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A COMPREHENSIVE STUDY ON PAPAYA CULTIVATION: A REVIEW

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ABSTRACT

The papaya, or *Carica papaya*, is a tropical fruit that is well-known for both its economic and nutritional importance. With its many health benefits and ability to thrive in warm climates, papaya is a useful fruit crop with substantial nutritional, medical, and economic significance. Originally from southern Mexico and Central America, it is currently grown in tropical and subtropical climates all over the world. Papaya, which is high in vitamins A and C and the enzyme papain, helps with digestion, strengthens the immune system, and supports healthy skin. The fruit can be eaten raw, in juices, or as a component of savoury salads and other cuisines. Papaya is an economically and nutritionally beneficial fruit since its seeds and leaves can also be used medicinally. Understanding a number of variables, including as climate, soil composition, propagation techniques, managing pests and diseases and post-harvest procedures, is essential to papaya cultivation. An extensive summary of papaya cultivation is provided in this article.

Key words : Papaya, Papain, Cultivation, Importance, Post-harvest.

Introduction

Papaya (*Carica papaya*) is a tropical tree that grows quickly and is grown for its fruit, papain, pectin, and antibacterial properties (Niklas and Marler, 2007). Papaya is now widely grown in lowland tropical and subtropical areas worldwide. A popular fruit, papaya is often referred to as papita or melon tree. Papaya plants have strongly lobed leaves and are herbaceous, evergreen plants. Fruits, which are typically spherical to oblong in shape and have a central cavity where many seeds are attached to the placenta, are formed from the axils of leaves. Depending on the cultivar, the flesh colour changes to either yellow, orange, or red as it ripens. A year-round climacteric fruit, papayas are long berries of different diameters with smooth, thin skin and a greenish-yellow hue (Calegario *et al*., 1997, Fuggate *et al*., 2010).

Papaya is the third most grown tropical crop globally. Mexico is the primary exporter of papaya, while Brazil and India are the world's greatest producers (Evans and Ballen, 2012). Papaya trees grown under cultivation reach maturity 9–12 months after planting, demonstrating their rapid growth. Commercially, a tree density of 1,500–2,500 per hectare can provide between 125,000 and 300,000 pounds annually (Gonsalves, 1998). Additionally, papaya fruits, stems, leave, and roots are utilised to produce papain and for a variety of medical purposes (Ming *et al*., 2008). Papain is produced commercially for use in beer brewing, protein digestion (primarily as a tenderiser for red meat), and the treatment of scars and warts on the skin (Ming *et al*., 2012). Papaya is extensively grown

in tropical home gardens due to its quick growth, constant harvest and variety of uses (Manshardt, 1992). The most economically significant species in the Caricaceae family is the carica papaya (Carvalho and Renner, 2012). According to Huerta-Ocampo *et al*. (2012), papayas rank first among common fruits in terms of their nutritional content, including the proportion of vitamin A, vitamin C, potassium, folate, niacin, thiamine, riboflavin, iron and calcium and fibre. It is rich in nutrients and has therapeutic benefits. Papaya is also known to have large levels of pectin, alkaloids (carpaine) and proteolytic enzymes, all of which have numerous industrial applications. Ripe fruit has diuretic, carminative, digestive, and stomachic properties. Green fruit has ecbolic qualities and is a mild diuretic and lexative. Papaya roots function as a generative tonic, while leaves can help with nerve pain. Papain, which is made from the dried latex of its immature fruits, is used to soften meat, make chewing gum, make cosmetics, degum natural silk, and make wool resistant to shrinkage. Additionally, it is employed in the manufacturing of cleaning paper and adhesives for textiles and clothing, pharmaceuticals, sewage disposal, etc.

Origin

The papaya tree (*Carica papaya* L.) was first mentioned in Europe in 1535 by the Spanish writer G. H. de Oviedo, who told the King of Spain that papayas were discovered growing between the south of Mexico and the north of Nicaragua in his book "La natural hystoria de las Indias." It is thought that the first seeds were transported from this area to portions of South America, Panama, Santo Domingo and some Caribbean islands (De Candolle reported by Lassoudiére, 1968). It is thought that papaya originated in Mesoamerica, specifically in areas that included Central America and southern Mexico (Vavilov, 1926; Storey, 1976). The cultivation of papayas originated in Costa Rica and South Mexico. In India, papaya was introduced in early part of 16th century from Philippines through Malaysia (Schroender, 1958). The long history of the papaya illustrates its development from a native crop in Mesoamerica to a significant fruit crop on a worldwide scale.

