germination. (Morton, 1987).

#### **l) Propagation**

Pawpaws are normally propagated by seed. To start a plant, extract the seeds from ripe pawpaws and wash them to remove the gelatinous covering (Fig. 16 Propagation of maradol pawpaw). They are then dried, dusted with a fungicide and planted as soon as possible (the seeds lose their viability rapidly in storage). Plant the seeds in warm (80° F), sterile potting mix. Seeds should be planted in sterile soil as young pawpaw seedlings have a high mortality rate from damping off. Potting soil can be sterilized by mixing 50-50 with vermiculite and placing in an oven at 200° F for one hour. Under ideal conditions the seeds may germinate in about two weeks, but may take three to five weeks. Gibberellic acid can be used to speed up germination in some seasons. Seedlings usually begin flowering 9-12 months after they germinate.





**Fig. 16 Propagation of maradol pawpaw**

Seedling pawpaw do not transplant well. Plant them in large containers so the seedlings will have to be transplanted only once, when they go into the ground. Transplant carefully, making sure not to damage the root ball. To prevent damping off, drench the potting mix with a fungicide containing benomyl or captan. Set the plants a little high to allow for settling. A plastic mulch will help keep the soil warm and dry in wet winter areas, but remove it as soon as the weather becomes warm. Plant at least three or four plants to insure yourself of having females or plant hermaphroditic plants.

Pawpaw plants can also be grown from cuttings, which should be hardened off for a few days and then propped up with the tip touching moist, fertile soil until roots form. Semi hardwood cuttings planted during the summer root rapidly and should fruit the following year (CRFG, 1998).

Pawpaw is propagated by seeds sown in sand beds or they can be sown directly in polythene bags. The soil mixture used is 50% sand for good drainage, 25% organic manure and 25% top soil. The seedlings are ready for transplanting after about 2 to 3 months old. The planting distance is 2.5m x 3m square and the planting holes are about 30cm x 30cm x 30cm. After the holes are dug, some organic matter with phosphate fertilizer and limestone is added to the soil before the seedlings are placed in the holes (Agrolink, 2002).

To reproduce the characteristics of a preferred strain, air-layering has been successfully practiced on a small scale. All offshoots except the lowest one are girdled and layered after the parent plant has produced the first crop of fruit. Later, when the parent has grown too tall for convenient harvesting the top is cut off and new buds in the crown are pricked off until offshoots from the trunk appear and develop over a period of 4 to 6 weeks. These are layered and removed and the trunk cut off above the originally retained lowest sprout, which is then allowed to grow as the main stem. Thereafter the layering of offshoots may be continued until the plant is exhausted.

Rooting of cuttings has been practiced in South Africa, especially to eliminate variability in certain clones so that their performance can be more accurately compared in evaluation studies. Softwood cuttings made in midsummer rooted quickly and fruited well the following summer. Cuttings taken in fall and spring were slow to root and deficient in root formation. The commercial cultivar 'Honey Gold' is grown entirely from cuttings. Once rooted, the cuttings are planted in plastic bags and kept under mist for 10 days, and then put in a shade house for hardening before setting in the field.

Hawaiian workers have found that large branches 2-3 ft (60-90 cm) long rooted more readily than small cuttings. Planted 1 ft (30 cm) deep in the rainy season, they began fruiting in a few months very close to the ground.

In Hawaii, 'Solo' grafted onto 'Dwarf Solo' was reduced in vigor and productivity, but 'Dwarf Solo' grafted onto 'Solo' showed improved performance.

In recent years, the potential of rapid propagation of pawpaw selections by tissue culture is being explored and promises to be feasible even for the establishment of commercial plantations of superior strains.

Efforts have been made to determine the sex of seedlings in the nursery, Indian scientists making colorimetric tests of leaf extracts have had 87% success in identifying seedlings as female; 67% in classifying males/bisexuals grouped together (Morton, 1987).

Vegetative propagation is not practical, although it may be desirable to preserve good selections. Both grafting and rooting of cuttings are easily accomplished but are too laborious to justify their commercial use. In contrast, seeds are produced abundantly and germinate readily (in 10 to 15 days) and uniformly. Under suitable growing conditions fruit can be harvested in 8 to 10 months. Seeds should be obtained from ripe fruit, washed to remove the gelatinous aril, planted in small pots, and germinated under full sunlight. Peat pots are ideally suited for this, since they can be set directly in the field without removing the plants from individual containers. Two to three seeds are sown per pot to compensate for low germinations, damage by insects, and removal of male plants. Planting distance depends on soil fertility, irrigation facilities, and location. The home owner should space his plants 8 to 10 feet apart. The use of machinery in commercial operations requires rows to be 12 to 15 feet apart, but plants should be 6 to 8 feet apart in the row. Seedlings are set in the field when 6 to 8 inches tall. They begin flowering after 5 months, and only one vigorous bisexual or female plant is allowed to grow, in each site all others being removed. In south Florida, if plants are set in the field in February or March, it is possible, with good care, to harvest fruit in October or November. This requires starting seedlings in a greenhouse or under plastic, and protecting them against frosts by heating or sprinkler irrigation. In cooler areas of the state, May and June are better months for field planting, and good yields cannot be expected before the following April or May (Malo, 2001).

### **1.1 Economic and social impact of the Pawpaw crop**

Brazil is the main producer and trader of pawpaw in the world. As trade has increased new producers have appeared in the international market. With the development of better cultivation and post-harvest technologies, pawpaw is becoming a new star in the world tropical fruit market.

### a) Production and export

In 1998 the FAO reported an estimate of 5.1 millions of metric ton. that were harvested in the world, representing twice the harvest of 1980.

The main consumer markets are usually supplied by one major supplier; in the case of the US market, most of the fruit is supplied by Mexico, whereas for Europe, Brazil is the main exporter, and Japan's demands are covered by the US via Hawaii. (Table 2).

In general, pawpaw crops have shown a continuous and stable growth and importers are confident of the future of this market. The key for a successful prospect for pawpaw lies on development of new varieties, better crop handling and post-harvest technologies. (Medinilla, 2000).

<b>Table 2 Major pawpaw country producers in the world</b>					
<b>COUNTRY</b>	<b>PRODUCTION (Mt)</b>	<b>COUNTRY</b>	<b>PRODUCTION (Mt)</b>	<b>COUNTRY</b>	<b>PRODUCTION (Mt)</b>
World	5,443,702	Cuba	40,000	Argentina	2, 100
	1,450,000	Costa Rica	35,200	Oman	1,950
Nigeria	748,000	Mozambique	31,000	Fiji Islands	1,634
India	644,000	Guatemala	25,000	Ghana	1,600
Mexico	612,910	United States of America	24,950	Guinea Bissau	1,600
Congo, Dem Republic of	213,000	Dominican Republic	24,000	Cook Islands	908
Peru	173,600	Bolivia	23,000	Honduras	590
China	152,000	South Africa	21, 100	Reunion	420
Thailand	119,000	Paraguay	12,000	French Guiana	389
Colombia	113,500	Samoa	10,000	Iran, Islamic Rep of	100
Venezuela, Boliv Rep of	105,000	Jamaica	9,000	Guadeloupe	55
Ecuador	101,005	Pakistan	8,500	Tunisia	55
Philippines	77,417	Australia	7,000	Israel	50
Yemen	67,979	Chile	6,800	Morocco	50
Malaysia	60,000	Puerto Rico	3,200	Zimbabwe	30
Bangladesh	41,000	El Salvador	3,000	Cameron	10
Source: Faostat Database FAO, 2001					

From 1992 pawpaw world trade increased as much as twice of that in 1995. Certainly the appreciation for the fruit as well as the attractive prices have been the main causes for the increase in exports. The list of exporting countries has been expanding, but five are considered the most important: Malaysia, South Korea, Brazil, US and Jamaica. These five countries contribute together over 80% of total world exports. Out of these countries, Jamaica has shown the most dynamic trend in exports; between 1992 and 1998 export sales were doubled. Next, South Korea appeared in the export market in 1995, with a concomitant increase. For the period 1995-1998 sales topped 30,000 MT with represented 19.6% of the world total. Current average sales of Malaysia are near 40,000 MT, with is twice the amount reported in 1992. (Claridades Agropecuarias, 1999).

The main actors in the international trade market for pawpaw are presented in Table 3. There were included countries with reported production exceeding 1,000 MT/year.

<b>Table 3 International Market For Pawpaw</b>			
<b>Exporting countries</b>	<b>MT</b>	<b>Importing countries</b>	<b>MT</b>
Mexico	59,638	USA	47,908
Malaysia	34,312	Singapur	21,219
Brasil	9,878	Hong Kong	13,210
USA	6,024	China	4,919
Jamaica	4,000	Japan	4,670
Belice	3,557	UK	3,606
Holland	2,051	Canada	3,291
Guatemala	1,467	Holland	2,619
Costa Rica	1,000	Germany	2,546
Ghana	1,000	Portugal	1,486
		France	1,269
		Spain	1, 132

Source: Faostat Database FAO 1990 — 1998

## **1.2 World trade**

### ***a) World Trade in Fresh Pawpaw***

#### ***North and Latin América***

US production is concentrated in the Hawaiian islands. In 1994, 256 agricultural operations produced 28,000 MT of pawpaw, of which ca. 90% is used for fresh marketing directed to domestic markets as well to Japan and Canada. In 1998 US produced 18, 140 MT, the drop been attributed to the ring spot virus (RSV). Mexico is the largest producer of the region with 498,000 MT in 1998, it is also the main exporter of pawpaw to the US and Canada. Costa Rica produced in the same year 22,000 MT aimed mostly to the US and Dutch markets (Medinilla, 2000).



Brazil has become the main producer in the world, with most of the fruit been sent to European countries. In 1998 the country reported 35,000 ha's devoted to pawpaw production, with an average yield of 48.6 Ton/ha.

### Asia and Africa

Nigeria is the main producer in the African continent with 751,000 MT, with a 90,000 ha's devoted to the crop, and together with South Africa, Mozambique and Congo are the most important producers, but none of them reports any export activity.

Just after Brazil, India is the second world producer with 40,000 ha's and a total production of 400,000 MT and a yield of de 11.25 Ton/ha. Other important producers include: Indonesia with 336,068 MT, China with 149, 163 MT and Phillipines with 67,000 MT ((Medinilla, 2000).

### b) Market price

The acceptance of pawpaw fruit in the world has produced a wide range of prices for the different varieties. However, there are markets so important that are worth analyzing in detail, since these sometimes define the prices for other, geographically distant markets. Such is the case of the US, in which it is possible to find different prices for pawpaw varieties (red and strawberry pawpaw) all year long. (Table 4).

Variety	Origin	Minimum price	Maximum price	Average price
Pawpaw Maradol	Rep. Dominicana	0.94	1.00	0.97
Pawpaw Maradol	Mexico	1.05	1.16	1.10
Pawpaw Roja (Red Flesh)	Brazil	1.99	2.21	2.10
Pawpaw Roja (Red Flesh)	Belize	1.11	1.33	1.22
Pawpaw Maradol	Belize	1.33	0.00	

Source: Aserca, 2002

General prices for pawpaw as supplied either internally or imported from Jamaica, Brazil, Costa Rica and Belize, have been defined by the Baltimore market with an average price of \$2.68/kg through 1998; in Los Angeles the average prices was \$3.58/kg; in Miami \$2.20/kg and San Francisco \$3.06/kg. The strawberry variety was found mainly in Los Angeles and supplied by Hawaii; however, pawpaws from Brazil, Costa Rica and Jamaica were found in lesser amounts. Average price was \$3.58/kg.

In addition to the US market, Toronto and London have prices for pawpaw all year long as well. The main suppliers for Toronto are Jamaica and Brazil, while the London market is

supplied almost solely by Brazil and only marginally by Jamaica. The long distance between Brazil and England makes the product more expensive as compared to other American markets. Thus, pawpaw from Brazil in London was \$3.26/kg, compared to \$2.36/kg in Toronto. (Claridades Agropecuarias, 999).

### 1.3 Primary product

Importers require fruit at specific stages of ripeness for optimum sales; this varies between 50 and 70% yellow colour depending on the importer, the market and the time of year. For fruit to arrive in the importing country at the correct colour stage, attention has to be paid to the maximum and minimum colour stages on departure from the pack house, the length of the shipment period (24 hours when considering UK, Canada and USA, and 48 hours for Holland) and the temperature in the importing country. Thus, colour stages on departure from the packhouse for air shipment can vary from 20% to 50%, and the selections are generally more rigid during the summer months due to the rapid rates of ripening on arrival in importing countries. Fruit exported too green (less than 20% yellow colour) will fail to ripen adequately when temperatures in importing countries are low, particularly in winter months.

