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REVIEW ARTICLE

Karonda (*Carissa carandas* L.): A review on its varietal wealth, production and diversified uses in India

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Abstract

India enjoys tremendous diversity of fruit crops from temperate to tropical regions. The country is also home to many fruit crops including several underutilized and minor fruit crops. The minor fruits, besides being hardy, are often termed as 'protective food' because they can reduce the risk of over dependency on major fruit crops, preserving dietary diversity. Karonda (*Carissa carandas* L.) is one of them which has gained recognition for its nutritional advantages, therapeutic qualities and potential for diversified applications. Morphologically, the plant exhibits a dense, spinous branching habit with a characteristic Y-shaped branch structure. Leaves are opposite, glossy green on the upper surface and oblong to ovate in shape. The plant produces fragrant white flowers in small terminal clusters, primarily blooming from March to April, with fruit maturation occurring from August to September. Cytogenetic and phenological studies, including the use of the extended BBCH scale, have identified distinct growth stages across key developmental phases like bud, shoot, inflorescence and fruit maturity. These insights, along with knowledge of pollination dynamics, agronomic practices and use of modern breeding tools, are crucial for optimizing crop management and productivity in Karonda cultivation. This review explores advancements in cultivation, production and the broadened uses of karonda in India.

Keywords: karonda; production technology; value addition; varieties

Introduction

The demand for nutritionally rich and therapeutically important fruits is increasing day by day owing to rich in both medicinal and nutritional qualities. The underutilized and minor fruit crops in the recent past are becoming popular not only for their nutrient-dense nature, also for their hardiness and abilities to mitigate challenges posed by biotic and abiotic stresses. The minor fruit crops can help in meeting the nutritional needs of people and combat hidden hunger or deficiencies of various vitamins (1, 2). Most of these crops are hardy in nature, thus they can be successfully grown on marginal and wastelands while promoting sustainability (3). With increased understanding of health, nutrition and safety, plant materials with medicinal characteristics can be employed to create safe and low-cost therapeutic food items. Karonda is one such potential indigenous fruit crop which is a rich source of nutrients particularly iron and vitamin C. Karonda is hardy, evergreen, spiny and indigenous flowering shrub that grows in the arid and semiarid regions of the world (4). It is popular for its attractive colour edible fruits. This drought-tolerant plant thrives well in a variety of soil types and climates, making it ideal for wastelands (5). It also grows well in rainfed areas, providing support to tribal populations across India, including Bihar, West Bengal, Uttar Pradesh and South India (6, 7). Ripe fruits have a distinct scent and a taste that ranges from sub-acidic to sweet. Since it has spines and attractive flowers, it is also cultivated as a bio-fence in gardens, fields and orchards (7). The astringent and sour unripe fruits are used to make chutney and pickles that are highly sought in the global market. The mature fruits are consumed as dessert and are used to make a variety of products including sauce, syrup, squash, jam and jelly, the dried fruits could eventually be used in place of raisins. Like cherries, the fruits are candied and are known as Nakal cherry in some areas (8).

Origin and distribution, climate and soil, area and production

Karonda belongs to the genus *Carissa*, which is a member of the Apocynaceae family (2n=22). The genus has about 30 species that are native to Malaysia, tropical Asia, Australia and South Africa. *Carissa carandas, C. inermis, C. paucinerva and C. spinarum* are the five species that are native to India; the first two are found in the Western Peninsula, while the third is found in the arid regions (7). Different species of *Carissa* are cultivated for their small berry like edible fruits and for its thorny hedges. Some species are also cultivated for ornamental purposes in the gardens. Major natural areas of occurrence of karonda have been reported in the states of Maharashtra, Bihar, West Bengal,

Chhattisgarh, Orissa, Gujarat, Madhya Pradesh, Rajasthan and in the Western Ghats (9, 10). It is a xerophytic plant, well adapted to the arid and semi-arid climates. Karonda can be grown on a variety of soil types, including sandy, rocky and poor soils found in arid regions (5). However, growth and yield is higher in deep loamy or alluvial soils. It is an ideal crop for waste lands and planted on field boundaries for fencing purpose. It can also tolerate sodic saline soils (pH upto 8.5) to a greater extent.

