



Research status for technological development of jamun (*Syzygium cumini*) in India: A review

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Received: 01 March 2019; Accepted: 07 June 2019

ABSTRACT

Jamun, *Syzygium cumini* (L.) Skeels, belonging to the family Myrtaceae, is an important underexploited indigenous fruit with a wide distribution reflecting its adaptation to wide range of edapho-climatic conditions. It is an important fruit owing to its nutritional, therapeutical, postharvest and industrial values. In a bid for better utilization and improvement of the current genetic resources, there is a need to understand the studies on center of origin and diversity, characterization, conservation, taxonomy and systematic phenology, floral biology and pollination. In this review, basic biology of jamun plant, agro-techniques, propagation, canopy architecture, insect pests, and disease and their management have been covered.

Key words: Jamun, Myrtaceae, Semi-arid and arid zone, Underutilized fruits

Jamun (*Syzygium cumini* (L.) Skeels) is a fruit bearing tree of Indian origin. It is also known by other common names like jambul, black plum, java plum, Indian blackberry etc. (Ali *et al.* 2013). It is found naturally growing in Thailand, Philippines, Madagaskar and it has been successfully introduced in many other tropical countries including West Indies, California, Algeria and Israel. In India, jamun trees are found scattered throughout tropical and sub-tropical regions and in certain pockets of the lower Himalayan ranges up to an elevation of 1600 m. (Mishra *et al.* 2014). The tree is thought to be of prehistoric introduction into the Philippines where it is widely planted and naturalized. Jamun was introduced through seeds from Philippines to Florida for ornamental purpose (Singh *et al.* 2011, Singh 2006). Jamun trees flourish in California, especially in the vicinity of Santa Barbara. In Southern Florida, the tree was commonly planted in the past. In Hawaii, fruiting is profuse but only a small portion of the crop is consumed locally (Singh *et al.* 2011). It is mostly available in tropical and subtropical parts of the world. It is one of the most hardy fruit crops and can easily be grown even in marshy areas where other fruits fail to establish (Singh *et al.* 2007e). However, it thrives on well drained laterite soils of west coast of India. It also grows well in sandy loam and black cotton soils. It also grows in the ravines and degraded

lands and on lands having shallow water tables (Singh *et al.* 2011). It grows well in semi-arid regions having annual rainfall of about 500 mm. Jamun requires dry weather at the time of flowering and fruit setting (Singh *et al.* 2009 and Singh *et al.* 2016). In sub-tropical areas, early rains are considered beneficial for proper fruiting and colour development (Singh *et al.* 2011).

IMPORTANCE, USES AND MEDICINAL SIGNIFICANCE

Jamun, a multipurpose tree, has various phytotherapeutic and pharmacological uses (Stephen 2012). The fruit is a good source of iron, sugars, minerals, proteins, carbohydrates etc. Fully ripe fruits are eaten fresh and can be processed into beverages like jelly, jam, squash, wine and vinegar. The fruit has a sub-acidic spicy flavour and makes a very refreshing squash. A little quantity of fruit syrup is useful in curing diarrhoea. Vinegar made of juice extracted from slightly unripe fruit is stomachic, carminative, diuretic, cooling and digestive. Small fruits that are unfit for table use but rich in acids, tannins and anthocyanins can be processed into beverages (Singh *et al.* 2011). Fruits are used as an effective medicine against diabetes, heart and liver troubles (Singh 2006). Different parts of the jamun especially fruits, seeds and stem bark possess activities like antidiabetic, antihyperglycemic, antileishmanial, antifungal, anti-inflammatory, neuropsychopharmacological, antimicrobial, antibacterial, radio-protective, gastro-protective, antifertility, anorexigenic, antidiarrheal, ulcerogenic and anti-HIV and it has been confirmed by several clinical studies (Benherlal and Arumughan 2007, Jung *et al.* 2008, Mohanty and Cock