Sea-shipment of pawpaw is possible when fruits are shipped at the optimum harvest maturity, with one or two yellow streaks. Shipments should be made at 10° to 12°C and 85 to 95% relative humidity, in refrigerated holds or refrigerated containers. Post-harvest disease control is critical with sea-shipment, particularly anthracnose and *Phytophthora*. Colour development during sea-shipment usually increases from 10% to 40% during 10 days at 12°C, and will develop further during the customs, clearance and delivery period on arrival. (Medlicott, 2001).

Commercial pawpaws are normally harvested 9 to 10 months after being transplanted from nurseries. Fruit should be harvested when skin colour changes from dark green to light green and when one yellow streak begins developing from the base of the fruit upward. Fruit in this condition will continue to ripen normally after harvest. If harvested before or after this stage, however, pawpaws will either fail to ripen completely (if picked too early) or become more susceptible to damage and bruising during handling (if picked too late). Because their ideal stage of maturity is so short-lived, pawpaws are usually harvested three or four times a week. Leaving fruit as long as five to seven days between harvests can lead to its rejection as over-ripe.

Pawpaws are harvested by hand alone or with knives or specialized tools, depending on the size and age of the tree. When harvesting pawpaw by hand or with knives, harvesters snap or cut the stem directly adjacent to the tree and immediately trim it flush against the top of the fruit. To reach fruit at the top of tall trees, harvesters use a long pole with a small hoop and a small, mesh bag at the end. Above the hoop sits a horizontal blade, which the harvester positions below the stem of the fruit and moves upward to detach the pawpaw from the tree and catch it in the mesh bag below. Two or three fruits are collected at a time in this manner. Bags should be shallow to prevent overfilling and should be made of a soft material to prevent damage to the pawpaw skin.

After harvest, the fruit are placed gently—never thrown or dropped—in single layers in shallow, light-colored plastic field crates, preferably with a foam layer for cushioning. Mesh bags, sacks, or baskets are unacceptable for pawpaw transport because of the fruit's high susceptibility to bruising. Care should be taken during transport to minimize jostling of the

fruit, and all stems should be trimmed to ensure that no stem-to-fruit rubbing occurs. Prior to collection, field crates and fruit should be left in shaded conditions, protected from the sun and rain. Grading and packing should be carried out as soon as possible after harvest, normally within three hours, after which time the fruit should be kept at ambient tropical conditions (25°C to 28°C) to continue ripening, or cooled and stored at 10°C to 12°C. Standard packing house design and operations apply for pawpaw grading and packing. Operations can be carried out with basic equipment, including water tanks, field crates, and grading tables, or with automated washing and weight-grading or separation systems. All tanks and grading tables should be covered with foam to protect fruit from exposed edges; the skin of the pawpaw is delicate, and scratches will result in latex exudation and staining. Similarly, if the fruit is dropped, it will easily develop bruises as it ripens. (Market. A.G, 2002; Smith *et al.*, 1992).

**a) Food for humans**

Excellent quality fruit, high in vitamin A. Ripe fruit is consumed fresh as a breakfast or dessert fruit and with honey. Green fruits are grated in salads or boiled like squash. (Fig. 17 How to eat a pawpaw 1, Fig. 18 How to eat a pawpaw 2, Fig. 19 How to eat a pawpaw 3, Fig. 20 How to eat a pawpaw 4, Fig. 21 How to eat a pawpaw 5, Fig. 22 How to eat a pawpaw 6, Fig. 23 How to eat a pawpaw 7).



**Fig. 17 How to eat a pawpaw 1**



**Fig. 18 How to eat a pawpaw 2**



**Fig. 19 How to eat a pawpaw 3**



**Fig. 20 How to eat a pawpaw 4**



**Fig. 21 How to eat a pawpaw 5**



**Fig. 22 How prepare a pawpaw 6**

**b) Food for livestock**

Foliage is sometimes used as a feed source in fish ponds (herbivorous Tilapia, etc.).

**c) Other Uses:**

The green fruit is the source of the enzyme papain, which is used in commercial meat tenderizers. In the Philippines, meat is wrapped in young leaves to tenderize it (Smith, *et al.*, 1992).

Various parts of the pawpaw plant are used for medicinal purposes in various parts of the world. For example, as a treatment for intestinal parasites (Smith, *et al.*, 1992, University of Purdue, 2000).

**1.4 Preparation and uses**

Green, or unripe, pawpaws may be cooked like winter squash. Ripe pawpaws are terrific eaten plain or with a dollop of yogurt. Simply cut in half and remove the seeds; the flesh is tender enough to be scooped out with a spoon. Although pawpaw skin is not edible, its seeds are. Pawpaw seeds resemble large peppercorns and also have a peppery taste. They may be crushed and sprinkled on salads in the same way as crushed peppercorns. Left whole, they make an interesting garnish for a fruit salad. Add pawpaw to fruit salads or pouree into a thick juice (Healthnotes, Inc, 2001).

**Unripe and mature pawpaw fruits**

Pawpaw fruits should be harvested when the colour of the skin changes from dark green to light green and when one yellow streak begins development from the base upwards (Fig. 23. One-quarter ripe pawpaw). Fruits in this condition will continue to ripen normally after harvest. Those fruits harvested before this stage will fail to show complete ripening, and those harvested after, are more susceptible to damage and bruising during handling (Medlicott, 2001).





**Fig. 23 One-quarter ripe pawpaw**

***Selection and Care*** : Softening is the key to ripeness. Pawpaws that are one-quarter to one-half ripe should keep 1-2 weeks. The development of a yellow blush is associated with ripening when the fruit ripens at 65 °F, or over. At lower temperatures the colour process may stop and the fruit soften without changing colour. For this reason pawpaw should be stored at room temperature until ripe (soft). Ripening can be slowed by chilling at 60 °F. or stopped at 50 °F. Chilling below 50 °F will damage fruit. Chill a pawpaw once it is completely or almost ripe, not before. Serve within a day or two, or it loses flavor (UFL, 2000).

The most common use of pawpaw is fresh in slices or chunks and in fruit compotes. A thick juice can be prepared by blending diced pawpaw with a little water. Pawpaw can also be sliced and dried. Green pawpaw is sometimes cooked and eaten like squash. Pawpaw is a prime source of papain enzyme (meat tenderizer), so green fruit chunks and leaves can be wrapped around meat or fowl before cooking to enhance tenderness and flavor (Aggie Horticulture, 2002).

## **1.5 Alternative products from pawpaw**

### **1.5.1 Medicinal uses**

In tropical folk medicine, the fresh latex is smeared on boils, warts and freckles and given as a vermifuge. In India, it is applied on the uterus as an irritant to cause abortion. The unripe fruit is sometimes hazardously ingested to achieve abortion. Seeds, too, may bring on abortion. They are often taken as an emmenagogue (agent that promote the menstrual flow) and given as a vermifuge. The root is ground to a paste with salt, diluted with water and given as an enema to induce abortion. A root decoction is claimed to expel roundworms. Roots are also used to make salt.

Crushed leaves wrapped around tough meat will tenderize it overnight. The leaf also functions as a vermifuge and as a primitive soap substitute in laundering. Dried leaves have been smoked to relieve asthma or as a tobacco substitute. Packages of dried, pulverized leaves are sold by "health food" stores for making tea, despite the fact that the leaf decoction is administered as a purgative for horses in Ghana and in the Ivory Coast it is a treatment for genito-urinary illness. The dried leaf infusion is taken for stomach troubles in Ghana and they say it is purgative and may cause abortion (Morton, 1987).

#### **1.5.1.1 Folklore, medicinal and non-food uses**

A. Milky latex may cause dermatitis.

B. Hypoglycemic activity has been shown experimentally.

C. Toothache relief - the inner bark is used for this in Samoa.

D. Amebicide - latex and seeds used in Central America to kill *Entamoeba histolytica* which causes dysentery and liver absceses.

E. Cosmetics - pawpaw fruit pulp is the basic component of many facial creams, salves, and shampoos.

F. Papain - is one of two proteolytic enzymes (the other is chymopapain) found in pawpaw latex.

Papain is extremely useful since it retains proteolytic activity over a wide pH range, unlike other proteases. Papain is used during surgical procedures to dissolve ruptured spinal discs; it is referred to as "nature's scalpel" because it preferentially degrades dead tissue. Latex is extracted on a commercial scale in East Africa and Sri Lanka. The green fruit are "tapped" by making incisions on the fruit surface in the morning, and catching the latex in a container

hanging beneath. The latex is dried, ground into powder, and packed in tin containers. One thousand average-sized fruits will yield one pound of papain.

The most popular use is a meat tenderizer. Columbus, on one of his voyages to the Caribbean, noted that natives could consume a large amount of fish and meat without getting indigestion if unripe pawpaw was eaten after the meal. Green pawpaw can be rubbed onto a piece of meat, cooked with it, crushed leaves can be wrapped around meat, or a commercial tenderizer preparation sprinkled on the surface. Beef cattle are sometimes injected with papain 1/2-h before slaughter to tenderize them. Meat treated with papain should not be cooked "rare", as the enzyme will not have been inactivated. Additional uses include: beer clarification, wool and silk treatment before dyeing, de-hair hide before tanning, tuna liver oil extraction, treatment of ulcers, diphtheria, swelling, and fever, relief of gas and sour stomach.

G. Folk medicine - Fresh latex can be smeared on boils, warts or freckles to remove. Latex is smeared on the uterus to cause abortion in India, or sometimes the unripe fruit and/or seeds are eaten to induce abortion (The University of Georgia, 2002).

#### ***1.5.1.2 The healing power of the tropical Medicine Tree***

Nutrition for the Skin Vitamins were first used and applied through the skin after the Second World War. Ex-prisoners with severe vitamin deficiency, who were unable to take them orally, were treated through the skin with successful results. Dermatologists have often recommended hormonal creams to post menopausal women that are applied to the skin. The extracts from plants in the form of essential oils can also be absorbed through the skin. Tests have been conducted on animals where essential oils have been found in their urine, half an hour after application. A clove of garlic rubbed onto the soles of the foot of a baby could be smelt on its breath ten minutes later. Over the last decade the skin has been used more and more for taking in medication.

Vitamins can be applied to the surface of the skin, either from a capsule or mixed into creams, oils, ointments, herbal infusions or fruit juices. Here are just a few of the commonly applied skin benefactors:

Vitamin A - has been successfully used in treating dry aging skin and acne. It accelerates the formation of new cells, it protects the external layers of the skin.

Vitamin D - has a healing effect on the skin, it is often used in ointments for burns, acne and pimples.

Vitamin E - is a natural anti-oxidant. It promotes the formation of skin cells, improves blood circulation and nourishes the skin and assist in healing and minimizes scarring.

Vitamins C- is an anti-oxidant, it also strengthens and builds capillaries. (Kneipp Cure Pty Ltd, 2000).

#### **1.5.2 Pawpaw Tropical Skin Food Products**

- \* A unique range off 100% Australian made products.
- \* Based on all natural ingredients and anti-oxidants to strengthen and nourish the skin.
- \* Unique formulas based on the ancient art of Aromatherapy and Herbalism.

\* All products are "Skin Food Based" and environmentally friendly which are tested on humans only.

## **1.6 Benefits of Pawpaw**

Pawpaw is used in skin products for a natural 'face lift' and rejuvenation. The green fruit and leaves are used in cosmetics as it contains papain, and other enzymes. Pawpaw is beneficial for skin care and repair. Pawpaw contains vitamin A which accelerates the formation of new cells, it protects the external layers of the skin, vitamin C is an anti-oxidant, and builds capillary strength, the skin can be benefited with improved smoothness, softness, and resiliency. Pawpaw reduces the signs of premature aging and eliminates dead skin cells. Pawpaw tea and fruit contains an enzyme that dissolves surface cell debris making it a great facial peel. Beta-carotene, protects the skin and provides elasticity.

### **1.6.1 Essential Oils**

Essential oils are the volatile or end product of the plant metabolism. They are generated and stored by the plant in special cells and are extracted by steam distillation, cold pressing or effleurage - a form of extraction using fats. Scent globules can be found in different parts of the plant and this will influence the method of extraction such as flowers-rose, jasmine, neroli, roots-angelica, vetiver, seeds-anise, coriander, caraway, leaves-sage, geranium, thyme, bark-cinnamon, fruit rind- citrus oils an resin-sandalwood, frankincense. Essential oils can be used to help correct the imbalances represented by the skin types. The oils can be used to reduce the amount of sebum being produced, and control the bacteria, which thrive on the surface of the skin. Many essential oils stimulate the generation of new cells, which preserves the health and beauty of the skin.

#### **1.6.1.1 Essential Oils used in Pawpaw Skin Care**

Lavender (*Lavandula vera*) all skin types, minimizes scarring.

Geranium (*Pelargonium graveolens*) oily, acne, mature skin, sluggish congested skin. It also has a balancing effect on the sebaceous glands.

Orange (*Citrus aurantium*) combination skin, soothing to dry, irritated, or acne prone skin  
Frankincense (*Boswellia thurifera*) rejuvenating for mature skin, balances oily skin.

