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Unraveling nutrient stress in aonla (*Emblica officinalis*) : comprehensive insights into research and utilization- a review

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Abstract

Aonla (*Emblica officinalis* Gaertn), also known as Indian gooseberry, is a time-honored fruit tree species belonging to the Euphorbiaceae family. Widely distributed across diverse ecological regions, aonla demonstrates remarkable adaptability to varying edapho climatic conditions. The crop is highly valued for its rich nutritional value, therapeutic properties, and significant post-harvest and industrial applications. Historically, aonla's pharmaceutical benefits have been documented in ancient litrature, both as a standalone remedy and in combination with other ingredients. To enhance the utilization and improvement of this invaluable genetic resource, it is crucial to delve into studies on its origins, diversity, and geographical distribution. To achieve a deeper insight into its taxonomy, systematics, and biological traits, including phenology, floral biology, and pollination mechanisms, detailed investigation is essential. In addition to fundamental biological aspects, agro-technologies, propagation methods, canopy architecture, and strategies for managing physiological disorders, pests, and diseases play a critical role in conserving aonla germplasm and boosting production. This review aims to comprehensively address these areas, offering insights into the genetic, ecological, and agronomic aspects of aonla cultivation, with a focus on its conservation and enhanced production techniques.

Key words: Indian gooseberry, *Emblica officinalis*, Crop improvement, Agronomy, Genetic resource, Biotechnology, High-density planting

Aonla (*Emblica officinalis* Gaertn), commonly known as Indian gooseberry, is a significant fruit crop native to India, cultivated across the country in a wide range of agro-climatic conditions (Tiwari *et al.*, 2007). Revered as a sacred tree, it has been referred to as 'Amritphal' in ancient texts. Beyond India, Aonla is found growing in natural forests across various regions, including Cuba, the USA, Pakistan, Sri Lanka, Malaysia, China, Java, and the West Indies. The fruit plays a pivotal role in Ayurvedic medicine, particularly in the preparation of well-known formulations such as Triphala and Chyavanprash (Tiwari *et al.*, 2008). Owing to its robustness, adaptability to diverse wasteland conditions, high productivity, and remarkable nutritional and therapeutic attributes, aonla has emerged as one of the most promising fruits of the 21st century. Aonla is known for its medicinal benefits, including its effectiveness in treating conditions like dysentery, diarrhea, jaundice, anemia, bronchitis, and cough. The fruit is commonly processed into various value-added products such as murabba, candy, pickles, and jellies. Additionally, aonla powder, known for its high vitamin C content, is considered superior to synthetic alternatives in combating deficiencies.

It is a highly adaptable plant, thriving in diverse agro-climatic conditions. Although classified as a subtropical fruit, it successfully grows in tropical, arid, and rainfed semi-arid regions. In India, it is cultivated from the coastal areas of South India to the foothills of North India, and natural plants can even be found up to 1,800 m above sea-level (Pathak, 2003; Malik *et al.*, 2010). Mature aonla trees are resilient to both freezing temperatures and heat up to 48°C, although they can be susceptible to frost during winter, particularly in the hot, arid ecosystems of Rajasthan (Pathak *et al.*, 1993.

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Genetic resources and varietal wealth

Aonla, a hardy and versatile fruit, has exhibited remarkable genetic variability across India, particularly in regions like Uttar Pradesh, Uttarakhand, Bihar, Gujarat, Madhya Pradesh, and Rajasthan (Bala *et al.*, 2009; Pathak, 2003). This genetic richness primarily stems from seedling propagation and wild relatives found in diverse agro-climatic zones, including the North-Eastern states of India (Pathak, 2003). However, the risk of genetic erosion is high due to deforestation, natural calamities, and the growing dominance of a few popular cultivars in select regions.

Although genetic erosion threatens aonla diversity, significant untapped variability persists among its wild and cultivated forms. Strategic exploration and conservation of these resources are crucial for improving resilience and productivity. Related *Emblica* species, including *E. fischeri* and *E. myrobalan*, may further enrich breeding programs through their stress-tolerant traits (Shukla *et al.,* 2005; Rai *et al.*, 1993; Chandra *et al.,* 1998). Over the years, numerous cultivars have been developed through systematic selection and evaluation of seedlings, particularly in regions like Uttar Pradesh. For instance, the Banarasi genotype, originally selected from wild trees in the Vindhyan hills, laid the foundation for commercial aonla cultivation. Similarly, other cultivars such as *Chakaiya* and *Francis* have been cultivated, although they come with specific limitations like small fruit size or susceptibility to disease (Pathak, 2003; Pandey *et al*., 2013).