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2010, Murugan *et al.* 2011, Baliga *et al.* 2011, Sagraw *et al.* 2006, Adelia *et al.* 2011, Kumar *et al.* 2009). Glucose and fructose are the principal sugars in the ripe fruits; sucrose is completely absent. Malic acid is the major acid (0.59%); a small quantity of oxalic acid is also present. Gallic acid and tannins impart astringency to the fruits. The blossoms are important source of honey from *Apis dorsata* in North India (Singh *et al.* 2010b). Three triterpenoids are reported to be present in the flowers, viz. acetyl oleanolic acid, eugenia-triterpenoid A and eugenia-tritetrapeniod B. Jamun flowers also contain ellagic acid along with following flavonoids : isoquercitrin, quercetin, kaempferol and myricetin (Adelia *et al.* 2011). Jamun fruits contain fair amount of minerals (Ca, K), vitamin (B-complex, vitamin C) and amino acid (alanine, arginine, aspergine). The major anthocyanins are delphinidin and petunidin, whereas malvidine, peonidin and cyanidin are present in small proportions (Singh *et al.* 2011). Three esters, dihydrocarvylacetate, geranyl butyrate and terpinylvalerate are likely to be responsible for the characteristic flavour of the fruit. The antioxidant activity is attributed to presence of vitamins, tannin and anthocyanins (Singh and Singh 2006). Seeds contain crude protein (8.5%), crude fiber (16.9%), ash (21.72%), Ca (0.41%) and P (0.17%). Powdered seeds are quite useful in the treatment of diabetes (Singh *et al.* 2010b, Singh *et al.* 2011). Patel *et al.* (2005) and Singh *et al.* (2019) mentioned that seeds contained an alkaloid jambosin and glycosides jambolin, antimellin, which reduce the diastatic conversion of starch into sugars. Nutritive value of Jamun fruit is given in Table 1.

At CISH, Lucknow, the maximum antioxidant value was observed in accession CISH J-35 (1798.65 µg/ml AEAC unit) while least in CISH J-32 (828.45 µg/ml AEAC unit). The maximum antioxidant capacity (1870.8 µg/ml AEAC unit) was observed in CISH J-26. The maximum total carotenoids were present in CISH J-28 (63.1 µg/100ml) and minimum (4.2 µg/100ml) in CISH J-24. The phenol

content ranged from the maximum of 16.7 mg/100 ml in CISH J-38 to a minimum of 4.0 mg/100ml in CISH J-33. The flavonoid content varied from 0.41 to 2.7 mg/100ml in CISH J-24 and CISH J-27 respectively (Singh *et al.* 2010b, Singh *et al.* 2007e).

Morphology, reproductive biology, cytogenetics, pollination and pollinators

Taxonomy: Jamun belongs to the genus *Syzygium* of the family Myrtaceae having chromosome number $2n=40$. There are about 400–500 species, of which a few produce edible fruits. *Syzygium cumini* is a long lived large and evergreen tree attaining height up to 25–30 m and it's the main species of commercial interest in India. *S. alternifolium* (Wight) Walp. syn. *Eugenia alternifolia* Wight, a moderate-sized or large tree is found in Assam, Andhra Pradesh and Tamil Nadu. *S. aqueum* (Burm. f.) Alston syn. *Eugenia aquea* Burm.f. is a much branched tree, found up to an altitude of 1350 m in Assam and Meghalaya and cultivated in Bengal. *S. aromaticum* (Linn.) Merrill & Perry. syn. *Caryophyllus aromaticus* Linn. is a conical evergreen tree, 9–12 m in height. *S. bracteatum* (Willd.) Raizada syn. *Eugenia bracteata* Roxb., a shrub or small tree, is found in Arunachal Pradesh, Assam, Meghalaya and Tamil Nadu. *S. malaccense* (Linn.) Merrill and Perry. (syn. *Eugenia malaccensis* Linn.) a large, shrub sized tree with nearly straight trunk and densely foliated crown, is cultivated chiefly in the gardens in Bengal and South India. *Syzygium samarangense* (Blume.) Merrill & Perry. syn. *Eugenia javanica* Lam., a 5–15 m tall tree, with low branched trunk and widely branched crown, is found in the Andaman and Nicobar Islands. *S. jambos* (Linn.) Alston. (syn. *Eugenia jambos* Linn.) also known as rose apple is an ornamental species. The fruits are light yellow-white and rose scented with persistent calyx. The seeds are polyembryonic and it is being grown in Assam, Bihar, Andhra Pradesh, Tamil Nadu, West Bengal, Coastal areas of Maharashtra and Gujarat. *S. fruitecosum* (Roxb.) DC is medium sized and evergreen tree. It is suitable for windbreak. Fruits are edible and small in size. *S. densiflorum*, trees are medium sized and evergreen. It is a suitable rootstock for jamun as it is resistant to attack of termites. *S. uniflora* Linn. (Surinam cherry or Pitanga cherry), a small tree and bears small-sized fruits having bright red colour and aromatic flavour. The tree is found in South India. *S. malaccensis* trees are found in south India. Berries are sub-globose, white, up to the size of a pea. It is found in Western Ghats of India (Mishra *et al.* 2014).