Sandalwood (*Santalum album*) oily, dry and mature skin, cracked or damaged skin, dehydrated skin, itching or inflammation of the skin.

Neroli (*Citrus aurantium*) sensitive, dry and mature skin, broken capillaries, all skin types, stimulates cellular activity and growth.

Rose Moroc (rosaceae) mature skin, promotes cell renewal, ideal for all skin care, broken capillaries (Kneipp Cure Pty Ltd, 2000).

## **1.7 Requirements for export and quality assurance**

### **a) Export grading**

Grading should be carried out as soon as possible after harvest, and fruit left under ambient



conditions to continue ripening or placed at 10° to 12°C for cooling and storage. On arrival in the packing facility, fruit should be washed in water to remove latex and debris then treated in a 0.05% Thiabendazole solution for anthracnose control. Washing, treatment and grading can be carried out using mechanized or manual systems (Fig. 24 Washer and disinfectant container for pawpaw fruits.), depending on the volumes of fruits. Grading in each carton is required in terms of size, sex (shape) and stage of ripeness. Female and hermaphrodite fruit cannot be mixed in the same carton; all fruits must be of a similar size in each carton resulting in a range of counts, and separations must be made for the degree of ripeness. Carton net weight is dependent on the importer, ranging from 3.5 to 5 kg (8 to 11 lbs), and must not be overfilled during packing (Medlicott, 2001).



**Fig. 24 Washer and disinfectant containers for pawpaw fruits**

**Quality Criteria:** Pawpaw should be exported with the required size and stage of ripeness (as defined in the market specifications) with sufficient yellow peel and orange or red pulp coloration, free from bruises, blemishes, insect and spray damage and uniform in size and ripeness within each carton (Medlicott, 2001).

**Export Criteria:** Pawpaws intended for export are carefully graded by size and stage of ripeness. Fruit should be uniform in size and ripeness and be free from bruises, blemishes, and insect damage. Most importers also require that pawpaws be mostly yellow and have a uniform softness; a smooth, unblemished skin; and a minimum sugar content of 12 °Brix.

When harvested, pawpaws are green with a stripe of yellow at their base; they ripen during transport or are commercially ripened on arrival. As pawpaw ripens, skin colour changes from green to yellow, and the fruit becomes softer and develops a fruity aroma. Pawpaws are normally sold to consumers when they are at least one-quarter ripe. Optimal ripeness occurs at the three-quarter stage, when the fruit bears a yellow-orange peel and an orange-red pulp. Peel colour may vary from yellow to reddish-orange, depending on the variety of pawpaw.

Three Hawaiian varieties —Solo Sunrise, Kapoho, and Waimanalo— are the most popular, and Solo Sunrise is the most important in world trade. Pawpaws of all three varieties are relatively small, normally weighing from 250 to 500 grams. Some countries are beginning to produce and export several Taiwanese varieties, which tend to be larger than those from Hawaii. Some markets require very large, local varieties of pawpaw. In the Latin market in the United States, for example, pawpaws weigh about 3 kilograms.

Fruit shape is not a function of variety but of the sex of the plant the fruit grows on. Round fruit comes from a female plant, and traditional pear-shaped fruit comes from a hermaphrodite plant. Because the market prefers pear-shaped fruit, female plants are normally removed from production as soon as their sex is known.

Pawpaws are harvested by hand alone or with knives or specialized tools, depending on the size and age of the tree. When harvesting pawpaws by hand or with knives, harvesters snap or cut the stem directly adjacent to the tree and immediately trim it flush against the top of the fruit. To reach fruit at the top of tall trees, harvesters use a long pole with a small hoop and a small, mesh bag at the end. Above the hoop sits a horizontal blade, which the harvester positions below the stem of the fruit and moves upward to detach the pawpaw from the tree and catch it in the mesh bag below. Two or three fruits are collected at a time in this manner. Bags should be shallow to prevent overfilling and should be made of a soft material to prevent damage to the pawpaw skin.

After harvest, the fruit are placed gently —never thrown or dropped— in single layers in shallow, light-colored plastic field crates, preferably with a foam layer for cushioning. Mesh bags, sacks, or baskets are unacceptable for pawpaw transport because of the fruit's high susceptibility to bruising. Care should be taken during transport to minimize jostling of the fruit, and all stems should be trimmed to ensure that no stem-to-fruit rubbing occurs. Prior to collection, field crates and fruit should be left in shaded conditions, protected from the sun and rain.

Grading and packing should be carried out as soon as possible after harvest, normally within three hours, after which time the fruit should be kept at ambient tropical conditions (25°C to 28°C) to continue ripening, or cooled and stored at 10°C to 12°C.

Standard packing house design and operations apply for pawpaw grading and packing. Operations can be carried out with basic equipment, including water tanks, field crates, and grading tables, or with automated washing and weight-grading or separation systems. All tanks and grading tables should be covered with foam to protect fruit from exposed edges; the skin of the pawpaw is delicate, and scratches will result in latex exudation and staining. Similarly, if the fruit is dropped, it will easily develop bruises as it ripens (Market. A.G, 2002, Smith *et al.*, 1992).

#### **b) Market requirements**

**Storage and Transportation** Importers require fruit at specific stages of ripeness for optimum sales; this varies between 50 and 70% yellow colour depending on the importer, the market and the time of year. For fruit to arrive in the importing country at the correct colour stage, attention has to be paid to the maximum and minimum colour stages on departure from the pack house, the length of the shipment period (24 hours when considering UK, Canada and USA, and 48 hours for Holland) and the temperature in the importing country. Thus, colour stages on departure from the pack house for air shipment can vary from 20% to 50%, and the

selections are generally more rigid during the summer months due to the rapid rates of ripening on arrival in importing countries. fruit exported too green (less than 20% yellow colour) will fail to ripen adequately when temperatures in importing countries are low, particularly in winter months.

Sea-shipment of pawpaw is possible when fruits are shipped at the optimum harvest maturity, with one or two yellow streaks. Shipments should be made at 10 to 12°C and 85 to 95% relative humidity, in refrigerated holds or reefer containers. Post-harvest disease control is critical with sea-shipment, particularly anthracnose and Phytophthora. Colour development during sea-shipment usually increases from 10% to 40% during 10 days at 12°C, and will develop further during the customs, clearance and delivery period on arrival.

Importers require fruit at specific stages of ripeness for optimum sales; this varies between 50 and 70% yellow colour depending on the importer, the market and the time of year. For fruit to arrive in the importing country at the correct colour stage, attention has to be paid to the maximum and minimum colour stages on departure from the packhouse, the length of the shipment period (24 hours when considering UK, Canada and USA, and 48 hours for Holland) and the temperature in the importing country. Thus, colour stages on departure from the packhouse for air shipment can vary from 20% to 50%, and the selections are generally more rigid during the summer months due to the rapid rates of ripening on arrival in importing countries. fruit exported too green (less than 20% yellow colour) will fail to ripen adequately when temperatures in importing countries are low, particularly in winter months.

Fruit harvested and placed to ripen at the recommended harvest stage (one yellow stripe) will ripen to 60 to 70% yellow coloration within four to six days under ambient tropical conditions (25° to 28°C). Fruit transferred to low temperature storage (10° to 12°C), when harvested at the one-stripe stage, will store successfully for 14 to 21 days if post-harvest disease incidence can be controlled. When harvested at more advanced stages of ripening, the storage life will be significantly reduced (Medlicott, 2001).

## **1.8 Consumer preferences**

### **a) Characteristics of pawpaw fruits**

Pawpaws have a creamy, custard-like flesh with a complex combination of tropical fruit flavors. They are most commonly described as tasting like banana combined with mango, pineapple, melon, berries, or other fruit. There is a considerable variety of flavors among wild pawpaws, ranging from awful to sublime. Most pawpaws taste good, some are truly wonderful, and a few are better for throwing than for eating. All of the named cultivars produce tasty fruit, and different people will have different preferences. Ripe pawpaws usually give off a powerful fruity aroma, as well. Color change is generally not a reliable indicator of ripeness.

### **b) Varieties**

Despite the great variability in size, quality and other characteristics of the pawpaw, there were few prominent, selected and named cultivars before the introduction into Hawaii of the dioecious, small-fruited pawpaw from Barbados in 1911. It was named 'Solo' in 1919 and by 1936 was the only commercial pawpaw in the islands. 'Solo' produces no male plants; just female (with round, shallowly furrowed fruits) and bisexual (with pear-shaped fruits) in equal proportions. The fruits weigh 1.1 to 2.2 lbs (1/2-1 kg) and are of excellent quality. When the fruit is fully ripe the thin skin is orange-yellow and the flesh golden-orange and very sweet.

**'Kapoho Solo' or 'Puna Solo'** was discovered and became popular with growers on Kauai before 1950. In 1955 a 'Dwarf Solo' (a back-cross of Florida's 'Betty' and 'Solo') was introduced to aid harvesting, and this became the leading commercial pawpaw on the island of Oahu. It was, up to 1974, the only export cultivar. It is pear-shaped, 14 to 28 oz (400-800 g) in weight in high rainfall areas, and has yellow skin and pale-orange flesh.

**'Waimanalo'** (formerly 'Solo' Line 77) was selected in 1960 and released by the Hawaii Agricultural Experiment Station in 1968 and soon superseded Line 8' Solo' on Oahu for the fresh fruit market because of its firmness and quality, but there it is usually too large for export. It has long storage life and is recommended for sale fresh and for processing. Since 1974 this cultivar has been produced commercially on the low-rainfall island of Maui where it ripens at a greener colour than on the island of Hawaii and is exported to cities in the northwestern and central USA. The growers raised only bisexual plants; they say that the fruits of female plants are too rough in appearance.

**'Higgins'** (formerly Line 17A), the result of crosses in 1960, was introduced to Hawaiian growers in 1974. It is of high quality, pear-shaped, with orange-yellow skin, deep-yellow flesh, and averages 1 lb (0.45 kg) when grown under irrigation. In and territory or seasons of low rainfall, the fruit is undersized.

**'Wilder'** (formerly Line 25) is a cultivar admired for its uniformity of size, firmness and small cavity and it is now popular for export.

**'Hortus Gold'**, a South African cultivar, launched in the early 1950's, is dioecious, early-maturing, with round-oval, golden-yellow fruits, 2 to 3 lbs (0.9-1.36 kg) in weight. From 200 female 'Hortus Gold' seedlings planted at the University of Natal's Ukulinga Research Farm in 1960, selections were made of the plants showing the highest yield. Of these, one clone having the best sugar content and disease resistance was chosen and named 'Honey Gold' in 1976. This cultivar has a slight beak at the apex, golden-yellow skin; is of sweet flavor and good texture but becomes mushy when overripe. It averages 2.2 lbs (1 kg) per fruit except for those at the end of the season, which are much smaller. It does not reproduce true from seed and is therefore propagated by cuttings. It is late in season and late-maturing (10 months from fruit set to maturity) and therefore brings nearly double the price of other cultivars.

**'Bettina' and 'Petersen'**, long-standing cultivars in Queensland, Australia, were inbred for several generations to obtain pure lines. 'Bettina', a hybrid of Florida's 'Betty' and a Queensland strain, is a low, shrubby, dioecious plant producing well-coloured, round-oval fruits weighing 3 to 5 lbs (1.36-2.27 kg).

**'Improved Petersen'**, of local origin, is dioecious, tall-growing, with fruits deficient in external colour and indifferent as to keeping quality but noted for the fine colour and flavor of the flesh. In 1947 'Bettina 100A' was crossed with 'Petersen 170' to produce the superior, semi-dwarf 'Hybrid No. 5', smooth, yellow, rounded-oval, 3 lbs (1.36 kg) in weight, thick-fleshed, of excellent flavor and prized for marketing fresh and for canning. It bore more heavily than either of its parents and remained a preferred cultivar for more than 20 years. 'Solo' and 'Hortus Gold' are often grown but most plantations are open-pollinated mixtures.

In Western Australia, after trials of 9 cultivars – 'Hybrid No. 5', 'Petersen', 'Yarwun Yellow', 'Gold Cross', 'Goldy', 'Hong Kong', 'Guinea Gold', 'Golden Surprise' and 'Sunnybank' – only 'Sunnybank' and 'Guinea Gold' were chosen as having sufficient yield and quality to be worth



cultivating commercially. 'Sunnybank' fruits average 1.39 lbs (0.63 kg), and ripen over 11 months. 'Guinea Gold' averages 2.4 lbs (a little over 1 kg) and ripens over a period of 18 months.

The Universidad Agraria, La Molina, Peru, began to assemble pawpaw strains in 1964, collecting 40 strains from various parts of the country and introducing 3 from Brazil, 1 from Puerto Rico, 3 from Mexico and 2 lines of 'Solo' from Hawaii, and embarked on an evaluation and breeding program and the creation of a germplasm bank.