As Karonda is an underutilized fruit crop, the estimated data on area and production is not available however, it is wildly grown in Chhattisgarh especially near Bastar, Raipur and Jagdalpur districts, Madhya Pradesh, Karnataka, Konkan region of Maharashtra, Rajasthan, Uttar Pradesh and some parts of Western Ghats. Karonda has a rich diversity in southern parts of Rajasthan, including Jhalawar, Banswara, Dungarpur, Chittorgarh and the border areas of Madhya Pradesh (11). In Maharashtra, most of this crop is grown in sub-mountainous regions of districts Kolhapur, Ratnagiri and Pune (10). This review deals with Karonda's nutritional richness, culinary and medicinal applications. Additionally, challenges and advances in cultivation, varietal wealth and value addition, are discussed, emphasizing the fruit's potential as a valuable resource for various end uses.

Importance, uses and medicinal significance

Karonda holds significant importance due to its nutritional composition, medicinal properties and various uses (12). Furthermore, it is a source of phytochemicals (Table 1) that have potential health benefits, such as anti-inflammatory and anticancerous properties (Fig. 1). The roots have been reported to possess bitter, stomachic, antidiarrheal and antianthelmintic qualities (13, 14). The root extract is used for chest pain and leaf extract is used for fever. Leaf extract is externally applied for curing leprosy (15) used for rearing the tussar silkworm (14).

Karonda fruits are used in the traditional herbal medicine to cure a variety of ailments, including anorexia, anaemia, ulcers, fresh and infected wounds, skin problems, urinary issues and diabetic ulcers (5, 16, 17). It is also well known for its aphrodisiac, antipyretic, appetizer, anthelmintic and astringent properties (18-20). The ripe fruits of karonda are sweet, cooling, appetizer and are useful in controlling burning sensation, skin diseases, scabies and pruritus (21). As ripe karonda fruits contain pectin content, therefore, also used in making jelly, jam, candied murabba, squash, syrup, tarts and chutney which have great demand in market (22).

Morphology, floral biology, cytogenetics and pollination

The genus *Carissa* contains species which are densely branched, spinous and erect shrubs. *C. carandas* (karonda) and *C. grandiflora* (natal plum) are well-known for their fruits. It is an evergreen shrub or small tree, attains a height of 3-6 m. Young shoots have greenish white bark, whereas older stems have greyish brown bark. The spines are simple or forked, measured 1 -3 cm in length. Leaves are opposite; leaf blades are broadly ovate to oblong (3.7×1.5-4.0 cm) with a broadly cuneate to rounded base and short apiculate apex (29). They have a dull green hue underneath and a glossy green top. The defining feature of karonda's growth is its branching pattern, where each branch divides into two, forming a Y-shape (Fig. 2). The flowers are white, scented and produced in clusters of 2 to 5 flowers. The corymbose cymes appear at the end of twigs (18). The main flowering season is during the month of March-April with fruit maturing during August-September which enables the plants to make best use of monsoon rain (30). The fruit is a globose berry and shape of fruit is ellipsoid and pointed or globose or oval or round; 1.8 to 2.5 cm long containing 1-4 flat brown seeds (29). In green-fruited varieties, as they mature, their color shifts to white to

Table 1. Phytochemical composition of mature karonda fruits

Constituents	Mature fruit (per 100g FW)	References
Lutein	6.12-7.52 µg	
Zeaxanthin	1.14 -1.68 µg	23
Total carotenoids	55.89-74.26 µg	
Vanillic acid	0.12 -2.30 mg	
Protocatechuic acid	0.37-0.58 g	
Salicylic acid	0.031-0.232 g	24, 25
p-coumaric acid	0.16-0.20 mg	
Gallic acid	0.032-0.099 g	
Flavonoids		
Luteolin	1.21-1.52 mg	
Myricetin	0.12-0.25 g	23, 26
Naringenin	0.99 mg -1.20 mg	
Vanillin	123.4- 128.36 mg	
Vanillic acid	0.12 -2.30 mg	
Protocatechuic acid	0.37-0.58 g	
Salicylic acid	0.031-0.232 g	27
p-coumaric acid	0.16-0.20 mg	
Gallic acid	0.032-0.099 g	
Hesperetin	0.0023-0.0052 g	
Naringenin	0.003-0.0109 g	23, 25
Luteolin	0.0016-0.0406 g	
Apigenin	0.0002-0.0003 g	
Anthocyanin content (DW)		
Cyanidin-3-rutinoside	1.140-1.652 mg	
Malvidin-3-glucoside	1.985-2.156 mg	
Peonidin-3-O-glucoside	2.937-3.254 mg	28
Cyanidin-3-O-glucoside	8.940-9.215 mg	