Breeding and cultivar development

Breeding efforts have focused on selecting superior seedlings and cultivars with desirable traits like large fruit size, disease resistance, and high yield. Notable cultivars like NA-4, NA-5, NA-6, and NA-7 have been developed through seedling selection and are now commercially cultivated in different parts of India (Pathak, 2003). *NA-7,* in particular, is the leading cultivar, occupying the maximum cultivation area in the country.

Clonal selection from elite trees has also led to the development of high-yielding varieties like BSR-1 (43.05 t/ha), Goma Aishwarya, and Anand series (Pathak, 2003). However, challenges remain in ensuring stable yields and quality across diverse agro-climatic conditions. The introduction of biotechnological tools offers promising solutions to accelerate the development of disease-resistant and high-yielding cultivars.

Biotechnology and improvement

Conventional breeding methods have struggled to address certain challenges in aonla cultivation, such as susceptibility to diseases like leaf rust, wilt, and anthracnose. The plant's small flower size, varied chromosome numbers, and complex taxonomy have further complicated breeding efforts (Pathak, 2003). However, genetic engineering presents an exciting avenue for overcoming these obstacles.

Research has shown potential in developing transgenic aonla through somatic embryogenesis. A protocol for high-frequency somatic embryogenesis from juvenile leaf tissues has been successfully developed by Thilaga *et al*., (2013), providing a robust foundation for genetic transformation in aonla. In addition, protocols for in-vitro regeneration from various explants, including endosperm, epicotyls, and hypocotyls, have been reported, albeit with some variability in reproducibility.

Seed propagation and rootstock management

Seedlings raised from seeds are not true-to-type plants because they have prolonged juvenility and wide variability. Multiplication through seed is mostly done for raising rootstock. For these purpose seeds from fully mature fruits of *desi* trees should be taken. During March /April before rain, pretreated seeds are sown into the field or perforated polythene bag (40 cm × 15cm) under irrigated hot arid region. Seeds germinate within two weeks. Six months to one year old seedling is used as rootstock, and scion of desired varieties are patch budded on to them during the period from May to September for optimum success. Generally, the seed sown in first week of March in perforated polythene bag size (40 × 15cm) becomes ready for budding in July, which saves about six months, and also helps in effective nursery management than conventional methods (Saroj *et al*., 2001). For better germination and healthy seedling, seeds should be soaked in 500 ppm GA_3 over night. Effect of age and position of scion shoot on mineral composition in aonla has been reported by Awasthi *et al*., (1993). Murali, (1997) studied the pattern of seed size, germination and seed viability of tropical trees species in southern India.

Vegetative propagation

Among the various vegetative propagation methods for aonla, budding has proven to be the most practical and effective. Patch budding has consistently shown the highest success rates, followed by modified ring budding. For optimal success, budding operations should be carried out between mid-May and mid-August, though success remains significant if performed up to September (Pathak *et al*., 2006). For a more traditional method, softwood grafting on rootstocks raised in-situ for one year or more achieved a 70% success rate. *In-situ* patch budding is considered the most effective propagation method under dryland conditions. Singh and Singh (2014) reported that aonla seedlings become graftable when their stems reach about 3.0 cm in diameter at 5–6 months of age. The minimum size for rootstocks should be 0.5 cm in diameter at the time of budding or grafting. Moreover, cuttings treated with IBA (15000 ppm) and given bottom heat (33°C) showed 87.30% rooting success.

In terms of improving the chemical composition and growth of aonla seedlings, studies by Singh and Singh, (2002) explored the effects of gypsum and distillery effluent on shoot growth under north Indian conditions. They found that shoot regeneration was most successful when both BA (0.2 mg/l) and IBA (0.1 mg/l) were included in the media. In South India, where the climate allows extended propagation periods, aonla can be propagated almost 8-10 months a year, thanks to the use of greenhouses and net houses (Pathak, 2003). These controlled environments significantly extend the propagation window, leading to more efficient multiplication and stronger plant development. Overall, a combination of traditional and innovative propagation methods, along with optimal environmental conditions, has led to more efficient cultivation and improved aonla plant production across diverse agroclimatic regions.