In Ghana, dioecious cultivars such as 'Solo', 'Golden Surprise', 'Hawaii', and 'No. 5595', were introduced and commonly cultivated by farmers but they hybridized with local types and lost their identities after several generations. A number of types were collected at the Agricultural Research Station at Kade in Ghana, from 1966 to 1970 and classified according to sex type, fruit form, weight, skin and flesh colour, flesh thickness, texture and flavor, number of seeds, and various plant factors. It was determined that preference should be given female plants with short, stout stems, early maturing, and bearing heavily all year medium-size fruits of bright colour, thick-flesh and with few seeds.

The Instituto Colombiano Agropecuario, at Palmira, Colombia, began a pawpaw breeding program in 1963 by bringing together Colombian-grown cultivars – 'Campo Grande', 'Tocaimera', 'Zapote', 'Solo', –with some from Brazil– 'Betty', 'Bettina' and '43-A-3' –South Africa– 'Hortus Gold' –and Puerto Rico, and representatives of related species: *C. candamarcensis* Hook. F., *C. pentagona* Heilborn, *C. goudotiana* Tr. & Pl. (one type yellow with green peduncles and another red with purple peduncles), *C. cauliflora* Jacq. of Colombia and *C. monoica* Desf. and *Jacaratia dodecaphylla* A. DC. from Peru. The first two of these species were not suited to conditions at Palmira.

The progeny of crosses with *C. cauliflora* were the only hybrids showing some virus resistance but they were unfruitful when attacked. There were no viable seeds and 30% of the fruits were seedless. *C. monoica* proved well adapted to Palmira, bore small, yellow fruits, but succumbed to virus. The introductions from Brazil were by far the most promising. 'Zapote', with rich, red flesh is much grown on the Atlantic coast of Colombia.

In India, pawpaw breeding and selection work has been carried on for over 30 years beginning with 100 introduced strains and 16 local variations. A well-known cultivar is 'Coorg Honey Dew', a selection from 'Honey Dew' at Chethalli Station of the Indian Institute of Horticultural Research. There are no male plants; female and bisexual occur in equal proportions. The plant is low-bearing and prolific. The fruit is long to oval, weighs 4.4 to 7.7 lbs (2-3 1/2 kg); has yellow flesh with a large cavity, and keeps fairly well. 'Washington', popular in Bombay, has dark-red petioles and yellow flowers. The fruits are of medium size with excellent, sweet flavor. 'Burliar Long' is prolific, bearing as many as 103 fruits the first year, mostly in pairs densely packed along the stem down to 18 in (45 cm) from the ground. Seedlings are 70% females and bloom 3 months after transplanting.

In 1965, a program of pawpaw improvement was undertaken in Trinidad and Tobago utilizing promising selections from local types, including 'Santa Cruz Grant', a vigorous plant mainly bisexual (having both male and female flowers), very large fruits weighing 10 to 15 lbs (4.5-6.8 kg), with firm, yellow flesh of agreeable flavor. The fruit is too large for marketing fresh but is processed both green and ripe. 'Cedro' is dioecious, rarely bisexual, a heavy bearer and highly resistant to anthracnose. The fruits weigh from 3 to 8 lbs (1.37-3.6

kg) but average 6 lbs (2.7 kg); have firm, yellow, melon-like flesh and are suitable for sale fresh or for processing.

In 'Singapore Pink', the plants are mainly bisexual, producing cylindrical fruit. The minor are female with round fruit. Average weight of fruit is 5 lbs (2.27 kg) though there is variation from 2 to 7 lbs (1-3 kg). The flesh is pink. The fruit surface is prone to anthracnose in rainy periods, so, at such times, the fruits must be picked and sold in the green state. Two smaller-fruited types, 2 to 3 lbs (1-1.37 kg) in weight, with bright-yellow skin and thick, firm flesh, were selected for marketing fresh.

The 'Solo' of Hawaii has performed unsatisfactorily in Florida, producing low yields of small fruits. Scott Stambaugh, a pawpaw specialist, began his pawpaw breeding with a strain designated USDA Bureau of Plant Industry #28533 obtained from the then Plant Introduction Station in Miami. From off spring of this he made a selection which he named 'Norton'. When he acquired seed of a type called 'Purplestem'; later 'Bluestem', he crossed it with 'Norton' and the hybrid yielded fruits 10 lbs (4.5 kg) in weight and was named 'Big Bluestem'. The latter was crossed with 'Solo' and the hybrid was called 'Bluestem Solo' or 'Blue Solo'. The 'Blue Solo' has been well regarded in Florida for its low growth, dependable yields of good quality fruits, 2 to 4 lbs (1-2 kg) in weight, orange-fleshed and rich in flavor.

'Cariflora' is a new cultivar developed at the recently renamed Tropical Research and Education Center of the University of Florida at Homestead. It is nearly round, about the size of a cantaloupe, with thick, dark-yellow to light-orange flesh; tolerant of pawpaw ringspot virus, but not resistant to pawpaw mosaic virus or pawpaw apical necrosis virus. Yield is good in southern Florida and warm lowlands of tropical America but not at elevations above 2625 ft (800 m).

'Sunrise Solo' (formerly HAES 63-22) was introduced from Hawaii into Puerto Rico. The fruit has pink flesh with high total solid content. In Puerto Rican trials, seeds were planted in mid-November, seedlings were transplanted to the field 2 months later, flowering occurred in April and mature fruits were harvested from early August to January. Recent selections from Puerto Rican breeding programs are 'P.R. 6-65' (early), 'P.R. 7-65' (late), and 'P.R. 8-65'. Venezuelan pawpaws are usually long and large, ranging in weight from 2 to 13 lbs (1-6 kg) and mostly for domestic consumption or shipment by boat to nearby islands (Morton, 1987).

## **2 Harvesting and Post-production operations**

Traditional and improved picking operations.

### **2.1 Harvesting**

Pawpaws are harvested manually depending on the size and age of the tree, using specialized tools, knives or by hand. When harvesting by hand or with knives, the peduncle is snapped or cut from next to the tree, then immediately trimmed flush against the top of the fruit. The specialized implement for harvesting of fruit inaccessible by hand due to tree height, comprises of a long pole, a small circular hoop at the top, a small mesh bag attached to the hoop, and a horizontal blade above the hoop and the bag. The blade is positioned below the peduncle of the fruit and the pole moved upwards; the fruit is detached from the tree and then drops gently into the mesh bag below the hoop at the top of the pole.

After harvest, the fruit are placed in single layers into shallow, light colored field crates, preferably containing a foam layer for cushioning. All stems should be trimmed after harvest to ensure that no stem to fruit rubbing occurs during transport to the packing facilities. Fruit should never be thrown or dropped. Field crates containing the fruit should be left in shaded conditions protected from the sun and rain, while awaiting collection for delivery to a packing facility. Mesh bags, sacks or baskets are unacceptable for pawpaw transport due to the high susceptibility to bruising (Fig. 25 Pawpaw covered with paper in order to avoid bruising). Care should be taken during transport in field crates to minimize the movement of fruit (Medlicott, 2001).



**Fig. 25 Pawpaw covered with paper in order to avoid bruising**

### 2.1.1 Yield

A typical arrangement for the orchards would be that the trees are planted in a free-draining soil with a plant population of 792 to the acre and a spacing of 3 by 1.5 m. The expected yield is 100 to 140 export boxes per acre per week with each box containing 4 kg of fruit. (Lancashire, 2000) The following gross margin was based on a family unit growing pawpaw under good management. Yields in year 1 and 2 were 0.8 cartons/tree and 5 cartons/tree respectively. It was assumed pawpaw took 10 months to grow and was then picked for the following 14 months. Pawpaws were packed into 13kg cartons. A wholesale market price of \$15 per carton was used. Then the gross margin= **Total Income** (\$15/carton\* x 6577 cartons) - **Total variable costs** (Seedlings, fertiliser, irrigation, cartons etc.). In this case, the gross margin **for two years (crop cycle)** was of \$ **38,282** Trees were planted at a density of 1800/ha. As a general rule 10% of trees are non bearing male trees, and 30% of the remainder die, leaving a density of 1134 bearing trees/ha. (Queensland Government, 2000).

\* Cartons per hectare over 14 months of harvest.

\*\* \$ Australian dollars.

In Mexico, the yield of pawpaw crop fluctuate between 40,000 kg and 85,000 kg/ha.

**2.1.2 Grading:** After pre-grading, washing, and fungicide treatment, the pawpaws are left to dry and then are graded for packing. Graders remove any fruit that shows signs of fresh mechanical damage or any of the conditions that qualify the fruit for rejection in the pre-grading stage. Remaining pawpaws are classified for packing based on size, stage of ripeness, and, if applicable, shape. Fruits of different shape may not be mixed in the same carton.

**2.1.3 Packing.** Fruit can be prepared for packing in two ways.

Single layer, one-piece self-locking or two-piece full telescopic fibreboard carton; bursting strength 200 to 250 lb/in<sup>2</sup>. Internal packaging material should include shredded paper in the base of the carton and individual tissue wraps for each or alternate fruit. Individual labels can be attached to the fruit for appearance and recognition. (Fig. 27 Pawpaws packing). Carton internal dimensions:

\* 10.9 by 34 by 26.9 cm (4.3 in by 13.4 in by 10.6 in).

\* 10.2 by 43.2 by 27.9 cm (4 in by 17 in by 11 in). (Medlicott, 2001).



**Fig. 26 Pawpaws packing**

The key packing processes followed in exporting pawpaws are shown below.

**i) Pre-grading:** Fruit that fail to meet export specifications (see Export Criteria above) should be removed before the washing and decontamination stages and packed later or in a different packing line. Failed fruit may be acceptable for sale on the domestic market.

A pawpaw can be rejected for export for the following reasons:

\* Over-ripeness -fruit exhibits localized softening or has more than three yellow stripes at its base.

\* Under-ripeness -fruit has no yellow stripes.



Mechanical damaged fruit has been damaged by knives, harvesting poles, rubbing from the crate, and the like.

**ii) Washing:** Pre-graded fruit should be placed in a water tank to remove latex and debris. In larger operations, fruit is washed with water in a separate tank or with overhead sprays before being passed to the main wash tank. Normally pawpaws require no additional cleaning, but some may benefit from a careful wiping with a soft cloth. Fruit can also be cleaned with rotating brushes if the brushes are very soft, but simple movement through a water tank for 10 to 15 minutes generally suffices. (Fig. 28 Manual washing of pawpaws).

To help prevent disease and microbial build-up, sodium hypochlorite can be added to the water tanks at a rate of 100 parts per million, or 0.01 percent. Processing personnel should develop a timetable for re-administering the sodium hypochlorite and changing the water, based on the volume of fruit passing through the system.



**Fig. 27 Manual washing of pawpaws**

**iii) Quarantine/fungicide treatment:** Depending on the pawpaws' origin, some importing countries require that the fruits be treated for fruit flies. Treatments are determined by importing-country requirements, but may include long-exposure, hot-water dip treatment, or vapor heat treatment. Pawpaws that travel from Hawaii to Japan must undergo vapor heat treatment.

**iv) Disease control:** Disease control begins in the field. In some cases, and where permitted, postharvest treatments can be used to help prevent the development of anthracnose and phytophthora neck rot.

**v) Grading:** After pre-grading, washing, and fungicide treatment, the pawpaws are left to dry and then are graded for packing. Graders remove any fruit that shows signs of fresh mechanical damage or any of the conditions that qualify the fruit for rejection in the pre-

grading stage. Remaining pawpaws are classified for packing based on size, stage of ripeness, and, if applicable, shape. Fruits of different shape may not be mixed in the same carton.

Because all the fruits in a carton must be similar in size, the counts across cartons can vary. A 4-kilogram carton, for example, can contain the following number of pawpaws, depending on fruit size:

- \* Small: 13 to 16 count (308 to 250 grams);
- \* Medium: 9 to 12 count (440 to 330 grams);
- \* Large: 6 to 8 count (666 to 500 grams).

Pawpaws are also separated according to degree of ripeness, normally as "one yellow stripe" (which is less than one-quarter ripe), "one-quarter ripe", and "one-half ripe". All fruit in a carton must be at the same stage of ripeness so as not to present problems during marketing. In this way, supermarket produce managers can easily identify which fruit are ready for display and which can be stored.

Because pawpaws produce ethylene when they ripen, they should not be stored or shipped with ethylene-sensitive produce. As noted earlier, pawpaws are particularly susceptible to postharvest losses because they are easily damaged and infected by disease. Measures pawpaw handlers can take to control fruit loss are shown below, by risk factor.

**vi) Mechanical damage:** Many factors contribute to pawpaw skin damage, including the harvesting tool used, dropping of fruit into crates, overfilling of crates, and jostling of fruit during field transportation. During ripening, bruised areas will develop into soft, dark regions that are susceptible to secondary microbial infection. Similar problems can result from poor handling during washing, grading, and packing.