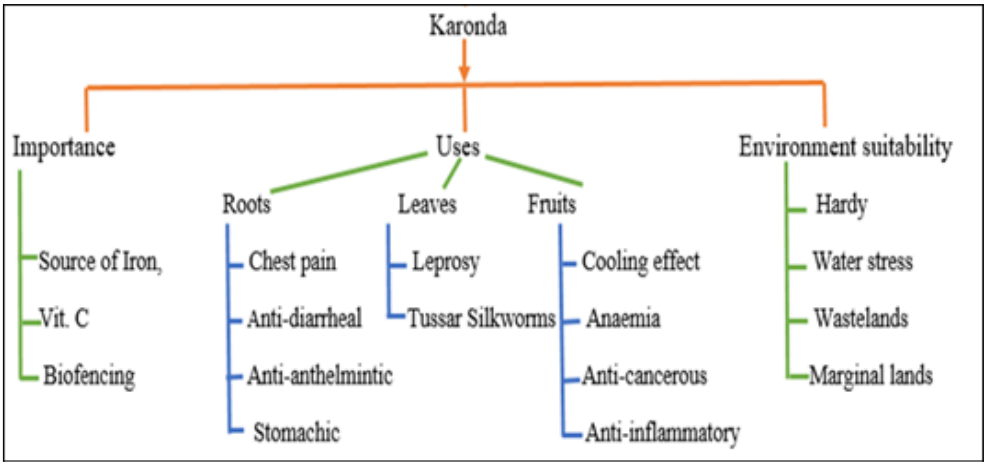

Fig. 1. Importance and utilization of Karonda.

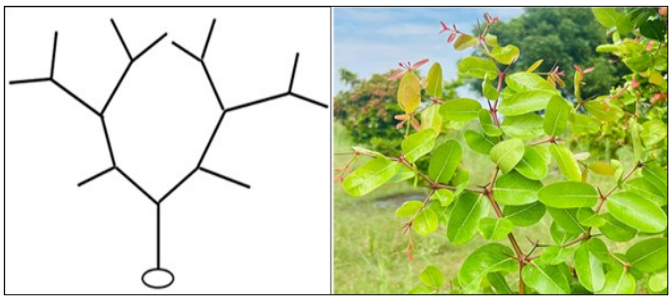

Fig. 2. Dichotomous branching pattern in k aronda.

reddish-purple. On the other hand, pink-fruited varieties show an initial white-to-pink blush when immature, eventually turning dark brown once ripe. It is a highly cross-pollinated crop. It is reported that self-pollination gave a fruit set of 20.24 % whereas, natural or open pollination improved fruit set upto 32-36 % (31). Previous researchers (32) identified and described 38 growth stages of Karonda using the extended BBCH scale, covering 7 main stages like bud, leaf, shoot, inflorescence, flower, fruit development and fruit maturity. The study also noted changes in plant chemistry and pest activity, aiding in better crop management and protection.

Genetic resources and varietal wealth

Genetic diversity in karonda plays a crucial role in the crop's adaptability, resilience and improvement potential. As an underutilized and hardy fruit crop, Karonda exhibits considerable variability in traits such as fruit size, color, taste, growth habit and tolerance to biotic and abiotic stresses. This diversity is vital for breeding programs aimed at enhancing yield, nutritional quality and stress resistance (33-35). Karonda populations show variations in fruit color ranging from green to white, pink, red and deep purple or brown at maturity. Fruit size, shape and taste also vary among different genotypes (35-37). The genetic diversity allows Karonda to thrive in arid, semi-arid and marginal lands, making it an important crop for dryland agriculture (5). Studies employing molecular markers such as RAPD, ISSR and SRAP have helped assess the genetic diversity and population structure, aiding in identification and selection of superior genotypes for conservation and breeding (34, 36, 38). Karonda germplasm is conserved in national and regional gene banks through seed collections, field gene banks and clonal repositories. This ensures the preservation of diverse genetic material for future breeding and research (5, 31). Conservation of Karonda in its natural habitat and on-farm conditions by tribal and local communities helps maintain genetic variability and promotes sustainable use (39). Efforts are ongoing to develop improved cultivars with better fruit quality, higher yield and enhanced resistance to pests and diseases by utilizing diverse germplasm (7, 30, 35). Conservation programs also focus on raising awareness among farmers and stakeholders about the importance of Karonda and its genetic resources, encouraging sustainable cultivation practices (40). Being an underutilized fruit crop, varietal improvement has received limited attention. The majority of existing studies focused on selection from naturally occurring populations or evaluation of seedling performance over a certain period (Fig. 3).

A survey conducted in eastern Uttar Pradesh identified 4 types of karonda fruits *viz.* green, white with pink blush, green with purple blush and maroon (41). These varieties are generally classified into two categories, i.e. pickling type and table purpose. A few karonda varieties/accessions identified till date with their characteristics are given in Table 2.