Reproductive biology: The new vegetative shoots in tree emerge in two distinct flushes from February–May and August–October. Flowering takes place in March–April and flowers are hermaphrodite (Singh and Singh 2012). However, in semi-arid parts of Western India, Singh *et al.* (2007) observed peak period of panicle emergence in the month of February. Peak period of flowering and fruit set were recorded in March (Singh *et al.* 2007). The inflorescence is terminal or lateral and develops on mostly

Table 1 Food value per 100 g of edible portion of Jamun fruit (Nath *et al.* 2008).

Nutrient	Food value	Nutrient	Food value
Moisture	83.7–85.8g	Potassium	55mg
Protein	0.7–0.129g	Copper	0.23mg
Fat	0.15–0.3g	Sulfur	13mg
Crude Fiber	0.3–0.9g	Chlorine	8mg
Carbohydrates	14.0g	Vitamin A	80I.U.
Ash	0.32–0.4g	Thiamine	0.008–0.03mg
Calcium	8.3–15mg	Riboflavin	0.009–0.01mg
Magnesium	35mg	Niacin	0.2–0.29mg
Phosphorus	15–16.2mg	Ascorbic Acid	5.7–18mg
Iron	1.2–1.62mg	Choline	7mg
Sodium	26.2mg	Folic Acid	3mg



Fig 1 A: High density planting of Goma Priyanka, B: Flowering in Goma Priyanka, C: Fruiting at approachable height, D: Fruits in Bunch, E: View of seed and fruit: Goma Priyanka

one year old shoots and older branches. Flowers are regular, bisexual with five free sepals, 8 stamens and a simple style. Before opening, the flower bud attains a size of 5.2 mm in length and 5 mm in diameter and requires 28–30 days from the appearance of the flower bud till opening of flowers. It is a cross-pollinated crop, pollinated by honeybees, houseflies and wind (Singh *et al.* 2011). The maximum fruit set is obtained when pollination is done one day after anthesis and thereafter, setting of fruit declines sharply (Mishra *et al.* 2014). The maximum anthesis (18.71–43.08%) and dehiscence were recorded between 10 am and 12 noon. The maximum receptivity of stigma was observed one day after anthesis. The pollen fertility was higher in the beginning of the season. The maximum insect activity was observed during the day between 11 am 3 pm (Singh *et al.* 2007b).

Genetic resources and varietal wealth

Jamun crop is facing severe genetic erosion and extinction of its several species as a result of activities related to the urbanization and intensive agriculture. The genetic diversity of the related wild species is of particular value in search for sources of resistance to biotic and abiotic stresses (Singh *et al.* 2011).

A large variability of seedling strains with respect to fruit shape and size, pulp colour, TSS, acidity and earliness are available particularly in Uttar Pradesh, Gujarat and Maharashtra, providing good scope for selection of better varieties. It was observed that fruit shape varied from round

to oblong and that of apex of fruits varied from flat to pointed one; great variability in physico-chemical characteristic of fruits offers possibility of selecting a variety suitable for fresh market and processing. Small seed size, high pulp content and better chemical properties are considered to be ideal characteristics (Singh and Singh 2012c, Mishra *et al.* 2014). An intensive survey was made to find out the existing natural variability among the jamun seedling trees and to identify superior genotypes with good fruit quality from Uttar Pradesh and Jharkhand (Patel *et al.* 2005). They reported that the genotypes, RNC-26, RNC-11, V-6, V-7 and V-8 were found promising. Singh and Singh (2005) also surveyed Gujarat to identify the elite genotypes among its population. The study revealed that there was a wide variation among the genotypes. Singh *et al.* (2007e) reported a wide variation among the identified accessions of jamun. The individual fruit weight, length, seed weight and pulp ranged in between 4.80–17.60 g; 2.22–4.51 cm; 1.30–2.36 g and 68.75–86.59% respectively (Singh *et al.* 2010b). The total soluble solids among different accessions varied from 12.2° to 18.40°Brix and titratable acidity from 0.79% to 1.25%.