Pawpaw handlers can minimize fruit damage by taking protective measures throughout all handling stages. Staff should be trained in proper harvesting techniques. As noted earlier, stems should be removed in the field to prevent puncturing or scratching of adjacent fruit, and fruit should never be thrown or dropped. In addition, transporters should drive slowly and carefully when taking fruit from the field to the packing house.

At the packing house, crates should include foam in their base and contain only one layer of fruit. In automated operations, all machinery should be padded where possible. Palletized systems are preferable for moving produce in both field crates and final packages.

**vii) Pathological factors:** Anthracnose is prevalent in pawpaws during long-term storage, particularly as a result of orchard humidity, inappropriate pre-harvest disease control, or other poor orchard management. The presence of the disease is characterized by small black or light-brown spots that gradually grow and may coalesce and sink.

Anthracnose (Fig. 29 Anthracnose in maradol pawpaw) can be controlled or reduced with pre-harvest sprays, which vary according to importer market. In operations that use pre-harvest sprays, postharvest control should consist of a cold-water dip or spray containing 0.05 percent thiabendazole solution and surfactant. (Before using any chemicals in the field or the packhouse on pawpaw for export, growers and packers should consult importing- and exporting-country legislation.).

Where no pre-harvest sprays are used and anthracnose is present in the orchard, the cold-water dip may be insufficient to disinfect the fruit. In that case, harvesters should use a hot-water treatment for 20 minutes at 46°C. Specialized equipment is needed during hot-water treatments to maintain proper temperature and water circulation. Regulation is necessary because temperature fluctuations will reduce the treatment's effectiveness and may damage the fruit.

Phytophthora can attack pawpaws during long-term storage at low temperatures if an orchard's disease-control systems are not in operation. Phytophthora is characterized by circular, translucent lesions that develop with gray surface mycelia. The disease is particularly apparent around the fruit's peduncle (Market. A.G, 2002, Smith *et al.*, 1992).



**Fig. 28 Anthracnose in maradol pawpaw**

#### **2.1.4 Storage**

Look for fruit with smooth skin. Avoid those with dark, sunken spots as it may affect the flesh of the fruit and spoil the flavor. You can gauge a pawpaw ripeness by touch and sight. The fruit is sent to market at various degrees of ripeness - 1/4, 1/2 and 3/4 ripe - with skin colours ranging from green to yellow-green to yellow-orange. Pawpaw at its ideal stage of ripeness is 3/4 yellow or yellow-orange (depending on variety). Pawpaws are ripe when they emit a soft fruity aroma.

*Hawaiian* If you want to eat the fruit the same day make sure the pawpaw is 100% yellow. If you want to wait a couple of days before eating/serving, make sure your hawaiian pawpaw that have more green on the fruit. The more green on the fruit, the longer you can hold it. Store at room temperature unless they are completely ripe (100% yellow). If they are completely ripe, you can store in the refrigerator (40°F) for 3 to 4 days. When you are ripening the fruit, turn it on the shelf everyday. This will ensure even ripening.

*Sunrise* Sunrise pawpaw is fully ripened when it is all yellow with small green speckles. If you want to wait a couple of days before eating/serving, make sure that sunrise pawpaw that have more green on the fruit. The more green on the fruit, the longer you can hold it.

Store at room temperature unless they are completely ripe (100% yellow with green speckles). If they are completely ripe, you can store in the refrigerator (40°F) for 3 to 4 days. When you are ripening the fruit, turn it on the shelf everyday. This will ensure even ripening.

*Maradol* Maradol pawpaws turn completely salmon colour when they are fully ripe. When they are picked at mature green (not ripe at all) they have three little stripes. As the fruit ripens you will still see faint stripes.

If you want to wait a couple of days before eating/serving, make sure you maradol pawpaw that have more green on the fruit. The more green on the fruit, the longer you can hold it. Store at room temperature unless they are completely ripe (salmon colour). If they are completely ripe, you can store in the refrigerator (40° F) for 3 to 4 days.

When you are ripening the fruit, turn it on the shelf everyday. This will ensure even ripening. Relative humidity: more than 80% (Calavo Products, 2002).

## **2.2 Packinghouse operations**

Before we begin the tour we must first understand how the fruit is harvested and delivered to the packinghouse. Field Managers are in contact with our Growers to schedule deliveries of fruit to meet market demands. Growers who want their fruit picked up in the groves will schedule transportation with the Field Manager. Many Growers elect to deliver the fruit to the packinghouse themselves.

The fruit is gradually pre-cooled before packing. This allows the fruit to cool down over a 12 hour period from the ambient temperature at delivery time, to 40-45 degrees before packing the next morning.

Packers have a built in system that allows full bins to be weighed before packing. Empty bins are then weighed so that the grower is given credit for every pound of fruit delivered to the packinghouse.

The fruit is placed on the packing line and graded. The fruit is then placed into tight fill cartons by Sizer machine. The fruit is labeled during the process. The sizer insures not only that the correct number of fruit is packed into the cartons by size, but also that the weight of the carton is correct.

All cartons of fruit are checked once more by a quality control person before the carton is sealed and placed in a cooler until shipment time. The cartons of fruit are stacked on pallets and these pallets are placed in a shipping cooler, where temperature is maintained between 40 and 42 degrees (Calavo Products, 2002).

### **a) Inspection**

One the fruits are harvested at optimum mature, are transported to the packinhouse where are inspected and selected by size and mature grade.



**b) Washing**

Washing the fruits immediately after harvest is essential, as the sap, which leaks from the stem bums the skin of the fruit making black lesions, which lead to rotting.

**c) Grading**

Grading and packing should be carried out as soon as possible after harvest, normally within three hours, after which time the fruit should be kept at ambient tropical conditions (25°C to 28°C) to continue ripening, or cooled and stored at 10°C to 12°C.

Standard packing house design and operations apply for pawpaw grading and packing. Operations can be carried out with basic equipment, including water tanks, field crates, and grading tables, or with automated washing and weight-grading or separation systems. All tanks and grading tables should be covered with foam to protect fruit from exposed edges; the skin of the pawpaw is delicate, and scratches will result in latex exudation and staining. Similarly, if the fruit is dropped, it will easily develop bruises as it ripens (Market. A.G, 2002, Smith *et al.*, 1992).

**d) Hydrothermic process** (rural installations and certification of automatic systems)

Hot water treatment: 30 minutes at 42°C (107.6°F) followed within 3 minutes by a 49°C (120.2°F) dip for 20 minutes (Kader, 2000).

**e) Thermal disinfestations treatments**

Pawpaw treated by vapor heat or forced hot air for export must be picked before the fruit is suitably ripe. Pawpaw is subjected to temperatures of 117°F for up to four hours. This results in premature wrinkling due to water loss.

**Hot treatments** are approved for insect disinfestations, but have demonstrated some commercial shortcomings. Vapor heat requires growers to harvest greener pawpaws, which more readily tolerate heat treatment than fruit at riper stages. Forced dry air has been shown to blacken lychee, while extended cold treatment of star fruit can render the fruit wilted and unmarketable. Dr Lyle Wong, Science & Public Policy Institute April, 1998.

Consumers prefer fresh fruit. We are committed to fruit picked tree-ripened for sweetness and quality. Research shows repeat customer sales with Brix over 12.

**Irradiation** research performed by Dr. James Moy and Dr. Robert Paull at the University of Hawaii shows equal or superior retention of vitamins at allowable doses.

For many decades, chemical fumigants have been used to allow fruits, vegetables and grains to be transported across state lines and imported from foreign countries. But that era is coming to an end.

In 1984, ethylene dibromide was cancelled for further use. Now, with adoption of the international Montreal Protocol, methyl bromide, the primary fumigant used worldwide, will be phased out effective January, 2001.

These fumigants have been determined to present environmental hazards, including damage to the earth's ozone layer.

In 1997, USDA researcher Donald Thayer stated: "A safe, effective alternative to methyl bromide, irradiation has no harmful side effects."

That is why the list of endorsers for irradiation includes the U.S. Department of Health and Human Services, U.S. Public Health Service, American Medical Association, World Health Organization, United Nations Food & Agriculture Organization, the Institute of Food Technologists, and the international Codex Alimentarius Commission (Hawaii Pride, 2002).

**Vapor heat treatment** : Fruit temperature is raised by saturated water vapor at 44.4°C (112°F) until the center of the fruit reaches that temperature, and then held for 8.5 hours.

Forced hot air treatment: 2 hours at 43°C (109.4°F) + 2 hours at 45°C (113°F) + 2 hours at 46.5°C (115.7°F) + 2 hours at 49°C (120.2°F) (Kader, 2000).

The single hot-water dip (49 °C for 15 min) is the optimum heat treatment for disease control of pawpaw diseases with minimal detrimental impact on fruit quality. The additional disease control provided by a single hot-water dip before or after forced air dry heat (FADH) or vapor heat (VH) is about the same level provided by postharvest applications of the fungicide thiabendazole applied to FADH or VH treated pawpaw. (Nishijima, 1995).

White peach scale was collected for the first time in Hawaii in September 1997 from pawpaw. This scale insect is a threat to the pawpaw industry as a source of tree stress and fruit downgrading, and as a quarantine pest on fruit for export.

Pawpaws exported from Hawaii now receive a vapor heat quarantine treatment for fruit flies that involves heating the fruit core temperature to >117°F (47.2°C) in not less than 4 h. We conducted a study to test the effectiveness of this treatment against white peach scale. Pawpaws infested with all stages of the scale were treated under commercial conditions. The vapor heat treatment killed all the scales tested including 19,000 eggs, 27,000 crawlers, 13,000 immatures, 1000 pupae, and 5600 hardshells. White peach scale on pawpaws subjected to vapor heat treatment should pose no threat to quarantine security in export shipments (Follett, 2001).

## **2.3 Packing and packaging materials**

### **Packaging practices**

A package or packaging is the material used to protect, contain or transport a fruit. A package can also be a material that is physically attached to a product or its container for the purposes of marketing. Packing material is generally used to preserve, transport, inform about as an aid while using the fruit it contains.

Solo Sunrise pawpaw, the most popular variety, are packed in single-layer cartons, each with a net weight of 4 kilograms to 5 kilograms, depending on importer and importing-country requirements. Internal packaging materials can include shredded paper in the base of the carton and individual tissue wraps for each or every other fruit. Pawpaw may be individually labeled for appearance and easy recognition.

Pawpaws are best packed on their sides, in rows, with the stem ends at an angle; interlocking rows support one another. Pawpaws should not be packed on their bases because they soften from the base up. Packers should guard against overfilling the cartons.

Importers require pawpaws at specific stages of ripeness for optimal sales. Stages vary from 50 to 70 percent yellow depending on importer, market, and time of year. In order for fruit to arrive in the importing country at the correct colour stage, exporters must be aware of the fruit's maximum and minimum colour stages upon its departure from the packing house, the length of the shipment period (for air shipment, 24 to 48 hours), and the temperature in the importing country. Colour stages for air shipments can vary from 20 to 50 percent, with selections generally being more rigid during the summer months because of accelerated ripening rates on arrival in importing countries. Fruits that are exported at less than 20 percent yellow will fail to ripen adequately when temperatures in importing countries are low, particularly during winter (Hawaii Pride, 2002).

## 2.4 Cooling system

### 2.4.1 Low Temperature.

Storage of unripe pawpaw below temperatures of 10°C will result in chilling injury. The symptoms are indicated by surface pitting, discoloration of the peel and the flesh, incomplete ripening, poor flavor and increased susceptibility to disease incidence. Ripe pawpaws will store successfully at lower temperatures (Fig. 30 Refrigeration room), but transport of ripe fruit (more than 50% yellow colour) is not recommended due to the susceptibility to mechanical damage and bruising (Medlicott, 2001).



**Fig. 29 Refrigeration room**

## 2.5 Storage of fruits and vegetables

Recommended storage temperature for pawpaw is 10 ° C. Handling with care to reduce bruising, skin of the pawpaw is very delicate. Ripen at room temperature, fruit should be slightly soft to the touch and turned 3/4 yellow, approx. 2 to 3 days. Ripe pawpaw should be refrigerated to slow down the ripening process. Place ripe, whole fruit in a plastic bag in the refrigerator, and it should last about a week. (About, 2002).

Little is known about pawpaw fruit ripening and its response to standard fruit storage techniques. The fruit ripening is probably regulated by naturally produced ethylene similar to apple, tomato and banana. Furthermore, storage at 4 ° C for 4 weeks or more seems to delay ripening until removal to room temperature. Due to the nearly non-existent data about pawpaw ripening and postharvest storability, it is critical to develop appropriate storage practices in order to maintain fruit quality for both the fresh and processing markets. (Archbold, 2001).

### 2.5.1 Forced ripening

Among those treatments designed to accelerate the ripening process of fruit, the treatments commonly used include exposure to ethylene, acetylene ethephon (2-chloroethylphosphonic acid).