Selection-based improvement work conducted at KKV, Dapoli (6), ICAR RS CHES, Godhra (7) IIHR, Bengaluru (18, 45), CAZRI, Jodhpur (46.), PAU, Punjab (37) and GBPUAT, Pantnagar (42) by analyzing traits like growth habit, fruit shape, color, pulp and other fruit quality characteristics, heritability and genetic advance. Currently, karonda breeding predominantly uses traditional phenotypic approaches and germplasm selection. However, to accelerate improvement, emerging genomic tools can be adapted like marker assisted selection (MAS) genomic (GS) and integrated genomic selection (IGS) and QTL mapping to predict genetic gain and select superior lines more efficiently (34, 43, 44).

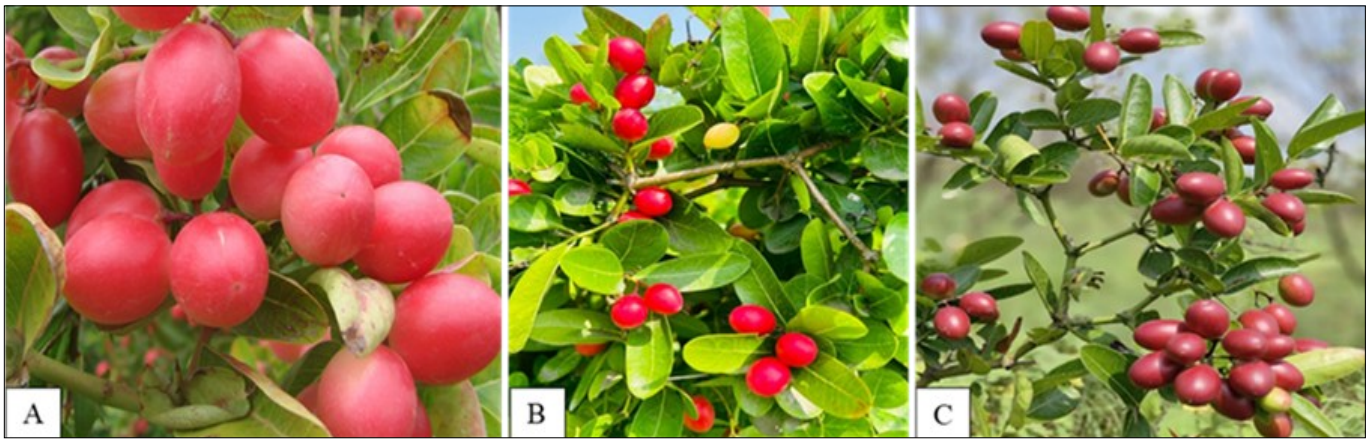

Fig. 3. Mature fruits of karonda variety, A) Thar Kamal, B) Pant Manohar, C) Pant Suvarna.

Table 2. Released varieties and identified lines of karonda and their characteristics

Cultivar	Institute	Characteristics	Reference
Pant Manohar	GBPUA&T, Pantnagar	Pickle type, fruit weight 3.49 g, TSS 3.92 %, acidity1.82 %, yield 27kg/plant.	42
Pant Suvarna		Pickle type, fruit weight 3.62 g, TSS 3.83 %, acidity 2.30 %, yield 22kg/plant.	
Pant Sudarshan		Pickle type, fruit weight 3.64g, TSS 3.45 %, acidity1.89 %, yield-29kg/plant.	
Konkan Bold	KKV, Dapoli	Table purpose, TSS- 10-12°B	
CHES K-II-7	CHES Chettalli	Table purpose, seedless (0.3 seeds/ fruit), fruit weight- 12-13g, TSS- 15°B, yield- 1800 -2100 fruits per tree per year	18
CHESK-35		Bold sized fruits, table purpose	
CHES-K-V-6		Table purpose, less seeded, fruit weight 13-15g, TSS- 16°B	
Maru Gaurav	CAZRI, Jodhpur	TSS 9.40° B, acidity 2.8 %, total sugar 5.63 %, yield 40 kg/tree/year	45
Thar Kamal	CIAH, Bikaner	TSS 9.54° B, total sugar 6.12 %, yield 13kg/tree	7

Plant propagation

Karonda is generally propagated by seeds, however, asexual methods like stem cutting, air layering, stooling, budding and grafting can also be used (Fig.4) (3). Mass scale production of clonal germplasm can also be successfully achieved through micropropagation (8). Seeds are extracted from fully ripened fruit during the month of August-September and sown immediately since they are recalcitrant in nature (29). Results showed the highest germination rate (63.32 %) was recorded in fresh seeds. However, Seeds stored up to 12 days maintained good germination and vigour, indicating that karonda seeds can be viably stored for up to 12 days under ambient conditions (46, 37). Whereas soil + FYM + vermicompost (2:1:1) reported as best media for seed germination (47) and germination took place within 20 days (45). However, when seeds soaked in cow dung slurry for 24 hrs showed highest germination (62.67 %) with high vigour indices (48). Soaking seeds with IBA @20 ppm for 12 hr gave higher germination percentage (80.83 %) (49).