Micropropagation

The micropropagating aonla comes with its own set of challenges, particularly in-vitro oxidative browning and contamination during shoot bud culture, which has been a persistent issue. To address the oxidative browning problem, various strategies have been developed, including explant waxing, which has shown about 80% success in initiating cultures, although it does delay bud induction and subsequent proliferation (Mishra *et al.*, 1998). The best time for initiating cultures under North Indian conditions has been found to be August to November, with the highest bud induction rate (76.4%) occurring during this period, followed by April to June. Shoots taken from the 10–15th nodes of slightly green and moderately hard stems yielded the best results, with indeterminate shoots being essential for further propagation (Mishra *et al.*, 2005). For shoot proliferation, Mishra *et al.*, (2006) found that a combination of 4.33 µM GA3, 13.9 µM Kinetin, and 342.11 µM Glutamine promoted the highest shoot proliferation rate—13.33 shoots per culture. A major challenge in aonla micropropagation, however, has been *in-vitro* leaf fall. This issue has been mitigated by the addition of Glutamine (342.11 µM) to the media, which has been found to reduce leaf drop, a common problem in tissue culture (Mishra *et al.*, 2006; Mishra and Pathak, 2001).

For *in-vitro* rooting, ½ MS medium supplemented with 49.20 µM IBA and 10.74 µM NAA has been found to work best for rooting aonla plantlets. This medium results in minimal callus formation at the base of the rooted plants, ensuring strong root development without unnecessary tissue growth. Acclimatization is a vital step in micropropagation, as the plantlets are prone to wilting and environmental stress during this period. The use of Paclobutrazol, a growth retardant, has shown promise in improving acclimatization by enhancing cuticular wax deposition, stomatal closure, and root thickening, thereby reducing wilting in plantlets. When grown in a substrate mixture of soil, sand, and compost, plantlets thrive better than in coconut husk substrates, which were prone to in-vitro leaf fall (Patidar *et al.*, 2010).

Additionally, successful regeneration of plantlets from mature endosperm explants has been reported on MS medium supplemented with auxins (2, 4-D or IAA) and cytokinins (Kinetin or BAP). Cultures grown with both BAP (0.2 mg/l) and IAA (0.1 mg/l) exhibited the highest shoot regeneration rates, resulting in the formation of plantlets and even embryo-like structures.

Other successful strategies have included the use of BMS medium supplemented with various growth hormones such as 2, 4-D and Kinetin to form callus and induce shoot formation. Moreover, secondary embryos derived from the culture also produced multiple shoots, which could be rooted using NAA or IBA to generate healthy, acclimatized plants..In conclusion, micropropagation of aonla holds great potential for the rapid and efficient mass production of planting material. While challenges like oxidative browning, leaf fall, and acclimatization need to be carefully managed, ongoing research and refinements in tissue culture protocols continue to enhance the success of this technique. By overcoming these obstacles, we can ensure a steady and reliable supply of high-quality aonla plants for commercial cultivation.

Planting and orchard establishment

For better orchard establishment, pits of 1 m^3 (1 m x 1 m x 1 m) are dug during May at a spacing of 8–10 m and exposed to the hot sun for about one month. Each pit is then refilled with the top one-third layer of surface soil thoroughly mixed with 20–25 kg of farmyard manure (FYM) and drenched with chlorpyriphos (Singh *et al.,* 2014f). Healthy budded plants are planted during rainy season, preferably soon after occurrence of first rain. Rootstock can also be raised *in-situ* at appropriate distance (8m x 8m or 10 x 10m) for budding with superior clone at pencil thickness stage to get maximum success particularly in semi-arid regions. For *in-situ* budding, rootstock should be planted in the already prepared pit in June and after 30-45 days budding may be carried out on them in the field itself.