Papaya cultivation worldwide

Nearly every nation in the tropical Americas—Central and South America, as well as the state of Hawaii—grows papaya. In addition, it is grown in the Antilles, tropical Africa, India, Sri Lanka, and other Asian nations (Chan and Paull, 2008). As the world's largest producer, Brazil supplies 25% of the global demand, followed by Mexico (14%), Nigeria (11%), India, and Indonesia (10%). Other countries that grow papayas include Venezuela, China, Peru, Congo and Ethiopia, but their combined contributions to the papaya supply are less than 3% (Benassi, 2010). According to FAOSTAT (2010), Brazil is the third-largest exporter of papayas worldwide, with the United States and Europe being the main consumer markets.

Papaya cultivation in India

The world's largest papaya producer is India. Papaya is widely grown in Karnataka, Uttar Pradesh, Assam, Gujarat, Maharashtra, Bihar, Orissa and West Bengal in addition to Tamil Nadu, Andhra Pradesh, Madhya Pradesh, Manipur and Meghalaya. The terai region, Kimpur, Dehradun, Varanasi, Sultanpur, Jaunpur and Meerut districts of Uttar Pradesh are the main locations for papaya cultivation. There are significant concentrations in the districts of Midnapore, 24-paraganas, Murshidabad and Nadia in West Bengal. Papaya is grown commercially in the districts of Ranchi, Santhal Pargana, Muzaffarpur, Samastipur and Vaishali in Bihar, as well as Ahmednagar, Pune, Satara, Aurangabad and Jalagaon in Maharashtra. It is grown as a rainfed crop in Assam's high rainfall regions, but irrigation is necessary for good output in other regions of the nation.

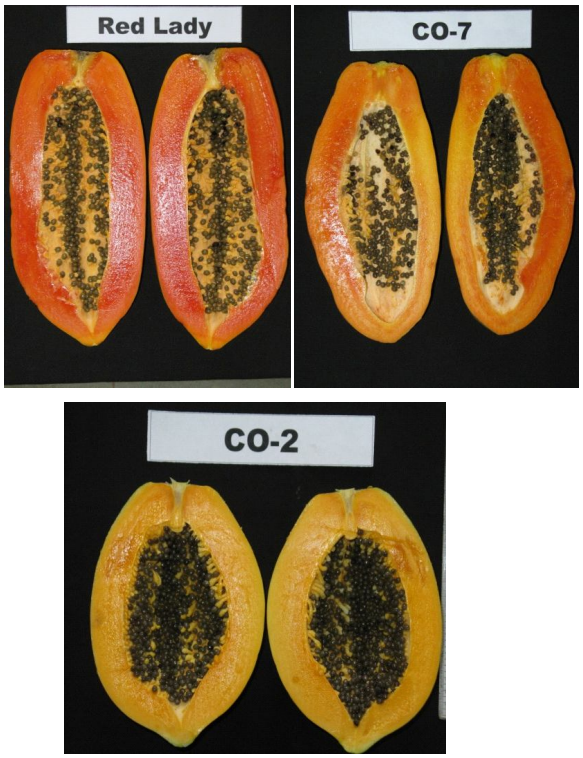

Fig. 1 : Different cultivars of papaya (https://ccari.icar.gov.in/dss/papaya.html).

Papaya Propagation Techniques

Commercial papayas are grown from seeds. Since seeds lose their viability after 45 days, it is best to utilize

fresh seeds for developing seedlings. To promote healthy germination, wood ash should be applied to the seed to remove the mucilaginous layer. It could take 3–5 weeks for germination to occur. Washing off the aril speeds it up to two or three weeks and increases the germination rate. After that, the seeds must be dried and covered with fungicide to prevent damping-off, a frequent seedling disease. The germination rate can be increased by dipping for 15 seconds in hot water at 70° C and then soaking in distilled water for 24 hours after being taken out of storage. To prevent frost damage during fruiting, the seeds should be sown during the second week of January to February. Papaya is normally propagated by seeds although propagation through cuttings or budding has been found successful (Bhuva, 1979; Mazumder,1988; Ram *et al.*, 1988; Singh *et al.*, 1986). By reduction of latex through storing in humid conditions and treatment with solution of IBA and NAA, rooting is promoted (Bhuva, 1979; Mazumder, 1988). Success in rooting is also enhanced by cincturing (Ram *et al.*, 1988). Patch budding on vigorous seedlings during June-August was found to be most successful (Singh *et al.*, 1986).