Various methods of vegetative propagation have been tried in karonda. The success rate for rooting is lower as it is difficult to root (4, 29). Karonda cutting (25 cm long) having 4 to 5 nodes and 1.0-1.2 cm thickness during monsoon season in Sand: Soil: FYM @ 1:2:1 media recorded highest rooting percentage (39.43 %) with IBA 8000 ppm (50, 51). Softwood grafting using a two months old scion and covering the graft with a polyethylene sheet resulted in a graft survival rate of 97.31 % (52). Air-layering in karonda with 5000 ppm IBA was most effective in inducing rooting in minimum time with 90.0 % survival (53). Soft wood grafting was an effective method for *in situ* propagation of karonda in dry regions (54).

Micro-propagation protocol of karonda was standardized using 1.5 cm long shoot tips in the spring (February-March) produced the highest sprouting rate. MS basal medium with 3.0 mg L^{-1}BA showed the maximum shoot proliferation, while half-strength MS medium with 0.8 mg L^{-1} IBA and 0.2 mg L^{-1} NAA resulted in optimal rooting. The rooted plantlets were successfully acclimatized in a potting mixture consisting of vermiculite, sand and soil in a 1:1:1 ratio (8). Smilarly, MS medium supplemented with 3.0 mg L^{-1}BA was found to be effective for the mass multiplication of karonda shoots whereas, the addition of 2.0 mg L^{-1} IBA into the culture medium was required for the rooting of the micro-shoots (55).

Agronomy, cultivation, pests and diseases

Planting and orchard establishment

Karonda is generally planted as a live fence; however, it is also suitable for both block and hedgerow planting (45). Monsoon season (July-August) is ideal for planting; however, planting can be also done during spring season (February-March) if assured irrigation facility is available. The option for square system is planting 3 m apart, however, under HDP it might be reduced to 2 m. For ease in intercultural operations, machinery uses and intercropping, the distance can be widened to 4-5 m apart. Under rectangular system the planting distance of 4 m×2 m (hedge row planting) or 5 m×3 m can be recommended as per convenience and future of the orchardists. For hedge planting, it can be planted at 60 cm distance in double rows along the boundaries of the orchards (56, 57).

Integrated nutrient management

Karonda plants used for protective hedges need minimal fertilization. However, applying fertilizers (Table 3) is advantageous as plants gradually become depleted after yielding two crops and exhibit signs of dieback (42). Thus, applying 10-15 kg of well-rotten farmyard manure or compost per plant before the flowering stage is beneficial (58). For optimal growth and productivity of plants, it is recommended to maintain leaf nitrogen levels between 0.99 and 1.37 % (59). Whereas applying 1.0 % urea solution on plants during fruit set, followed by 0.50 % Mono potassium phosphate 20 days after fruit setting, led the higher fruit retention (95.20 %) and pre-rainfall fruit yield (64 %) with superior fruit quality characterized by highest total soluble solids (60).

Pest and disease management

Karonda typically shows little susceptibility to pests or diseases in arid regions, though reports indicate the presence of leaf-eating caterpillars and fruit flies in certain locations (7). Orchard sanitation practices are necessary to prevent the spread of diseases and pests. Important insect-pests and diseases and their management is listed in Table 4.

Plant bio regulators

Gibberellic acid (1000 ppm) was found most effective for enhancing initial plant growth (62). Application of 20 ppm NAA at 50 % flowering stage and again 21 days after 1st spray led to highest fruit set (93 %), fruit retention (83 %) and fruit yield (4 kg/ plant) under the alluvial zone of West Bengal. In contrast, GA (20 ppm) proved effective for improving quality parameters such as TSS (8.87°B), total sugars (6.05 %), ascorbic acid (34.00 mg/100 g) and anthocyanin (3.87 mg/100 g pulp) content (63).