#### 2.5.1.1 Controlled atmospheres treatment.

**Ethylene effects:** Exposure to 100 ppm ethylene at 20 to 25°C (68 to 77°F) and 90-95% R.H. for 24-48 h produces a rapid and uniform ripening (yellowing of peel and pulp softening, but a nill improvement in flavor) of pawpaws harvested between colour break to 1/4 yellow (Kader, 2000).

Experiments carried out by our postharvest group (Instituto Tecnologico de Veracruz-UNIDA, Mexico), reported a reduction of the maturation time (three days) of maradol pawpaw fruits when were exposed with 500 ppm of ethylene, in modified atmospheres at ambient temperature (24-26°C and 85-95% HR). This fruits showed a better texture, taste and colour (Vela, 2002). (Fig. 30 Pawpaw ethylene treatment).







**Fig. 30 Pawpaw ethylene treatment**

### 2.5.2 Compatibility groups for storage of fruits.

The best storage environment for an individual fruit or vegetable depends on its unique requirements for temperature, relative humidity, and ethylene exposure. Most compatibility charts for mixing products during postharvest handling divide fruits and vegetables into eight groups. In practice it is very difficult to separate products into this many groups-very few wholesale or retail handling facilities, if any, have eight temperature-controlled rooms.

Researchers of UC Davis (Thompson, Kader and Sylva, 1999), have developed a three-group chart that is easier to use and still provides good product life (Table 5).

atemoya	rambutan
banana	sapodilla
breadfruit	sapote
canister	soursop
casaba melon	cherimoya
crenshaw melon	honeydew melon
jaboticaba	jackfruit
mamey	mango
mangosteen	papaya
Persian melon	plantain
*Source : (Thompson, Kader and Sylva,1999)	

Group 3- Fruits

code thermometer 55-65 ° F, 13-18 ° C & 85-95% rh (relative humidity).

## **2.6 Transportation system**

Based on the transit and storage life, a recommendation is made. Since many tropical products like pawpaw are high value and traded in small quantities, they are often shipped by air, even when surface transportation could be used. (USDA, 2002). (Fig. 26 Transportation of pawpaw fruits).

Although the UK market for pawpaw is expanding at a leisurely pace, efforts to increase it by shipping volumes by sea have proved unsuccessful due that the product doesn't respond well to this type of transit. (PGA, 1999).

Marketing and physical distribution of fresh produce inherently means moving the produce. The commodities are handled, either manually or mechanically, many times from harvest and through the distribution process before the consumer buys and prepares them to eat.

For domestic transportation the use of road vehicles offers substantial advantages of convenience, availability, flexibility permitting door-to-door delivery, and reasonable cost of transport. The use of road transportation for fresh produce is increasing and likely to increase in countries all over the world. Produce may be transported by pick-up, enclosed truck, open truck or refrigerated vehicle. (Harris, 1988).

For perishable products, however, the increased speed of handling and reduced transport costs that came with containerization were not enough. Ocean transport of cooled and frozen cargo received a substantial boost with development of mobile refrigerated cargo ships that lack this flexibility. Controlled atmosphere (CA) technologies allow operators to lower the respiration rate of produce by monitoring oxygen, carbon dioxide and nitrogen levels within a reefer. In this way, CA can slow ripening, retard discoloration, and maintain freshness of pawpaw. Although it is likely that container ships will dominate the perishable trade between North America, East Asia and Europe, conventional refrigerated vessels can serve many smaller ports, especially in the developing world, that are unable to handle large container vessels. Thus, in north-south trade and in certain niche markets, conventional refrigerated ships may have a brighter future, but even here, competition from container vessels is bound to increase as cost decline (Agricultural Outlook, 1999).



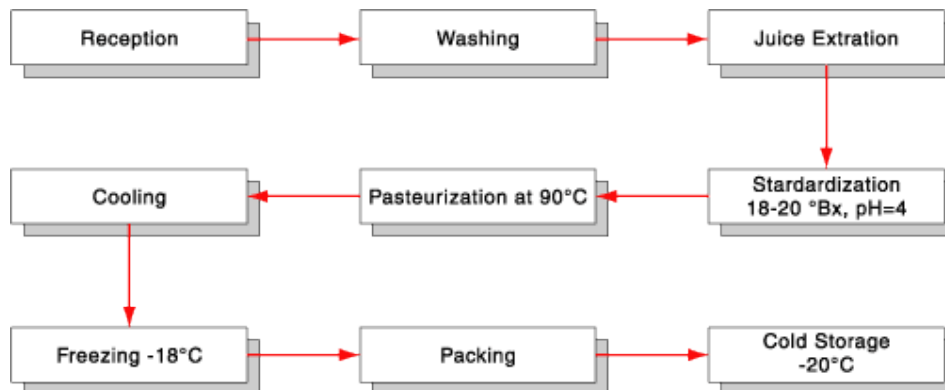
**Fig. 31 Transportation of pawpaw fruits**

## 2.7 Processing

Essentially a prime table fruit, pawpaw pulp (Table 6) is perfectly suited for conversion to juices Fig. 32 Processing of freeze pawpaw juice, nectars, drinks, jams, fruit cheese, concentrates (Fig. 33 Process for pawpaw concentrate) or to be had by itself or with cream as a superb dessert. It can also be used in puddings, bakery fillings, and fruit meals for children, flavors for food industry, and also to make the most delicious ice cream and yoghurt. While the raw fruits are utilized for products like chutney, pickle, sauce. pawpaw beverage, etc. ripe ones are used in making pulp, juice, nectar (Table 6), squash, leather, slices, etc. Major export products include dried and preserved vegetables, jams, fruit jellies, canned fruits and vegetables, dehydrated vegetables, frozen fruits, vegetables and pulps (Table 7) and freeze dried products.

Ripe pawpaw may be frozen whole or peeled, sliced and packed in sugar (1 part sugar to 10 parts pawpaw by weight) and quick-frozen in moisture-proof containers. The diced flesh of ripe pawpaw, bathed in sweetened or unsweetened limejuice, to prevent discoloration, can be quick-frozen. Half-ripe or green pawpaws are peeled and sliced as filling for pie, used for jelly, or made into sauce.

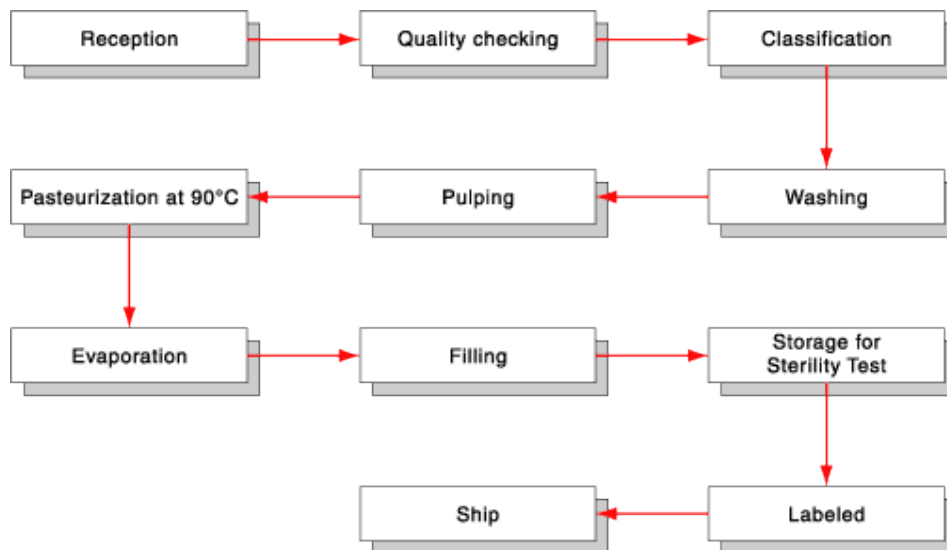
Pawpaw pulp	Glazings
Fruit cocktails	Dried pawpaw slices
Juice	Pawpaw wine
Nectar	Flavored yoghurt
Fruit sauces	Ice cream



**Fig. 32 Processing of freeze pawpaw juice**



Table 7 Pawpaw natural concentrates	
Name of product	Pawpaw concentrate
Variety	Hybrid
Colour	Orange Yellow
Flavor & Taste	Characteristic of pawpaw
Total soluble solids	18 - 20 °Brix
Acidity (% as citric acid)	0.8 ± 0.2
pH	4.0 ± 0.3
Ingredients	Pawpaw
Packing	Aseptic bag in barrel
Net weight per barrel	215 Kg. ± 1 Kg.



**Fig. 33 Process for pawpaw concentrate**

### 2.7.1 Fresh consumption and processing.

For long distance marketing, fruit should be harvested after the colour of blossom end has changed; but for local consumption pick up fruits at half way change in green colour. Size grade, treat with hot vapors of ethylene bromide to kill fruit fly, if required, wrap in newspapers and pack in boxes before shipping. For table use and processing, prefer pawpaw harvest at 3/4 ripe stage indicated by 75 % colour change to yellow. Such wrapped fruits will ripen completely to total yellow colour at room temperature within 2-4 days. Fruit harvested at 3/4 ripe stage will store successful at 7°C for 21 days. Ideal storage temperature is 13-16°C. Unripe fruit if stored at 12°C suffers from chilling injury. Fresh ripe pawpaw is consumed as 'it is' after peeling and slicing, often with added salt, spices, sugar or lime juice. (Fig 34 Peeling of maradol ripened pawpaw).



**Fig 34 Peeling of maradol ripened pawpaw**

It is preferred breakfast and dessert fruit. Pawpaw is quite nutritious having many therapeutic and medicinal uses. It is rich source of many vitamins and minerals. Use early drop unripe green pawpaw for the preparation of curried or dry vegetable, raita, burfey, pickle or chutney.

#### **a) Vegetable**

Wash, peel, halve, remove seed, slice, rewash and cook like other. For large scale consumption of early fallen green fruits, supply them in bulk to community kitchens of hostels, dhabas, hotels, restaurants and langers of religious places for use as vegetable and raita.

#### **b) Raita**

Boil grated pulp of peeled green pawpaw with equal amount of water. Press to squeeze out water. Mix curd with laddle. Add grated boiled pieces and mix. Mix edible salt and spices (cumin, black pepper, coriander, etc.) according to taste and serve.

### c) Drying

Prepare slices (6 mm thick) after washing, peeling, cutting and removal of seeds. Sulfuring of slices is done for 2 h by burning 3 g sulfur/kg slices in a closed chamber. Dry at 60-65°C in a drier with occasional turning, or sun dry. Pack in polyethylene bags. (Fig. 35 Dried pawpaw product and dryer).



**Fig. 35 Dried pawpaw product and dryer**

### d) Papain

Unripe green but fully mature fruits are lanced with a knife. Give four cuts at equal distance on single fruit. Collect latex in a suitable vessel of glass or porcelain. Latex hardens within 15

min. Sundry it as crude papain. To obtain high quality papain, precipitate it with alcohol followed by washing with acetone. Dry under sun or in an oven or preferably under vacuum oven sulfuric acid at room temperature. Small amount of sodium sulfate may be added during latex collection to obtain better quality product. Extract papain from the green fruits after collecting latex as pawpaw fruit contains 10 % papain on dry weight basis.

#### **e) Pectin**

Unripe green fruits otherwise unsuitable for product making or fruits after obtaining latex may be used for pectin extraction. Green pawpaw is rich in pectin, containing 10% of it on dry weight basis. Pectin has extensive applications in food and medicinal industries. Pectin can also be extracted from peel waste of green pawpaw.

#### **f) Pulp**

Pulp of fully mature and ripe pawpaw is used for the preparation of nectar and mixed ready-to-serve beverages. Unripe fruits may be sorted out from the bulk lot and ripened at room temperature by keeping them wrapped in newspaper. Combine in the ratio of 1:1 pectin rich slightly unripe fruit with full ripe pawpaw having fully developed yellow colour and flavor for pectin requiring products such as chutney, sauce, jam and jelly (Fig. 36 Maradol pawpaw pulp). For pulping, fruits are thoroughly washed, peeled and halved with stainless knives. Peeled halves are pulped with mechanical fruit crusher or home mixer. Filter or sieve the pulp to remove fibrous material. Use fresh pulp for the preparation of different products. However, for long distance marketing, pulp is usually concentrated, frozen or canned.



**Fig. 36 Maradol pawpaw pulp**

#### **g) Pickle**

Blanch 1 kg slices of peeled green pawpaw in boiling water for 3 minutes. Drain and sprinkle 100 g salt and dry under shade. Mix spices i.e. 10 g each of powdered red chillies, cardamom, large cumin and black pepper. Fill in jars. Cover with vinegar (>250 ml). Close with airtight lids. Curing will be completed within 2-3 weeks.