Therefore, it provides ample scope for selecting improved cultivars. There are no standard varieties available. However, a genotype grown under North Indian condition is “Ra-Jamun”. It produces big sized oblong fruit with deep purple colour. Goma Priyanka (Singh and Singh 2012b) and Thar Kranti are other varieties of jamun released

from CHES (ICAR-CIAH), Godhra (Singh *et al.* 2017b). Goma Priyanka fruits are bold in size and good in taste having 16.87°Brix TSS and vitamin C (45.44 mg/100g). Thar Kranti is semi-dwarf, ripens in 75 days and has high yield (Singh *et al.* 2017b). Rajendra Jamun-1 was released from Bihar Agricultural College, Bhagalpur, Bihar. It is early maturing and high yielding. CISH, Lucknow has also identified two promising genotypes – CISHJ-37 (Jamwant) and CISHJ-42.

Plant propagation

Since jamun has a long gestation period, utmost care is needed in selecting the genuine planting material at the time of orchard establishment. Jamun, being heterozygous in nature, does not produce true to the type from seeds, however, polyembryony has been reported to the extent of 20–50%, hence, nucellar seedlings may be utilized to produce uniform rootstocks for grafting and budding (Singh *et al.* 2011).

Seed propagation: Jamun seeds have no dormancy, hence, fresh seeds can be sown 4–5 cm deep in the nursery. Seeds start germinating about two weeks after sowing. The seedlings become ready for grafting during spring (Singh *et al.* 2011, Singh *et al.* 2010b). Seeds may also be sown in polythene bags, as it facilitates easy handling of rootstocks and grafted plants (Singh *et al.* 2007c).

Vegetative propagation: Budwood for grafting is available during the active growth period of spring or rainy season. The bud sticks with well swollen buds are collected for vegetative propagation. In case of budding, a healthy bud is selected from the axils of leaf. Leaf blade is removed with the help of sharp knife leaving petiole intact. Softwood grafting and patch budding methods are successfully used for jamun propagation (Singh and Singh 2014a, Singh *et al.* 2007c, Singh *et al.* 2018a). Results of study revealed that softwood grafting and patch budding in the months of March and April recorded the maximum success of 90.12% and 85.24%, respectively under semi-arid environment (Singh and Singh, 2006 and Singh 2018).

In jamun, vigorous tap roots get disturbed during the process of transplanting of grafts, ultimately affecting the growth and establishment of grafts in the field. Therefore, *in situ* patch budding was tried at CHES, Godhra (Singh *et al.* 2011). The plants propagated by *in situ* patch budding in the month of March and April recorded good success, i.e. 80.25% and 77.50% respectively (Singh *et al.* 2009 and Singh *et al.* 2007c). About 15–20 cm long mature shoots (2–3 months old) are defoliated 12–15 days prior to grafting operation. These shoots are detached from the mother plant with the help of secateurs or sharp grafting knife.

Micropropagation: It is a method by which true-to-type and disease free plants can be regenerated from a miniature piece of plant under aseptic conditions in artificial growing medium rapidly throughout the year. There are several methods of culturing plant tissues such as meristem culture, embryo culture, callus culture, protoplast culture and cell culture (Singh *et al.* 2019).

Cultivation, pests and diseases

Establishment of orchard: The land is prepared by ploughing, harrowing and leveling. There should be a gentle slope to facilitate proper irrigation and easy drainage to avoid the harmful effects of water stagnation during the rainy season. Jamun may be grown under various cropping systems, i.e. as an orchard crop in a pure land or as an agroforestry species in mixed cropping systems. After marking the places for the plants, pits of 90 cm × 90 cm × 90 cm are usually dug out during the summer months. The pits are filled with a mixture of top soil and 20–30 kg well-rotten farmyard manure. Planting is done during the rainy season when the soil in the pits has already settled. The plants should be irrigated immediately after planting. Jamun is planted at the distance of 10 m × 10 m.

High density planting: At CHES, Godhra, high density planting at spacing of 5 m × 5 m has been found efficient for the higher productivity of jamun (Singh *et al.* 2018b). Effect of shoot pruning on yield and quality of Goma Priyanka variety of jamun was studied by Singh *et al.* (2017c). Singh *et al.* (2017a) reported that planting at closer spacing with proper canopy management lead to higher yield and quality of jamun under dryland conditions of western India.