Training, pruning and canopy management

The size and shape of the plant can be controlled through its canopy architecture. Karonda may be trained on both single and double stems in regular plantations. To ensure optimal training, remove lateral shoots up to 15-20 cm from the ground level forming main stem (64). Plants do not require much pruning, except for mild pruning each year in November-December. Each plant is supported with a wooden stake during planting to

Table 3. Fertilizer requirement of karonda plant

Plant age (year)	Urea (g)	Single Super Phosphate (g)	Muriate of potash (g)
1	100	150	75
2	200	300	150
3	300	450	225

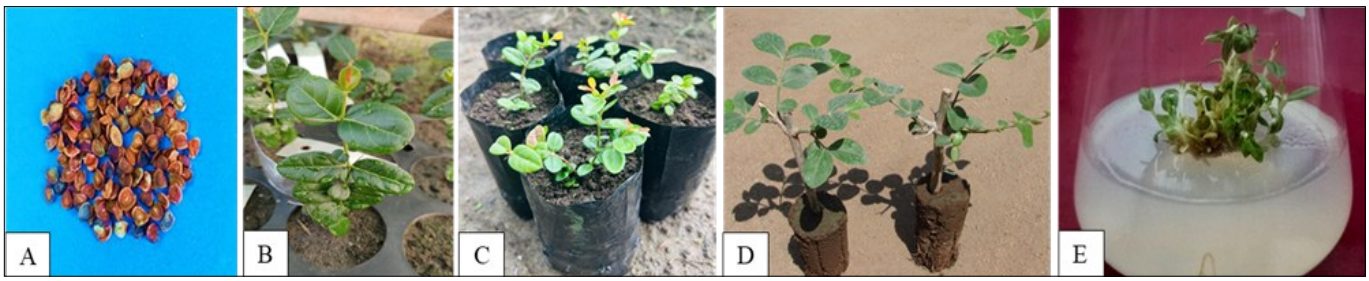

Fig. 4. Propagation methods in karonda A) seeds, B) seedling in protray, C) seedlings in polybags, D) hardwood cutting, E) microproagation.

Table 4. Pest and disease management in karonda

Insect-pests/disease	Symptoms	Management	Reference
Leaf eating caterpillars (*Digama hearseyama*)	Defoliation, plant death in severe conditions.	Azadirachtin 1.0 % EC (10000 ppm) 2.0 ml/ lit. or *Bacillus thuringiensis* 2g/lit.	56
Cotton cushion scale (*Icerya purchesi*)	Nymph and adults suck sap from tender leaves, affected portion turns purple, drying and dropping of leaves in severe condition.	Bio-control agent Vedalia beetle (*Rodolia cardinalis*) is used to control this disease.	61
Bihar hairy caterpillar (*Spilosoma oblique*)	Early instar larvae scrap the young leaves, but third instar eat the whole leaves.	Hand picking the first two instar and destroying them in kerosene oil. Methyl parathion @ 0.04 %	61
Anthracnose (*Colletotrichum inamdarii*)	Irregular black and brown spots of varying sizes.	Copper-based fungicides and proper orchard sanitation	7

ensure that it remains in upright growth. Young plants should be permitted to develop 3-4 well distributed branches that will form the main scaffold of the tree. Floral buds develop axially during new season growth, therefore, pruning of old branches is recommended in karonda as they seldom yield flower buds.

Irrigation, soil moisture conservation and inter cropping

Karonda is a hardy plant and owing to its xerophytic nature, needs very little irrigation. Irrigation is required after planting and manuring. During winters, young plants require watering every 10-15 days while in summer; the interval should be reduced to every 6 -7 days. The basin or flood method of irrigation is normally practiced. However, as this fruit is now becoming an important nutraceutical crop and demand is increasing, so the growers are rewuired to follow moisture conservation strategies. Management of water might play a pivotal role in improving yield and quality of harvested produce. Its impact can be seen in estimated yield/tree under various agro-climatic conditions of the country as yield varies from 4-5 kg to 30 kg per tree (18, 42). The efficient and sustainable use of available water is the prime priority in arid and semi-arid zones of India. Therefore, it is imperative to use water efficient management strategies so that a greater number of karonda plants can be irrigated with existing limited water resources i.e. drip irrigation (65). Deficit irrigation with the water application at the rate of 0.5-0.8 PE can be employed. However, the standardization of nutrient and water requirement through drip system under various agro-ecological situation is still required. Further mulches are known as growers' front line of defence to protect the plants against environmental vagaries (66) which are common in karonda growing belts. Any mulch material either organic or inorganic can be used for basin cover in karonda plants. Under organic mulches, dry leaves, straw, sugarcane trash, grass, droppings, compost, sawdust, pruned material etc. can be used. Organic mulches add organic matter after decomposition and improve infiltration rate as well as water holding capacity by enhancing porosity of the soil (67). However, inorganic mulches have some inherent disadvantages *viz*., non-availability in huge quantity as per the requirement, difficulty in application, harbouring of harmful pests and threat of fire hazards etc. (67). Inorganic mulches directly impact the microclimate around the plants by modifying the radiation budget of the surface and minimizing the soil water loss. These are easily available, easy to handle, transport and lay. Among various colours available, mostly black and silver-black colour is preferred as plastic mulching. The recommended thickness for organic mulching is 4-6 inches (10-15 cm) as per the material used and for plastic mulch it is of 100 microns for karonda plants. Enhanced quality attributes of karonda were recorded under black plastic mulch with 15 L irrigation water at 15 days interval. Leaf mulching with irrigation also improved quality attributes when compared to non-mulched karonda plants (68).