**h) Chutney**

Cook 1 kg of pulp of ripe firm peeled and grated pawpaw with chopped onion (100g) and 50g salt till soft. Add 50g ginger and 15g garlic after chopping and 10g each of the powdered aniseed, red chillies, cumin, large cardamom, cinnamon, black pepper, and 2g headless cloves. Cook gently to desired consistency. Add sugar (3/4kg). Cook again to thick consistency. Add vinegar (200ml) Cook for 5min. Fill hot into previously cleaned dry jars followed by capping.

**i) Sauce**

Concentrate 1 kg strained pulp containing 20 g sugar to 1/3 of its original volume in the presence of suspended spice bag containing 50 g chopped onion, 5 g garlic and 50 g ginger, 10 g powdered spices and 5 g red chillies. Press out spice bag occasionally and squeeze it out finally to obtain maximum spice extract. Add 15 g salt and remaining 40 g sugar and cook to thick consistency. Add 450 ml vinegar and cook again to end point. Add and mix preservative after dissolving in minimum quantity of water. Heat to boiling and hot pack.

**j) Jam**

Boil 1 kg pulp of ripe firm peeled fruit with 100 ml water and 3 g citric acid. Add 3/4 kg sugar and cook to thick consistency. End point is confirmed by sheet test. Boiling mass is allowed to fall after cooking from a serving spoon, which will flow in the form of a sheet. Pack hot in clean dry glass jars.

**k) Jelly**

Mix 1 kg grated pulp of fully mature peeled but somewhat raw fruits with ripe pawpaw pulp (1 kg), 2.5 l. water and 10 g citric acid. Boil for 30 min, cool and allow to settle for 2 hours. Separate the supernatant (upper layer) and filter. Test for pectin quality. Formation of single clot with small quantity of ethyl alcohol added to test samples indicates high pectin content. Concentrate further, if necessary to obtain single clot. Cook gently the extract with equal quantity of sugar to obtain the end point indicated by the formation of sheet. Pack hot. Cover with a layer of melted wax and close the lid.

**l) Burfi**

Boil the grated pulp of peeled green pawpaw for 5 min. Press out excess water. Fry in equal amount of animal mil-fat. Add sugar equal to the grated material. Mix and heat for 2 min. Spread it in the form of 1 to 2 cm thick uniform layer on aluminum/steel tray smeared with fat. Allow to dry. Cut pieces of suitable size.

**m) Preserve and candy**

Cut rectangular slices (4x1 cm) or suitable sized cubes from the fully mature ripe washed peeled fruits after removing seeds. Puncture with a stainless steel fork. Keep in 1.5 % limewater for 3-4 hours. Drain and wash 3-4 times in plain water. Dissolve 400 g sugar in 600 ml hot water and filter. Boil pieces in sugar syrup and keep overnight. Next day drain the syrup, raise its Brix to 50. Add slices, boil and keep again. Repeat this process every day, until Brix reaches 70-75°. Keep for a week. Drain the syrup, fill the pieces in dry jars and cover slices with freshly prepared sugar syrup of 70°Bx.

For the preparation of candy, raise the Brix of syrup to 75°, and keep it for a week. Drain and dry the pieces under shade. Dip pieces in boiling water to remove adhering sugars. Drain, dry and pack.

**n) Toffee**

Concentrate 1 kg sieved pulp to 1/3 volume and cook with added sugar (600 g), glucose (100 g) and hydrogenated fat (100 g) till a speck of the product put into water forms compact solid mass. Make thick paste of 100 g skim milk powder in minimum quantity of water and mix with the boiling mass. Spread 1-2 cm thick layer of the cooked mass over /SS trays smeared with fat. Add flavouring material at this stage, if necessary. Allow cool. Cut and wrap in butter paper.

**ñ) Leather**

Mix thoroughly powdered sugar (50-75 g) citric acid (0.5 g) and KMS (Sulphite Mono Potassium) (3 g). Smear /steel tray with fat and spread the above mixture in 1cm thick layer. Dry in a home drier at 55-60°C. Roll the dry leathery product for storage as slab or cut it into pieces of suitable size.

**o) Canning**

Cut slices (2.5 x 4 cm) or cubes of suitable size from fully developed ripe firm washed, peeled fruits after removing seeds. Pack slices in plain cans. Cover with hot sugar syrup (33°Brix). Exhaust at 90°C for 5 min. Seam and process in boiling water. Cool, label and store (Indiaagronet.com, 2000).

**p) Papain from pawpaw**

Papain is prepared from pawpaw Latex, which is viscous and milky. It has good protein hydrolysis properties.

In the year 1987 world production of pawpaw was 34.54 ton. India's contribution was 3.4 ton. which has increased considerably during past years due to its increasing use in food industry, pharmaceuticals, leather tanning, beer industry, textiles, etc.

The pawpaw fruit has got a wide spectrum of applicability both in the form of raw and ripe fruit. Some of the important applications has been shown below:

At present there is production of more than 100 tonnes of papain in the country of which 35 t. is BPC (British Pharmacopoeia Commission) grade and the rest is pure Papain. BPC grade papain is used in the country and 90% of pure papain is exported. For marketing of papain entrepreneur could contact pharmaceutical, beer plants, food & tanning industry, meat & cheese processing industry, etc. They can also contact Agricultural Process Food Export Promoter Agency, Bikajee Camp Place, New Delhi for export of Papain.

**q) Latex**

Tropical and sub-tropical climate is suitable for cultivation of pawpaw and it is widely grown in India. Fertile soil having good water retention quality is suitable for pawpaw cultivators. Tamil Nadu Agriculture University, Coimbatore has developed CO2, and CO5 varieties which are suitable for obtaining good latex production. Generally papain manufacturers grow pawpaw to cater to their needs or else they could collect from nearby farmers. For obtaining 50-60 kg. of latex per day for 300 days there is need for cultivation on 25 acres of land. The land is divided into 3 sections the plantation is done in one section at a time in a cycle of 3-4 months so as to make availability of latex round the year (Timeis, 2000).

Pawpaw fruits on the trees itself are launched by giving 1/2 in deep 4-6 longitudinal cuts with a stainless steel knife or razor blade fitted in a curved wooden frame with a handle. The latex

is collected in suitable stainless steel or trays or polyethylene sheet held below the tapped fruit. Five to six tappings in the course of 30 days have been found to be sufficient for the purpose. At the end of each tapping, the latex coagulated on the surface is scrapped and added to the batch. The collected latex is passed through 50 mesh sieve to remove dirt. It is mixed with 0.5% potassium metabisulphite and spread on stainless steel or aluminum trays (0.5-1 lb/ft<sup>2</sup> of tray area) and dried in a vacuum shield drier at a temperature of about 55°C for 4-5 hours. Vacuum dried product is superior in quality and is easier to remove from the trays due to its porous structure.

The dried product is packed in air-tight containers and stored in a cool dry place. It is advisable to keep the product in flake form as powdering decreases the stability of the product during storage. In pilot plant trial, the average yield of wet latex was about 20-25% of the tapped fruits. The yield of the dry papain was 20-25% of the wet latex collected. The yield of papain thus obtained was about 80 BPC units per gram. The dried flakes are powdered and blended with a diluent to the desired concentration just before the dispatch of the consignment. It is preferable to have a dehumidifier in the powdering and packing rooms (Timeis, 2000).

### **3 Pest control and decay**

#### **3.1 Pest species**

A serious disease during the seedling stage is seedling rot or phytophthora causing soft rot and wilting of seedling, which also affects mature trees. It can be controlled by good drainage and sanitation control that is by removing all infected plants.

Anthracoise cause dark depressed lesions on ripe fruits, which then become soft, dark coloured and unattractive. (Fig. 37 Depressed lesion by anthracnose in maradol pawpaw).



**Fig. 37 Depressed lesion by anthracnose in maradol pawpaw**

It can be controlled by spraying Dithane M-45 (a broad spectrum fungicide that is composed by Ethylenebisdithiocarbamate 80 %, manganese 16 %, and Zinc 2 %) on the leaves and fruits every ten days. The fungus *Collectotrichum gloeosporoides* can be controlled by recommended fungicides. The root knot nematode affects the roots causing galls and damage to the root system.

The most serious of the pests is the fruit flies, which cause damage to the fruits. Cultural control is practised by removing all ripe and infested fruits. Damages caused by the leaf sucking pests such as aphids and mites can be controlled by recommended insecticides (Agrolink, 2002).

#### **a) Pests**

A major hazard to pawpaws in Florida and Venezuela is the wasp-like pawpaw fruit fly, *Toxotrypana curvicauda*. The female deposits eggs in the fruit, which will later be found infested with the larvae. Only thick-fleshed fruits are safe from this enemy. Control on a commercial scale is very difficult. Home gardeners often protect the fruit from attack by covering with paper bags, but this must be done early, soon after the flower parts have fallen, and the bags must be replaced every 10 days or 2 weeks as the fruits develop. Rolled newspaper may be utilized instead of bags and is more economical. India has no fruit fly with ovipositor long enough to lay eggs inside pawpaws.

An important and widespread pest is the pawpaw web-worm, or fruit cluster worm, *Homolopalpia dalera*, harbored between the main stem and the fruit and also between the fruits. It eats into the fruit and the stem and makes way for the entrance of anthracnose. Damage can be prevented if spraying is begun at the beginning of fruit set, or at least at the first sign of webs. The tiny pawpaw whitefly, *Trialeuroides variabilis*, is a sucking insect and it coats the leaves with honeydew which forms the basis for sooty mold development. Shaking young leaves will often reveal the presence of whiteflies. Spraying or dusting should begin when many adults are noticed. Hornworms (immature state of the sphinx moth—*Erinnyis obscura* in Jamaica, *E. ello* in Venezuela, *E. alope* in Florida) feed on the leaves, as do the small, light-green leafhoppers. Other pests requiring control measures in Australia include the red spider, or red spider mite, *Tetranychus seximaculatus*, which sucks the juice from the leaves. In India and on the island of Maui, plant and fruit infestation by red spider has been a major problem. This pest and the cucumber fly and fruit-spotting bugs feed on the very young fruits and cause them to drop. In Hawaii, the red-and-black-flat mite feeds on the stem and leaves and scars the fruit. The broad mite damages young plants especially during cool weather.

In the Virgin Islands scale has been most troublesome, apart from rats and fruit-bats that attack ripe fruits. In Australia, 5 species of scale insects have been found on pawpaws, the most serious being oriental scale, *Aonidiella orientalis*, which occurs on both the fruit and the stem. So far, it is confined to limited areas. In Florida, the scale insects *Aspidiotus destructor* and *Coccus hesperidum* may infest bagged fruit more than unbagged fruit. Another scale, *Philaphedra* sp., has recently been reported here.

Indian scientists have observed that immature earthworms, *Megascolex insignis*, are attracted by and feed on rotting tissue of pawpaw plants. They hasten the demise of plants afflicted with stem rot from *Pythium aphanidermatum* and may act as vectors for this fungus. Root-knot nematodes, *Meloidogyne incognita* acrita, and reniform nematodes, *Rotylenchulus*



*reniformis*, are detrimental to the growth and productivity of pawpaw plants and should be combatted by pre-planting soil fumigation if the nematode population is high.

#### **b) Diseases**

Hawaii, partly because of its distance from other pawpaw-growing areas, is less afflicted with disease problems than Florida and Puerto Rico, but still has to combat a number of major and minor maladies. Most serious of all is the mosaic virus, on plant and fruit, which is common in Florida, Cuba, Puerto Rico, Trinidad, and first seen in Hawaii in 1959. It is transmitted mechanically or by the green peach aphid, *Myzus persicae*, and other aphids including the green citrus aphid, *Aphis spiraecola*, in Puerto Rico. Two forms of mosaic virus are reported in Puerto Rico: the long-known "southern coast pawpaw mosaic virus", the symptoms of which include extreme leaf deformation, and the relatively recent "Isabela mosaic virus" on the northern coast which is similar but without leaf distortion. Both forms occur in some northcoast plantations. There is no remedy, but measures to avoid spread include the destruction of affected plants, control of aphids by pesticides, and elimination of all members of the Cucurbitaceae from the vicinity. Mosaic is sporadic and scattered and not of great concern in Queensland.

Pawpaw ringspot virus, prevalent in Florida, the Dominican Republic and Venezuela, is occasionally serious in the Waianae area on the dry leeward side of Oahu. It is transmitted by the same vectors. Mosaic and ringspot viruses are the main limiting factors in pawpaw production in the Cauca Valley of Colombia.

In Florida, virus diseases were recognized as the greatest threat to the pawpaw industry in the early 1950's. The first signs are irregular mottling of young leaves, then yellowing with transparent areas (Fig. 38 Pawpaw "mancha anular" virus ("monkey hand" symptom), De Los Santos, 2000), leaf distortion, and rings on the fruit. If affected plants are not removed, the condition spreads throughout the plantation. Fruits borne 2 or 3 months after the first symptoms will have a disagreeable, bitter flavor.