High-density planting

A field trial was conducted to determine the effects of various planting systems and plant densities on vegetative growth pattern and their influence on yield and quality attributes of NA-7 aonla. The average plant height was recorded highest in double hedgerow system (8.87m) and the lowest in square system (7.95m), whereas the rootstock (60.52cm), scion girth (58.53cm) and plant spread (7.20m) was measured the maximum in square system of planting. However, these parameters were measured the lowest in double hedgerow followed by hedgerow and cluster planting systems. Results of the study revealed that the mean yield/plant (121.20 kg) was recorded the highest in square, but the yield/ha were recorded the maximum in double hedgerow (284.02 q) and it was the lowest in square system (121.20 q). An increase in yield/ha in double hedgerow system over square, paired, cluster, hedgerow system ranged between 25.62-134.34 per cent under semi-arid conditions, whereas an increase in yield in double hedgerow, hedgerow, cluster and paired over square systems was recorded 134.34, 121.10, 97.51 and 53.77 per cent purely under rainfed conditions (Singh *et al.,* 2014h). Among the different planting systems, the square system exhibited better values for physical qualities, whereas chemical attributes like TSS, total sugar, vitamin C and total phenols were observed the highest in double hedgerow followed by hedgerow planting system. (Singh *et al.,* 2024b; Singh *et al.,* 2007g; Singh *et al.,* 2005b; Singh *et al.,* 2024a; Singh *et al.,* 2011a; Singh *et al.,* 2014g; Singh *et al.*, 2010c; Singh *et al.*, 2014f). There were significant differences amongst different planting system with regards to fruit physico-chemical attributes. The net economic return was computed the highest in double hedgerow (₹ 2,34,020.00) and it was the minimum in square (₹ 1,01,200.00) system of planting under rainfed hot semi-arid conditions (Singh *et al.*, 2018a;Singh *et al.*, 2004h; Singh *et al.,* 2007a; Singh *et al.,* 2014b; Singh *et al.,* 2014a).

Irrigation management

Mature aonla orchards need no irrigation under normal rainfall. Avoid watering during flowering (February–March), but irrigate after applying manures and fertilizers if soil moisture is low. In areas facing water scarcity, the drip irrigation system has shown promising results and is particularly effective in rainfed conditions. Studies have demonstrated that plants irrigated through drip systems, with water applied every alternate day and 60% wetted area, experienced improved growth, yield, and fruit quality (Singh *et al.*, 2008c; Singh *et al.*, 2016c).

Additionally, construction of low-cost earthen dams and a series of check dams have had a significant positive impact on soil moisture conservation, thereby enhancing the productivity of fruit crops under the semi-arid conditions of Gujarat (Meshram *et al.*, 2008; Meshram *et al.*, 2009).

Training, pruning and canopy management

Aonla trees generally do not require regular pruning; however, during the early years, proper training and shaping are essential to develop a strong and well-balanced framework. To achieve this, the tree should be trained with a single stem up to a height of approximately 0.70 meters, and primary branches should be spaced evenly around the trunk. The recommended training method is the modified centre leader system, where the framework is developed by encouraging the growth of four to six well-spaced branches at a wide angle.

The main branches should emerge around 0.70 meters above the ground. Unwanted branches should be pinched off during March-April to maintain a balanced structure. In the following years, 4 - 6 branches should be allowed to grow. Subsequent pruning involves removing dead, infested, broken, weak, or overlapping branches after harvest. It is important to note that limb breakage has been observed in the aonla cultivar NA-7, particularly due to overbearing and narrow angles between branches and the main stem. Therefore, maintaining a balanced canopy is essential for this variety to ensure its structural integrity (Pathak *et al.*, 2006; Singh *et al.*, 2014f).

Integrated nutrient management

The dosage of manures and fertilizers for aonla cultivation depends on factors such as soil fertility, the age of the plant, and the desired production levels. For one-year-old aonla plants, a recommended dose of 15 kg of FYM (Farm Yard Manure), 100 g of nitrogen (N), 50 g of phosphorus (P), and 100 g of potassium (K) should be applied. This dose should gradually increase each year until the plant reaches ten years of age, after which a constant dose should be maintained (Singh, 1998). The growth, yield, and quality of aonla are significantly influenced by various nutrient sources. Additionally, the physical, biological, and chemical properties of the soil are also positively affected by organic nutrient sources.

Several nutrient sources, including biofertilizers like Azotobacter, Azospirillum, PSB (Phosphate Solubilizing Bacteria), and VAM (Vesicular Arbuscular Mycorrhiza), as well as organic matter such as FYM and cakes (neem, mahua, castor, and groundnut), have been proven beneficial for the sustainable production of high-quality aonla fruits (Korwar *et al.*, 2006; Yadav *et al.*, 2007;Singh *et al.*, 2008a;Singh *et al.*, 2012b;Singh *et al.*, 2007b;Singh, 2007;Singh *et al.*, 2014f). Among various organic nutrient sources, combinations such as FYM + neem Cake + CPP (Crop-Promoting Proteins) and FYM + Azotobacter + VAM have been particularly effective in improving soil fertility, enhancing microbial activity, increasing earthworm populations, and boosting both the yield and quality of aonla fruits under semi-arid conditions of western India (Pathak *et al.*, 2006;Singh *et al.*, 2007a;Singh *et al.*, 2008a;Singh *et al.*, 2012a;Singh *et al.*, 2012b;Singh *et al.*, 2014a;Singh *et al.*, 2014c).