During the early stages of establishment, the space between plants can be effectively utilized for growing intercrops such as vegetables and leguminous crops, which can provide additional income (61). Karonda is generally planted at wider space (5 m × 5 m or 5 m × 3 m) under arid ecosystem and the between alley spaces can effectively be utilized for growing leguminous cover/ green manure crops during summer and medicinal plants/ seasonal vegetables and other crops during monsoon and winter seasons as per availability of water and resources. Under conventional and HDP, when the plant achieves full canopy, cover/ green manure crops are always advocated as these enhances soil fertility along with conserving and retaining soil moisture (7). It can also be intercropped with bael, aonla, ber etc. Multi-storeyed fruit cropping systems with aonla - guava - karonda and aonla - ber - karonda have been suggested for salt affected soils (69).

Harvesting, yield and storage

The karonda plants begin to bear fruits two to three years after planting. Flowering occurs in March and the fruits mature throughout rainy season i.e. July to September, however, unripe fruits are available from the month of May. The change in colour with a specific gravity exceeding 1.0 is an effective sign of fruit ripeness (64). Harvesting often takes three to four cycles since not all fruits mature at the same time. A complete harvest of fruits per plant typically requires many (4-6) pickings. The yield of karonda generally varies according to variety and growing environment. Under *tarai* conditions karonda yields around 22-29 kg/tree/year, whereas in semi-arid and arid areas, Thar Kamal yields 13 kg/tree/year and Maru Gaurav yields 40kg/tree/year. Under Maharashtra condition, Konkan Bold yields 30.87 kg/tree whereas under south Indian conditions karonda yields 15-22 kg/ tree (25). Fruits when harvested at the purple stage have a delicious flavour and high antioxidant content (70). Whereas, fruits collected 80 days after fruit set contain maximum phyto-nutrients such as ascorbic acid, phosphorus, calcium and iron (71). Harvested fruits are sorted and kept in the shade, then packed into shallow baskets for marketing. Unripe fruit can be stored at room temperature for 5-7 days, whereas ripe fruit can only be stored for 2 days (7).

Post-harvest handling and value addition

The fruits are valued for their taste, ranging from slightly acidic to sweet and are known for their unique aroma. Despite being underutilized, karonda fruits are processed to a variety of products with extra nutritional value (Fig. 5), such as alcoholic drinks (72), jam (73), ready-to-serve beverages (74), pastries (75), salsa (76), vadiyam (77) and squash (78). One of the most popular products is candied fruit, which serves as a substitute for cherries in the confectionery sector (79). Additionally, the white latex found in their unripe fruits is utilized in the production of chewing gum and rubber (29). Additionally, low power (200 W) microwave drying and sun