Varieties

To improve fruit quality, disease resistance, and productivity, many papaya cultivars have been created. At various locations throughout the nation, a number of papaya varietals have been developed. In 1971, the gynodioecious cultivar Coorg Honey Dew was chosen from Variety Honey Dew (Madhubindu) at Citrus Experiment Station, Chethalli. It was kept pure by cultivating in isolation (Aiyappa and Nanjappa, 1959). Six varieties of papaya have been released as a result of papaya breeding efforts at TNAU, Coimbatore. Co.1, Co.2, Co.5 and Co.6 are the four inbred selections. Ranchi's selections are likewise included in Co.1 (Ram, 1983).

In papaya, selection followed by in-breeding has been used extensively to improve cultivars, and inbreeding depression is not seen, in contrast to other cross-pollinated crops. Eight generations of inbreeding and selection between 1966 and 1982 produced robust and consistent Pusa lines, including Delicious, Pusa Majesty, Pusa Giant, and Pusa Dwarf. While, the latter two are dioecious, the former two are gynodioecious. In terms of papain yield, Pusa Majesty is similar to Co.2 and has been shown to be extremely resistant to the root-knot nematode (Reddy *et al.*, 1988). High-yielding cultivars like Arka Prabhat have been produced by the Indian Institute of Horticultural Research (IIHR). For cultivation to be effective, the right types must be chosen based on market demand and local climate circumstances. Commercial cultivars such as Coorg Honey Dew, Washington, Pusa Delicious, Pusa Dwarf, Solo, Zinta, Red lady, Surya and others are grown in northeastern states and in India.

Cultivation Practices of Papaya

Papaya (*Carica papaya*) is a tropical fruit having commercial importance because of its high nutritive and medicinal value. Cultivating papaya requires understanding various factors, including climate, soil conditions, propagation methods, pest and disease management, and post-harvest practices.

Agro-climatic requirements

As a tropical fruit, papaya thrives in the country's warm subtropical climates up to 1,000 meters above sea level. It grows well in regions where summer temperature ranges from 35°C - 38°C. Well drained soils of uniform texture are highly preferable to avoid the collar rot disease. The growth and output are significantly impacted by nighttime temperatures that fall below 120 to 140 degrees Celsius for many hours throughout the winter. It is extremely vulnerable to water stagnation, severe winds, and frost. Tolerates frost and comes up to an elevation of 1200 m above mean sea level. The best soil for papaya growing is deep, well-drained sandy loam.

Land preparation

A well-drained upland is chosen for farming. Plants are exposed to severe winds or storms in open, high-lying locations. Therefore, an appropriate wind break should be established at the orchard boundary in order to properly construct a papaya plantation.

Planting material

Commercial papayas are grown from seeds and tissue cultures. 250–300 g of seed per hectare is the rate. The seedlings can be grown in pots or polythene bags, or on nursery beds that are 3 meters long, 1 metre wide, and 10 centimetres high. The seeds are sowed 1 cm deep in rows 10 cm apart after being treated with 0.1% Monosan (phenyl mercuric acetate), ceresan, etc., and then covered with fine compost or leaf mould. In the morning, there is some light watering. The nursery beds are covered with polythene sheets or dried paddy straw to protect the seedlings. In roughly two months, seedlings that are 15–20 cm tall are selected for planting.

Planting season

Papaya is planted during spring (February-March), monsoon (June-July) and autumn (October-November).

Spacing

A spacing of 1.8 × 1.8 m is normally followed.

However, higher density cultivation with spacing of 1.5 × 1.5 m./ha enhances the returns to the farmer and is recommended. A closer spacing of 1.2 × 1.2 m. for cv. Pusha Nanha is adopted for high density planting, accommodating 6,400 plants/ha.

Planting method

The seedlings are placed in pits that measure 60 by 60 by 60 cm. The pits are excavated around two weeks prior to planting during the summer. In addition to 20 kg of farmyard manure, 1 kg of neem cake and 1 kg of bone meal, the pits are filled with top soil. Medium and dwarf kinds are planted closer together, whereas tall and strong varieties are placed farther apart. For dwarf variety: 1.2 × 1.2 m, seedlings of 35-40 days age are transplanted into pits. Proper staking with bamboo poles is essential to avoid lodging. Mulching of basin and thatching with coconut leaves are essential practices to be followed.