Soil moisture conservation

In rainfed semi-arid regions, mulching with materials like paddy straw, maize straw, rice husk, grasses, or subabul loppings was practiced by applying about 20 kg per tree over a 4 m^2 basin area in September, with the mulch maintained for a prolonged duration. Organic materials like paddy straw, maize straw, grasses, and rice husk, which are locally available and easily decomposable, were applied in 20 cm thick layers after the rainy season. These mulching materials have been found to significantly improve soil quality, plant growth, and the yield of NA-7 aonla (Singh *et al.*, 2006; Singh *et al.*, 2014g; Singh *et al.*, 2007e and Singh *et al.*, 2008d). Each year, these materials were thoroughly incorporated into the basin soil at the end of the monsoon season.

Under rainfed conditions, organic mulching has proven to be very beneficial for the successful cultivation of aonla (Singh and Singh, 2004a;Singh *et al.*, 2015a;Singh *et al.*, 2014c;Singh *et al.*, 2010b). Mulches not only conserve soil moisture but also contribute multiple benefits to soil fertility, plant growth, and yield (Rao and Pathak, 1996a and 1998b). Even the leaf litter under the aonla tree canopy serves as an effective mulch, retaining moisture during summer months and improving soil properties.

Among mulching materials, highest average yield per plant (87.48 kg) was recorded with paddy straw mulch, followed by maize straw mulch (84.00 kg), grasses (80.37 kg), and rice husk (79.30 kg). The lowest yield was observed in the control group (76.29 kg) under rainfed conditions in the hot semi-arid ecosystem during the 10th year of orchard life (Singh *et al.*, 2008d). The yield in paddy straw mulch was 14.66% higher than in the control (Singh *et al.*, 2010). In terms of quality, the highest levels of total soluble solids (TSS) (9.50° Brix), total sugar (6.00%), and vitamin C (510 mg/g) were observed in the paddy straw mulch, while the lowest values were recorded in the control (Singh *et al.*, 2010b; Singh *et al.*, 2008a).This demonstrates that mulching, especially with organic materials like paddy straw, plays a key role in enhancing the yield and quality of aonla under rainfed semi-arid conditions.

Crop diversification

Aonla, being a deep-rooted deciduous tree with sparse foliage, is ideally suited for intercropping. The large space between rows and the 2-7 years required for the trees to reach economic production make aonla orchards perfect for cultivating intercrops in the interim. This not only provides growers with an additional source of income in the early years but also helps in maintaining maximum soil cover.

Under the rainfed conditions of Gujarat, cucurbitaceous vegetables such as bottle gourd, sponge gourd, bitter gourd, cucumber, and pumpkin can be successfully grown under aonla based cropping system. Economic analysis of aonla-based cropping systems

Fig.1: Intercropping in aonla orchard with A: bottle gourd and, B : cucumber. (source: Singh *et al.*, 2014f.)

Table 1. Net income, cost benefit ratio under different intercropping systems in aonla under rainfed hot semi-arid conditions

Inter crops	Details of cost and benefits from intercrops					Details of cost benefits from sole crop aonla							
	Produce of intercrop (q/ha)	Rate (₹/kg)	Cost of cultivation /ha (₹)	Gross income (₹)	Net income (₹)	Produce of main crop (q/ha)	Rate (Rs/kg)	Cost of cultivation (₹)	Gross income (₹)	Net income (₹)	Input costs (₹)	Total net Return (₹)	B:C ratio
Bottle gourd	79.95	15.00	18142.20	119925.00	101782.80	60.53	10	15000	60530.05	45530.50	33142.20	147312.80	4.44
Pumpkin	74.40	10.00	17225.00	074400.00	057175.00	58.35	10	15000	58350.03	43350.00	32225.00	100525.00	3.11
Bitter gourd	49.14	15.00	18035.50	073521.00	055485.50	56.03	10	15000	56030.50	41030.40	33035.50	96515.00	2.92
Cucumber	68.61	10.00	16054.83	068610.15	052555.17	52.85	10	15000	52850.15	37850.00	31054.83	90405.17	2.91
Sponge gourd	43.73	10.00	15147.57	043730.20	028582.43	59.50	10	15000	59500.00	44500.07	30147.57	73082.43	2.42
Control	--------	------	---------	----------	--------	64.65	10	15000	64650.30	49650.52	01500.00	49650.00	------

has shown that the highest net returns of Rs. 147,312.80 per hectare and Rs. 1,000,525.00 per hectare can be obtained from aonla + bottle gourd and aonla + pumpkin intercropping, respectively, in the semi-arid ecosystem (Singh *et al.*, 2013b;Singh *et al.*, 2008b;Singh *et al.*, 2007d). Detailed information on net income and cost-benefit ratios can be found in Table 1.