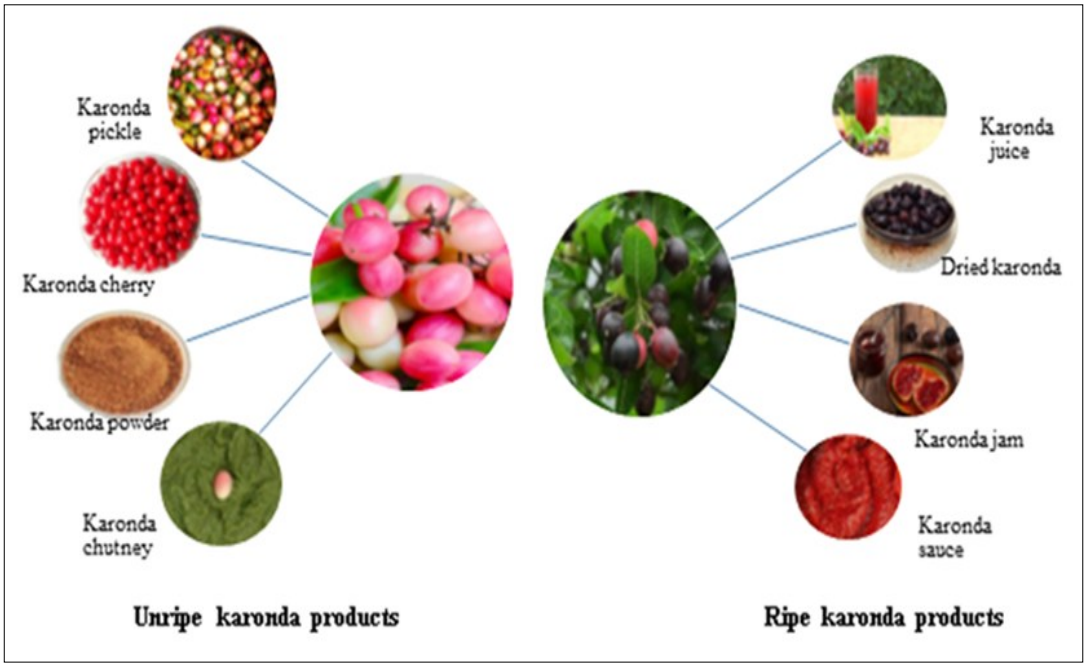

Fig. 5. Value added products of karonda.

drying offered the most effective processing methods for retaining maximum nutritional compounds including total phenols, flavonoids, anthocyanin, vitamin C, antioxidant activity and mineral contents in karonda powder (80). However, cabinet drying increased ascorbic acid retention and decreased non-enzymatic browning 70 days after harvesting (81). Osmotic pre-treatment with 5 % NaCl for 3 hr was extremely effective, yielding the maximum sensory score after four months of room temperature storage (82). Osmo-dried karonda made from 70° Brix sugar syrup had improved colour, texture, taste and acceptability based on sensory evaluations and may be stored for more than 90 days (83). Karonda juice can be blended with other fruit juices like guava, papaya and pineapple juices in different proportions. Combination of karonda juice with pineapple juice offered best organoleptic quality and acceptability (74). Preservation of imitation cherries from three karonda cultivars (Pant Manohar, Pant Sudarshan and Pant Suvarna) were studied, picking them at 40, 60 and 80 days after fruit set. The study indicated that imitation cherries from three karonda cultivars (Pant Manohar, Pant Sudarshan and Pant Suvarna) were studied, picking them at 40, 60 and 80 days after fruit set. The study indicated that imitation cherries made from Pant Suvarna at 80 days after fruit setting retain good nutritional content and sensory qualities even after 9 months of storage (19).

Challenges

Owing to spiny nature, harvesting is difficult. Lesser sale in local markets and processing facilities is also not available at many growing places for additional produce. Agro-techniques have not yet been standardized for different growing regions.

Future thrusts

Maintaining germplasm block comprising of all genetic variability including varieties, species and variants and their conservation. Expansion of karonda cultivation in wastelands, arid and semi-arid regions of country. Precise nutrient and irrigation management through fertigation for different agro-climatic regions including arid and semi-arid climate need to be standardized. It is necessary to develop post-harvest technology, value addition and effective marketing strategies for karonda products.

Conclusion

As demand for nutrient dense fruits is increasing day by day, people are favouring plant based supplements to supplement their nutritional demand. Earlier these minor fruit crops were fulfilling the needs of local populace only; however, with growing health awareness, the demand of fruit/products of it is increasing in urban and metropolitan areas. Therefore, this fruit can be categorized under 'Fruits for the future' and expansion and popularization of its cultivation need to be prioritized particularly in arid and semi-arid areas of the country. Efforts should be made to utilize available genetic resources for further improvement of this crop. Crop improvement methods such as hybridization, mutation and molecular breeding should be used alongside selection to develop cultivars tailored to specific region/industrial demands. Value addition and marketing avenues is need of the hour to increase the area under karonda cultivation in the country.

Authors' contributions

VPS and K conceptualised the work, carried out the systematic literature review and drafted the manuscript. VPS and RR carried out the graphical presentation. K, DSM, VY, PR, VK, OS, RK and AS wrote the manuscript, edited the manuscript and Literature survey. RR, DSM, OS and AS attended the editing work and coordination. VPS, K, DSM, RR, VK, OS, RK, AS, PR participated in editing the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

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