Irrigation: Water is a limited natural resource in most of the semi-arid and arid regions. Therefore, due care should be taken for judicious utilization of water. Too much watering in jamun creates superficial root system. The irrigation should be done preferably in the evening. The pH of irrigation water should be 6.5 to 7.5 and it must be free from harmful salts (Singh *et al.* 2011). Water deficiency in the soil particularly during development of fruit, affects the metabolic activity and fruit yield. Excess and scarcity of water often cause considerable losses both in quantity and quality of jamun fruits. Therefore, optimum water use practices considering the water requirement and application techniques must be followed. Drip irrigation is a high-tech irrigation system effective in water scarce areas. In this system, required quantity of water is applied at low pressure to the root zone of the crop through a network of pipes. Through this system, irrigation efficiency could be around 90% vis-à-vis 30–40% in the conventional methods of irrigation (Singh *et al.* 2013a).

Mulching: The effectiveness of mulches in conserving moisture has generally been found to be higher under drought conditions and also during early periods of plant growth when canopy cover remains scanty. As soil moisture is one of the limiting factors for successful cultivation of jamun, use of mulch is very beneficial (Singh *et al.* 2017). It reduces the loss of soil moisture, enhances the rate of penetration of rainwater or irrigation in the soil and controls the growth of weed, thus, eliminating the competition between weeds and the fruit trees. Mulching can be done with black polythene or any organic materials. In general, mulching with grasses, paddy straw and rice husk reduces weed population and conserves soil moisture. Earthworm and microbe population in the basin soil increases with the use of different mulches. Leaf litter of jamun under the canopy is effective to retain

soil moisture during summer months (Singh *et al.* 2010b, Singh *et al.* 2007e).

Nutrient management: Nutrient management is generally not followed in jamun. However, an annual dose of about 20 kg of FYM during the pre-bearing period and 50–80 kg/tree at bearing stage is considered beneficial. Trees often produce more vegetative growth in nutrient rich soils, delaying the fruiting. Under such conditions the trees should not be manured and irrigation should also be given sparingly and withheld in September-October and again in February-March. This helps in proper fruit bud formation, blossoming and fruit setting. Jamun leaf litter available in the canopy of the plant may become an integral part of the soil fertility management. It may be managed with Earthworm culture in plant basin for degradation of biomass. Beneficial effect of *S. cumini* litter fall biomass on soil has been reported by Singh *et al.* (2007e).

In general, 5 kg FYM, 125 g N, 50 g P_2O_5 and 50 g K_2O per plant per year may be applied to one year old jamun plants. This dose should be increased every year in the same proportion up to 10th year, after which the fixed dose should be applied. Full dose of farmyard manure should be applied during July-August. Half dose of N, P and K should be applied in the month of July and remaining dose should be applied by the end of August or the first week of September under rainfed conditions (Singh and Singh 2012). Application 6 kg castor cake per plant per year along with standard dose of FYM and NPK after 5th year of plantation is found effective for improving vegetative growth, yield and fruit quality attributes (Singh *et al.* 2011). Earthworm and microbe population in the soil beneath plant canopy is found to increase with the use of FYM and cakes. Under rainfed conditions, foliar feeding is very useful in supplementing nutrients, particularly nitrogen and micronutrients. The optimum concentration of urea for foliar application is around 1.0% and one spray in the month of April is effective to improve fruit retention, its growth and productivity. Supplementing micronutrients through foliar spray of 0.2–0.1% zinc sulphate has been observed to improve fruit quality attributes in terms of TSS, total sugars and vitamin C content and result in the development of deep purple colour in fruit. Application of recommended dose of NPK+FYM+*Azotobacter*+PSB or FYM+*Azospirillum*+VAM or FYM+*Azotobacter*+VAM improved soil properties in terms of bulk density, hydraulic conductivity, pH and ECe. Plant growth, yield and quality parameters are influenced by application of biofertilizers (Singh *et al.* 2011, Singh *et al.* 2010b, Singh *et al.* 2007e).

Canopy management: Canopy management intends to develop and maintain tree structure for the maximum fruit productivity and quality. The basic concept of canopy management in perennial trees is to make the best use of resources for increased productivity. Tree vigour, light, temperature and humidity play a vital role in the production and quality of fruits. The crux of canopy management lies in the fact, as to how best we manipulate the tree vigour and use the available sunlight and temperature to increase

the productivity and quality of produce. The main central leader is allowed to grow for a few years, until 8 to 10 scaffold develop around the central leader. The central leader is then cut to form side laterals which in due course grow as a modified leader. In this training, the tree develops well-spaced limbs with strong crotches. The top being open, allows more sunlight to penetrate deep inside the tree. This system is appropriate for training of jamun plants (Singh *et al.* 2017c). To maintain the dwarf framework of jamun plant, topping of main stem (3–5 m) is required. It facilitates easy harvesting of the fruits (Singh *et al.* 2017c). It was also observed that pruning 50% annual extension growth after harvesting was effective in reducing the plant canopy and improving quality attributes (Singh *et al.* 2018b).