Nutrition

Papaya plants require high fertilizer and manure dosages. For a good yield, 200–250 g of N, P_2O_5 and K_2O are advised in addition to the basic dose of manures (10 kg/plant) placed in the pits. The ideal amount of nitrogen to apply is 200 g, however papain output rises as N levels rise to 300 g. Apply 10 litres of water per day + 13.5 g urea and 10.5 g muriate of potash/ week through drip irrigation and soil application of super phosphate 300g per plant at bimonthly intervals starting from 3-4 months after planting immediately after thinning of plants is recommended. $ZnSO_4$ (0.5%) and H_2BO_3 (0.1%) are micronutrients that are sprayed to improve growth and yield characteristics.

Irrigation

The kind of soil and local weather are taken into consideration while determining the watering schedule. During the initial planting year, protective irrigation is offered. In the second year, irrigation is given every two weeks in the winter and every ten days in the summer. Most people use the basin irrigation system. Sprinkler or drip systems can be implemented in regions with little rainfall.

Intercultural Operations

To monitor weed growth in the first year, deep hoeing is advised. Regular weeding is necessary, especially in the vicinity of plants. Two months after transplanting, a pre-emergence herbicide application of fluchloralin, alachlorin, or butachlorine (2.0 g/ha) can effectively control the weeds for four months. In order to help the plants, stand upright and prevent water-logging, earthing up is done either before or after the monsoon season begins.

Inter-cropping

Intercropping leguminous crops after non-leguminous ones, shallow rooted crops after deep rooted ones are beneficial. No intercrops are taken after the onset of flowering stage.

Removal of male plants

In orchards where dioecious types are grown, roughly 10% of the male plants are retained for optimal pollination. The excess male plants are pulled as soon as the plants begin to blossom.

Plant Protection Measures

Insect pests

Production and productivity of papaya is affected by insect, pests, nematodes and diseases, and intensity of damage depends upon agro-ecological regions. Many insect pests have been identified on papaya (Butani, 1975) but only a few causes serious damage and their incidence is also localized. Mites cause the damage by feeding on leaves and fruits. Occurrence of fruitfly is also recorded which causes pre-mature shedding of fruits. But systematic information's on insect pests of papaya in different regions, extent of damage and population dynamics are lacking. Different species of aphids are also reported on papaya which cause more losses as vector than the pest. The insect pests mostly observed are fruit flies (*Bactrocera cucurbitae*), ak grasshopper (*Poekilocerus pictus*), aphids (*Aphis gossypii*), red spider mite (*Tetranychus cinnabarinus*), stem borer (*Dasyses rugosellus*) and grey weevil (*Myllocerus viridans*).

The papaya mealybug (*Paracoccus marginatus*), which consumes plant sap and results in yellowing, leaf curling, and stunted growth, is one of the most damaging pests. Fruit flies (*Bactrocera* spp.) are another significant pest; they lay their eggs in fruit, causing infestations of larvae and rendering the product unsellable. Additionally prevalent are red spider mites (*Tetranychus* spp.), which discolour leaves and cause early defoliation. Furthermore, *Dasyses rugosella*, the stem borer, weakens the plant by damaging the stem and interfering with nutrient transport. To reduce losses and guarantee healthy papaya production, effective management through integrated pest control—such as biological control agents, neem-based products, and sound agricultural practices—is crucial. In all cases the infected parts need to be destroyed along with application of prophylactic sprays of Dimethoate (0.3%) or methyl demeton (0.05%).

Papaya diseases

A number of illnesses that can seriously affect papaya's growth and yield are common. One of the most destructive infections is Papaya Ringspot Virus (PRSV), which manifests as yellowing, stunted development, leaf mottling and the distinctive ring-shaped spots on fruits. Fruit quality is impacted by anthracnose, which is brought on by *Colletotrichum gloeosporioides* and causes tiny, water-soaked lesions on fruits that become black and sunken. *Oidium caricae* is the causative agent of powdery mildew, a white, powdery fungal growth on plants that causes defoliation and decreased photosynthesis. A major problem in wet settings is Phytophthora Blight, which is produced by *Phytophthora palmivora* and causes root rot, damping-off, stem lesions, and rapid plant decline. *Asperisporium caricae* is the source of Black Spot, which results in tiny, black, angular dots on leaves and fruits that detract from their marketability. To lessen these difficulties, effective disease control using resistant cultivars, hygienic field practices, and prompt fungicide administration are crucial. It has been discovered that the infections can be effectively controlled by applying wettable sulphur (1 g/l), carbendazim/thiophanate methyl (1 g/l) and Kavach/Mancozeb (2 g/l).