**Fig. 38 Paw paw "mancha anular" virus ("monkey hand" symptom)**

At the Agricultural Research and Education Center of the University of Florida in Homestead, the late Dr. Robert Conover established a test plot of pawpaws grown from seed of 95 accessions from a number of countries and 94 collections in Florida in the hope of finding some virus-free strains. Most of the introductions were highly susceptible to pawpaw ringspot virus; local strains showed some resistance. Highest tolerance was shown by a dioecious, round-fruited, yellow-fleshed strain brought from Colombia by Dr. S.E. Malo several years ago. The fruits weigh 3-5 lbs (1.36-2.27 kg).

It is thought that at least 3 virus diseases are involved in pawpaw decline in East Africa and it has been suggested that the diseases are spread in part by the tapping of green fruits for their latex (the source of papain).

Bunchy top is a common, controllable mycoplasma disease transmitted by a leafhopper, *Empoasca pawpawe* in Puerto Rico, the Dominican Republic, Haiti, and Jamaica; by that species and *E. dilitara* in Cuba; and by *E. stevensi* in Trinidad. Bunchy top can be distinguished from boron deficiency by the fact that the tops of affected plants do not ooze latex when pricked. In the subtropical part of Queensland, but not in the tropical, wet climate of northern Queensland, pawpaw plants are subject to die-back, a malady of unknown origin, which begins with shortening of the petioles and bunching of inner crown leaves. Then the larger crown leaves quickly turn yellow. Affected plants can be cut back at the first sign of the disease and if the cut stem is covered to avoid rotting, the top will be replaced by healthy side branches. The problem occurs mainly in the hot, dry spring after a season of heavy rains.

Anthracnose, which usually attacks the ripe fruits and is caused by the fungus *Colletotrichum gloeosporioides*, was formerly the most important pawpaw disease in Hawaii, Mexico and India, but it is controllable by spraying every 10 days, or every week in hot, humid seasons, and hotwater treatment of harvested fruits. A strain of this fungus produces "chocolate spot" (small, angular, superficial lesions). A disease resembling anthracnose but which attacks pawpaws just beginning to ripen, was reported from the Philippines in 1974 and the causal agent was identified as *Fusarium solani*.

A major disease in wet weather is phytophthora blight. *Phytophthora parasitica* (Fig. 39 Pawpaw rotting stem by phytophthora sp. De los Santos *et al.*, 2000) attacks and rots the stem and roots of the plant and infects and spoils the fruit surface and the stem-end, inducing fruit fall and mummification. Fungicidal sprays and removal of diseased plants and fruits will reduce the incidence. *P. palmivora* has been identified as the chief cause of root-rot in Hawaii and Costa Rica.



**Fig. 39 Pawpaw rotting stem by phytophthora sp.**

Root-rot by *Pythium* sp. is very damaging to pawpaws in Africa and India. *P. ultimum* causes trunk rot in Queensland. Collar rot in 8- to 10-month old seedlings, evidenced by stunting, leaf-yellowing and shedding, and total loss of roots, was first observed in Hawaii in 1970, and was attributed to attack by *Calonectria* sp. Collar rot is sometimes so severe in India as to cause growers to abandon their plantations.

Powdery mildew, caused by *Oidium caricae* (the imperfect state of *Erysiphe cruciferarum* the source of mildew in the Cruciferae)

often affects pawpaw plants in Hawaii and both plants and fruits elsewhere. Sulfur, judiciously applied, is an effective control. Powdery mildew is caused by *Sphaerotheca humili* in Queensland and by *Ovulariopsis pawpaw* in East Africa. Angular leaf spot, a form of powdery mildew, is linked in Queensland to the fungus *Oidiopsis taurica*. *Corynespora* leaf spot, or brown leaf spot, greasy spot or "pawpaw decline" (spotting of leaves and petioles and defoliation) in St. Croix, Puerto Rico, Florida and Queensland, is caused by *Corynespora cassiicola*, which is controllable with fungicides.

A new pawpaw disease, yellow strap leaf, similar to YSL of chrysanthemums, appeared in Florida during the summer in 1978 and 1979.

Black spot, resulting from infection by *Cercospora pawpawae*, has plagued Hawaiian growers since the winter of 1952-53. It causes defoliation, reduces yield, blemishes the fruit, and is unaffected by the hot-water dip. It can be prevented by field use of fungicides. *Rhizopus oryzae* is most commonly linked with rotting fruits on Pakistan markets. *R. nigricans* is the usual source of fruit rot in Queensland. Injured fruits are prone to fungal rotting caused by *R. stolonifer* and *Phytophthora palmivora*. Stem-end rot occurs when fruits are pulled, not cut, from the plant and the fungus, *Ascochyta caricae*, is permitted entrance. This fungus attacks very young and older fruits in Queensland and also causes trunk rot (Fig. 40 Fungus attack in maradol pawpaw, De los Santos *et al.*, 2000). In South Africa, it affects the cultivar 'Honey Gold' which is also subject to spotting by *Asperisporium caricae* on the fruits and leaves. Both of these diseases are controllable by fungicidal sprays.



**Fig. 40 Fungus attack in maradol pawpaw**

Infection at the apex by *Cladosporium* sp. is manifested by internal blight. A pre-harvest fruit rot caused by *Phomopsis caricae* pawpawae is troublesome in Queensland and was announced from India in 1971. A new disease, pawpaw apical necrosis, caused by a rhabdovirus, was reported in Florida in 1981.

Pawpaws are frequently blemished by a condition called "freckles", of unknown origin; and mysterious hard lumps of varying size and form may be found in ripe fruits. Star spot (grayish-white, star-shaped superficial markings) appears on immature fruits in Queensland after exposure to cold winter winds. In Uttar Pradesh, an algae, *Cephaleuros mycoidea*, often disfigures the fruit surface.

In Brazil, Hawaii and other areas, a fungus, *Botryodiplodia theobromae*, causes severe stem rot and fruit rot. Trichothecium rot (*T. roseum*) is evidenced by sunken spots soon covered by pink mold on fruits in India. Charcoal rot, *Macrophomina phaseoli*, is reported in Pakistan. Young pawpaw seedlings are highly susceptible to damping-off, a disease caused by soil-borne fungi—*Pythium aphanidermatum*, *P. ultimum*, *Phytophthora palmivora*, and *Rhizoctonia* sp.,—especially in warm, humid weather. Pre-planting treatment of the soil is the only means of prevention.

Pawpaws generally do poorly on land previously planted with pawpaws and this is usually the result of soil infestation by *Pythium aphanidermatum* and *Phytophthora palmivora*. Plant refuse from previous plantings should never be incorporated into the soil. Soil fumigation is necessary before replanting pawpaws in the same field (Morton, 1987).

Pests and diseases: Thrips, mites and white flies as well as In red spider and fruit spotting bugs are potential problems in some areas. The plants may also be attacked by mildew, anthracnose (Fig 36 anthracnose in maradol pawpaw), root rot and various virus diseases. Fruit flies often ruin the fruit in Florida and Hawaii. Nematodes can attack the roots and are often a factor in the decline of individual plant. Gopher damage can be avoided by planting in wire baskets. Pawpaw plants should probably be replaced every 4 years or so (CRFG, 1998).

### **c) Insects, Diseases, And Nematodes**

There are three insect pests of pawpaw which can occasionally be damaging in Florida. In order of importance they are: 1) pawpaw fruit fly (*Toxotrypana curvicauda*), the larvae (maggots) feed on the seeds and interior tissues of the fruit. 2) pawpaw webworm (*Homolapalpia dalera*), the worms produce a web around the fruit and stem and feed on the tissue under the web. 3) pawpaw white fly (*Trialeurodes variabilis*), adults and immature stages of this sucking insect feed on the underside of the younger leaves. Sooty mold, a black mildew, which grows on the excretions of the whitefly, is often associated with infestations.

The major fungus diseases in Florida are: 1) Anthracnose (*Colletotrichum gleosporioides*), together with other fungus rots (Table 8), may cause considerable spoilage of the fruit, particularly during rainy weather. 2) Powdery mildew (*Oidium* spp.) is recognized by the whitish mildew growth on leaves and on stems of seedlings and can be troublesome during the winter and spring. For more information and current control recommendations, please contact your local County Agricultural Extension Agent.

Nematodes, such as root-knot, can be very damaging to pawpaws, particularly in sandy soils (Fig 41 Pawpaw "Mayate prieto" worm, De Los Santos *et al.*, 2000). Since effective chemical control is difficult and very costly, the homeowner should try preventive measures such as rotating planting sites, or maintaining plants in the most vigorous condition possible. Mulching helps plants withstand nematode attack under some conditions (Malo, 2001).





**Fig. 41 Pawpaw "Mayate prieto" worm**

### **3.2 Pest Control**

#### **a) Control**

Remove infected plants as soon as these are detected. Regular inspection and roguing can contain the disease in many instances.

A quarantine area was proclaimed in 1991 in an effort to restrict the movement of pawpaw ringspot. Pawpaw plants and cucurbit seedlings are not able to be moved out of south-east Queensland without written approval of an inspector.

Within south-east Queensland do not move seedling pawpaw or cucurbit plants from a property where pawpaw ringspot is known to occur (Persley, 2002).

Table 8 Diseases, symptoms and control measures in pawpaw fruits.

#### **b) Physiological and Physical Disorders**

**Skin abrasions** result in blotchy coloration such as green islands (areas of skin that remain green and sunken when the fruit is fully-ripe) and accelerate water loss. Abrasion and puncture injuries are more important than impact injury for pawpaw.

**Chilling injury** symptoms include pitting, blotchy coloration, uneven ripening, skin scald, hard core (hard areas in the flesh around the vascular bundles), water soaking of tissues, and increased susceptibility to decay. Increased alternaria rot was observed in mature-green pawpaws kept for 4 days at 2°C, 6 days at 5°C, 10 days at 7.5°C, or 14 days at 10°C. Susceptibility to chilling injury varies among cultivars and is greater in mature- green than ripe pawpaws (10 vs. 17 days at 2°C; 20 vs. 26 days at 7.5°C).

**Heat injury** Exposure of pawpaws to temperatures above 30°C (86°F) for longer than 10 days or to temperature-time combinations beyond those needed for decay and/or insect control result in heat injury (uneven ripening, blotchy ripening, poor colour, abnormal softening, surface pitting, accelerated decay). Quick cooling to 13°C (55°F) after heat treatments minimizes heat injury (Kader, 2000).

## **4 Economic and Social Considerations**

### **4.1 Gender aspects:**

#### ***Role of the men and women in post harvest operations***

A study of the role of women in postharvest handling and marketing of banana and pawpaw was conducted in Lampung, West Java and Jakarta provinces of Indonesia from Aug. to Sept. 1992. 52 farmer families, 20 fruit traders and 5 processing companies were selected using purposive stratified random sampling. The study observed the contribution of women in decision making, farming and gathering income. Women played no major role in postharvest handling and marketing but a significant role in processing companies. Daily wages for women labourers were lower than those for men due to differences in jobs and productivity. There were no differences between male and female permanent staff monthly salaries. The main constraints women faced were lack of appropriate technology, knowledge and skills. Women's roles could change if they developed skills in the use of new technology.

Cottage agro-industries in Dominica are based on citrus, bananas, soya beans, sorrel, spices, cocoa beans, herbs Spices and fruits like pawpaw. The total numbers of industries have declined over the past five years due to migration of persons involved. However, the operating industries are functioning satisfactorily. Cottage industries are created in different ways: private entrepreneurs with processing ideas and capital; cooperative groups initiated by governments departments, e.g Youth Development Division and Women's Bureau. Marketing is usually done directly by the processors to retail outlets all over the island. The products like crystalized pawpaw fruit processed by a male cooperative group, are sold in supermarkets, small shops and stores (in various parts of Dominica), and in tourist stalls and booths. (FAO, 1992).

The Government of El Salvador it called on the principal public agricultural research organization, the National Center for Agricultural Technology (Spanish acronym: CENTA), and CENTA worked on establish a gender program at headquarters to review proposed projects from a gender perspective. The gender program was very successful in bringing woman farmers closer to CENTA's work, specially in marketing pawpaw and banana (sold in town). (ISNAR, 2002).

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## 6 GLOSSARY (List of Terms)

%	percent.
m	meter.
cm	centimeter.
in	inch.
FADH	forced air dry heat.
VH	vapor heat.
ft	feet.
ppm	parts per million.
g	gram.
kg	kilograms.
MT	metric tons.
lbs	pounds.
lbs/in <sup>2</sup>	pounds per square inches.
lb/ft <sup>2</sup>	pounds per square foot.
ml	milliliter.
°C	degrees Celcius.
gals	gallons.
oz	ounce.
°F	degrees Farenheit.
ha's	hectares.
m	meters.
l litres.	litres.
Ton/ha	tones per hectares.
H	hours.
\$/kg	US dollars/Kilograms.
min	minutes.
Fig	Figure.
USA	United States of America.
\$	US dollars.

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