Crop diversification: Compatible crop combination is necessary with regard to species, cultivars, planting method and sequence. Peas, gram, lentil, blackgram, cowpea, cluster bean, cucurbitaceous crops and capsicum may be grown as intercrops in the jamun orchard (Singh *et al.* 2011, Singh *et al.* 2010b).

Flowering, fruit set and fruit drop: Flowering and fruit set to take place in March-April. Fruit drop starts just after fruit set and only 15–30% fruits reach maturity. The flower and fruit drop are found at three stages. The first drop takes place during bloom or shortly thereafter, and this proves to be the pre-harvest drop as about 52% of the flowers drop off after 4 weeks of flowering. The second drop starts after 35–40 days of full bloom and apparently there is no distinction between the developing and aborting fruits. The third drop takes place 42–50 days after full bloom and continues till 15th July. The extent of flower and fruit drop in jamun is reduced by two sprays of 60 ppm GA_3 , one at full bloom and other 15 days after initial setting of fruit.

Maturity indices: An investigation was carried out to study the fruit developmental pattern pertaining to quality characteristics for fixing harvesting time of jamun fruits under semi-arid ecosystem of western India (Singh *et al.* 2006). It was observed that the fruit growth was faster initially and slowed down while reaching maturity and followed a sigmoid growth pattern in all the genotypes. The specific gravity showed increasing trend (>1) in all the genotypes during development. Total soluble solids, total sugar and vitamin C increased as the fruits reached maturity. Titratable acidity showed declining trend while reaching the ripening stage. Deep purple colour on fruit surface was observed in all the genotypes during ripening (Singh *et al.* 2010b).

Harvesting practices, yield and quality attributes

Seedling Jamun plants start bearing after 8–10 years of planting while grafted ones after 4–5 years. The fruits ripen in the month of June-July. Fully ripe fruits are deep purple or black in color. Fruits should be picked immediately after ripening to minimize wastage of ripe fruits. Ripe fruits are picked manually and care should be taken to avoid any possible damage to the fruits. The fruits are generally harvested daily and sent to market same day. The average

yield of fruit from a full-grown seedling jamun tree is 80–100 kg/year and 60–70 kg/year from grafted one. Variability in physico-chemical attributes in jamun germplasm has been reported (Kaur and Bal 2015, Srivastava *et al.* 2010, Prakash *et al.* 2010, mGhojage *et al.* 2011). Compositional and biochemical attributes in the germplasm have been studied by Ali *et al.* (2013).

Postharvest technologies

Considerable variation exists in the quality of harvested fruit due to genetic, environmental and agronomic factors and therefore, grading is required to get better returns for the produce (Singh *et al.* 2010b). Proper grading coupled with scientific packaging and storage reduces postharvest losses substantially, enabling the producer to fetch premium price. Jamun should be graded on the basis of fruit size, ripening stages, fruit uniformity and cleanliness. Ideal packaging protects the fruits from physiological, pathological and physical deterioration in the marketing channels and retains freshness of fruits. Fruits pre-packed in leaf cups covered with perforated polythene showed less loss in weight and shriveling and appearance was better as compared to the conventional prepackaging. Depending upon the distance of transportation, jamun fruits are transported as head loads and in trucks and trains. Among different types of containers shallow plastic crates are better during transportation of the fruits from field to distant market to prevent bruising losses. An experiment was conducted to study the effects of different packaging materials for transportation and storability of jamun fruits by Singh *et al.* (2011). It was found that the minimum spoilage loss was recorded in the fruits kept in corrugated fiberboard box with newspaper liner closely followed by corrugated fiberboard box with polythene liner (200 gauge, 2% ventilation). Same treatment also showed lowest respiratory activity and exhibited higher 3 days shelf life at ambient storage. Studies conducted to evaluate the postharvest physiological changes and shelf life of fruits of 10 genotypes during storage at room temperature at CHES, Godhra by Singh *et al.* (2009) revealed that after harvest, maximum fruit weight (20.05 g) and TSS (17.75°Brix) were recorded in GJ-2 closely followed by GJ-8. Increase in physiological loss in weight, spoilage percentage, TSS, total sugar and reducing sugar and decrease in acidity, ascorbic acid with advancement of storage period were general phenomena in all the genotypes.