Harvesting and Yield

When the fruit reaches full size and is light green with a hint of yellow at the apical end, it is harvested. Some types of fruits turn yellow as they ripen, while others stay green. The fruits are ready to be picked when the latex stops being milky and turns watery. The papaya plant only lasts three to four years economically. The production varies greatly depending on the orchard's management, climate, soil and variety. Depending on spacing and cultural customs, a papaya orchard can generate 75–100 tonnes/ha in a season.

Post Harvest Management

Grading

Fruits are graded on the basis of their weight, size and colour.

Storage

Papaya, being highly perishable fruit, needs extended storge life which can be obtained by storing at low temperature or by use of ripening retardants. Papaya fruits at colour can be stored at 7°C and will have normal ripening. But the fruits at colour breaking stage will not ripen normally if stored at 7°C and need the temperature of 12 to 13°C for storge to attain ripening after storage. Shelf life of fruit is also extended by storing at 13°C with 1.0 to 1.5 per cent oxygen or at 10 per cent CO_2. Waxing of fruit and storage under low pressure (LP) has also been found successful in reducing the disease incidence, and increasing the shelf life of papaya. Careful post-harvest handling of fruit is essential to minimize the losses.

Packing

Bamboo baskets with banana leaves as lining material are used for carrying the produce from farm to local market. Mishandling of fruits during harvesting, treatments and packing results in bruised fruit. Bruised fruits develop abnormal discoloration which begins to manifest as fruit ripens. Such fruits are unattractive and prone to attack of post-harvest diseases. Normally, fruits sent for distant markets are wrapped with newspaper and packed in wooden or cardboard boxes.

Transportation

Due to its ease of access from orchards to the market, road transport by trucks or lorries is the most practical means of transportation.

Marketing

The farmers usually dispose off their produce to the wholesalers and middlemen at the farm gate.

Processing of Papaya

A variety of papaya-based processed items have been created, including canned papaya, papaya cake, papaya burfi, papaya sweets, papaya jam, papaya halwa, papaya chutney and papaya beverages. The papaya juice produced at TNAU, Coimbatore is ready to serve and has the potential to be processed commercially. Papaya candy, also known as tooty fruity, is one of the processed goods that has been commercially exploited. It is made in huge quantities by domestic factories in Bangalore, Coimbatore, and Jalagaon. Bakeries and other food sectors are becoming more and more interested in the product.

A good way to obtain pectin is papaya. Lanced fruits, which are used to extract papain, can also be used to extract complex carbohydrates, primarily galacturonic acid (Biswas *et al*. 1969), and pectin (Singh, 1959). Pectin is also being used more often in a variety of food preparations. It is also utilized as an emulsifying agent and flavouring extract. Pectin has numerous industrial applications as well. Papaya pectin is mostly extracted from green fruits using hydrochloric acid. Alcohol precipitates the extract, which is then cooled, filtered, concentrated, separated, and dried (Datta, 1967). Carpaine can also be extracted from green leaves.

Papain extraction

The most significant of papain's many industrial

applications is in the brewing sector. It is utilized in medications, textile and leather "sanforization" procedures, and as a "meat tenderizer". Papain may be extracted from papaya fruits using a straightforward process. The immature papaya fruits should be tapped to extract the latex. Choose fruits that are 75 to 90 days old. Make cuts (incisions) on the chosen fruit using a stainless-steel knife or razor blade. The cuts ought to be made from the fruit's stem to its tip. The maximum depth of the cut should be 0.3 cm. On the fruit's surface, four similar slices are made, evenly spaced apart. Start tapping the latex early in the morning and finish it by 10:00 a.m. The same fruit should be tapped four times, separated by three days. The cut ought to be made on the fruit's surface where no prior cuts have occurred. To eliminate any foreign material, the latex collected from every tree in a given day should be put together, shade-dried in an aluminum pan or tray, and then run through a 50-mesh sieve. Large plantations can benefit from the use of vacuum driers. Artificially heated papain will be higher grade and have a better hue. A 0.5% addition of potassium meta-bi-sulphite (KMS) will improve colour and storage quality.

At temperatures between 50° and 55°C, the latex should be cured extremely quickly. When the dried product separates into porous-textured flakes, stop drying. Using wooden mallets or electrically powered granulators, grind the dried papain into a powder and then strain it through a 10-mesh screen. In convenient amounts, place the powder in plastic bags and seal them. After removing the air, place the wrapped bags in a tin container and close it. Because papain loses quality when exposed to air, airtight sealing is required. A granulator and vacuum sealing equipment will be helpful for the large-scale production of papain. After papain is extracted, the green papaya fruits can be used to make pectin and "tutty-fruity," or they can be left to ripen and utilized to make other goods. The development of cultivars that yield a high amount of papain, the timing and stage of latex collection, and papain processing and preservation have all been attempted (53, 60, 96, 106, 108, 128-131). Papain yield is influenced by plant nutrition, tapping time, and cultivar. Co-2 has been determined to be the most effective for papain yield based on the examination of numerous cultivars (Rao *et al.*, 1974). According to reports, two cultivars—Co-5 and Co-6—created at Tamil Nadu Agricultural University in Coimbatore are better than Co-2 (Anonymous, 1991). It has also been discovered that Pusa Majesty is ideal for the manufacture of papain. Rahuri Co-2 and Pusa Majesty outperformed other cultivars in an MPAU experiment, and these cultivars also showed increased enzyme activity. Papain yield improved as fruit age evolved, peaking between 60 and 75 days, after which it declined, and fruit growth is unaffected by lacing (Singh and Tripathi, 1957). The ideal fruit stage for lacing in Tamil Nadu was determined to be between 70 and 110 days after fruit set, and there was a negative correlation between the mean maximum temperature and the latex output (Seemanthani and Balakrishnan, 1964). Depending on the cultivar, papain yield ranges from 5 to 8 g per fruit. For papain yield in the Co-6 cultivar, 1.6 x 1.6 m spacing and 300 gN treatment were determined to be ideal. Attempts to use ethephon to improve latex yield have also been made (Bhattacharya and Rao, 1970; Chacko *et al.*, 1972 and Shanmugavelu *et al.*, 1976), but the results are not very useful for commercial application.

Factors limiting production and productivity in India

The nation's papaya output and productivity are influenced by a number of factors. The most significant of these are:

- Insufficient production of superior cultivars' genetically pure seeds.
- Insufficient disease-resistant and high-yielding cultivars for both the domestic and international markets.
- Insufficient knowledge about commercial tissue culture propagation
- Insufficient knowledge about production technologies, including irrigation, fertilization, and orchard management.
- Insufficient viral management techniques and a lack of virus disease-resistant types.
- Inadequate facilities for marketing, transportation, and storage.
- Inadequate post-harvest handling knowledge and insufficient fruit processing use.

Importance of Papaya Cultivation

The papaya is a tropical fruit with a rich nutritional profile and numerous health benefits. It offers more than the recommended daily intake of vitamins A and C, which are essential for strong immune function and good skin. Papaya contains an enzyme called papain, which has anti-inflammatory and protein-breaking properties. Regular papaya consumption can boost general wellbeing, support digestive health and strengthen immunity. High in fibre and potassium, which lower blood pressure and cholesterol. Vitamins A and C are antioxidants that increase skin suppleness and minimize wrinkles (Adebiyi

et al., 2002).

In India, papaya farming is very important since it supports the country's industrial uses, agricultural economy, and nutritional security. With an estimated 5.3 million tonnes produced annually in 2022, India is the world's largest producer and contributes more than 38% of the world's papaya production (FAOSTAT,2024). The nation's warm, humid environment, which offers perfect growing conditions all year round, makes this significant production possible. A fruit with many uses, papayas are praised for their taste, nutritional content, and health advantages. It is essential to traditional medicine, nutrition, and agriculture worldwide. Papaya is a sign of prosperity and health in certain cultures. In tropical nations, the fruit is frequently offered during religious events.

Conclusion

A fruit with many uses, papayas are praised for their taste, nutritional content and health advantages. It is essential to traditional medicine, nutrition and agriculture worldwide. Growing papayas can be profitable, particularly if better cultivating techniques and superior cultivars are used. According to profitability studies, including those carried out in greenhouse environments, papaya can be a profitable crop when grown in the right conditions. The introduction of high-yielding cultivars, production technologies, and efficient pest and disease management techniques have all contributed to a significant rise in papaya production and productivity. Papaya usage, both as a fresh and processed product, has been trending significantly. In order to attain high production, papaya research is anticipated to be expanded by appropriate fortification of existing infrastructure. A concentrated effort is needed to increase the export of papain and processed papaya products. Selecting appropriate cultivars, comprehending environmental needs, putting into practice efficient pest and disease management techniques, and using appropriate post-harvest procedures are all essential to successful papaya farming. Productivity and profitability can be further increased by implementing cutting-edge cultivation methods and keeping up with research advancements.

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