Jamun fruit respire and transpires continuously resulting into high weight loss leading sometimes to the pathogen infections and thus reduced market value. Due to prevalence of high temperatures (35–42°C) during the time of harvesting, jamun fruits start deteriorating rapidly and it is necessary to prolong shelf life of fruits during storage. Preharvest spray of calcium chloride (1–1.5%) 20 days prior to harvesting was effective in improving the fruit quality and enhancing shelf life at room temperatures (Mishra *et al.* 2018). GA₃ restricts ethylene accumulation in the fruit tissue and has been known to delay ripening process and regulate the nucleic acid and protein synthesis. Fruits treated

with GA₃ (50 ppm) and stored in perforated polyethylene bags, had enhanced shelf life by restricting the transpiration and respiration at room temperatures (Singh *et al.* 2019).

Processing for value added products

Jamun, being highly perishable in nature, suffers from the heavy losses after harvest particularly during the postharvest handling. It is necessary to process the fruits into different value added products by employing different methods of fruit preservation. The fruits may be utilized for making jam, jelly, beverages, wine, vinegar and pickles (Das 2009 and Mishra 2018). Jamun beverages R.T.S, nectar, squash, syrup, vinegar and cider are important postharvest products of jamun (Singh *et al.* 2010b).

Marketing and economics and socioeconomic considerations

Marketing problems are more in jamun due to high degree of perishability and season bound availability. About 75% of the farmers sell their produce at the farm level to the village merchants, retailers or to the preharvest contractors as small and marginal farmers cannot afford to transport the produce to distant markets. Information regarding demand, supply, price, market outlook, knowledge of the consumer's preference, marketing channels are important for marketing of produce. Jamun fruits are harvested from naturally established trees or a few trees grown in patches. Because most of the fruit comes from trees scattered in home gardens and field borders, it is not possible to compile reliable statistical data for calculating the economics of the crop. Jamun seed powder also has tremendous potential in the global market.

Plant protection

The major pests of the crop are leaf eating caterpillar (*Corea subtilis*), bark eating caterpillars (*Indarbela tetraonis* and *Indarbela quadrinotata*), fruit borer (*Meridarchis reprobata*), leaf miner (*Acrocercops syngamma* and *Acrocercops phaeospora*), leaf roller (*Polychorosiscellifera*), leaf webbers (*Argyroplote aprobola* and *Argyroplote mormopa*), fruit fly (*Bactrocera correctus*) and white flies (Singh 2006, Singh *et al.* 2011). Leaf eating caterpillar, jamun leaf miner, fruit borer and bark eating caterpillars can be controlled by spray of Dimethoate 30 EC(2ml/l) at fortnightly interval, whereas jamun leaf roller, leaf webbers can be managed with the spray with Chlorpyrifos 20 EC(2ml/l) at 15 days interval. White flies can be controlled by maintaining sanitary conditions in the orchard, which consist of picking up the affected fruits and burying them deep in the soil, and area under the tree should be dug, so that the maggots in the affected fruits and the pupae hibernating in the soil may be destroyed. Pheromone traps are also useful for managing this pest (Singh *et al.* 2007e). Anthracnose is major disease of jamun. The fungus incites leaf spot and fruit rot. Affected leaves show small-scattered light brown or reddish brown spots. Affected fruits show small, water soaked, circular and depressed lesions. Fruits

rot and shrivel. This disease can be controlled by spraying Dithane Z-78 @0.2%.

Conclusion

Jamun cultivation has still not been commercialized due to several reasons. The future of this fruit depends on selection of high yielding cultivars having tolerance to abiotic stresses. Further, emphasis should be given to development of high quality trait specific varieties, economically feasible production technologies and popularization of value added products as health promoting food. Being a medicinal plant, there is need for correlating the therapeutic activity with the chemical marker of the plant as well as studying the mode of action of the marker compound and clinical trials against various diseases. Jamun is a 'hot' commodity in health product markets and with firm evidences regarding its usefulness in combating against various diseases, the prospect for jamun research is enormous in the country.

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