Hiwale, (2014) reported that aonla + okra intercropping yielded a net return of Rs. 72,505 per hectare without negatively affecting the aonla crop. Among other suitable intercropping options, guava (Sardar) and karonda can also serve as effective filler crops in aonla plantations (Singh, 1998). A variety of other intercrops like okra, bottle gourd, cauliflower, coriander, matricaria, gladiolus, and marigold have been successfully grown alongside aonla plantations) Krishna *et al.*, 2013; Krishna *et al.,* 2018).This intercropping strategy not only enhances farm profitability but also improves the sustainability of aonla orchards, making it a win-win for growers in semi-arid regions.

Fruit setting, fruit growth and development

In North India, aonla trees begin shedding their determinate shoots starting from February, leaving the indeterminate shoots devoid of foliage by mid-March. New determinate shoots emerge at the nodes from the scars left by the abscission of the previous season's determinate shoots, beginning in late-February and continuing through the first week of April. Blossom buds appear on the newly developed determinate shoots, but shoots that emerge after mid-April do not bear flowers (Pathak *et al.*, 2006).

The zygote remains dormant for 120-130 days, and the endosperm nucleus persists for 70-80 days after fertilization (Bajpai, 1968;Ram, 1971). After fruit set, the embryo stays dormant, and the ovary shows no noticeable external growth until mid-August. The fruit, however, grows rapidly during the rainy season from the second fortnight of August to the last week of September, completing around 70% of its growth during this period. Growth slows between the second week of October and the first week of November, then picks up slightly thereafter. The variability was observed among different germplasm of Aonla fruit such as small, medium and large. Growth ceases after November. Thus, the fruit growth of aonla follows a double sigmoid pattern.

Auxin levels rise in the fruit as dormancy sets in during April, gradually peaking by the end of May, then decrease in June, reaching their lowest levels in July before dormancy breaks. These elevated auxin levels halt fruit growth, a phenomenon confirmed by the application of IAA, which translocates from the shoot tip to the fruit. It was also found that external auxin applications do not break dormancy and shoot tips were found to contain similar auxin levels as dormant fruits. Additionally, restricting shoot growth and inducing flowering through defoliation from July to October prevents fruit dormancy. The levels of cytokinin and gibberellins were also found to be inadequate in dormant fruits.

Since aonla is self-incompatible, planting about 10% compatible varieties as pollinizers is recommended to ensure adequate fruiting. The physiology and vitamin content in aonla have been studied by Amal and Raghwan, (1957). Significant differences in the physical and chemical composition of aonla cultivars during their growth and development have been documented by Ojha and Pathak, in North India, and by Singh *et al.*, (2014b) under semi-arid conditions of western India.

Maturity, harvesting, yield and quality attributes

Aonla fruits should be harvested once they reach full maturity to ensure optimal quality. The maturity of aonla fruits can be assessed visually by the change in color from greenish to yellowish-green or light-green to pinkish tinge, along with a shift in seed color from creamy white to brown fig. In addition to these visual cues, physiological maturity can also be determined based on factors such as specific gravity (ranging from 1.07 to 1.24), fiber content, and TSS/acid ratio (which typically falls between 5 and 6).

Varieties like NA-7, Banarasi, and Agra Bold generally mature by the last week of October, while Kanchan and Chakaiya are ready for harvest by the last week of November. Varieties like Anand-1and Anand-2 mature by the last week of November under the semi-arid conditions of Gujarat (Singh *et al.*, 2008a; Singh *et al.*, 2006b).

For proper harvesting, aonla fruits should be individually picked and placed carefully in lined baskets to avoid bruising and spoilage. Figure 9 depicts the variability in fruit surface among different aonla germplasm, showing both shiny and dull types.Aonla trees begin fruiting from the third year after budding, with commercial yields typically starting from the fifth year. Under rainfed conditions in Gujarat, when planted at a spacing of 10m × 10m, 10-year-old trees of varieties like *Chakaiya, NA-7, Francis, Kanchan,* and *Krishna* yield 14-15, 15-18, 13-15, 8-9, and 7-8 tons per hectare, respectively (Hiwale, 2015; Singh,2007). The yield and quality attributes of various aonla cultivars have been thoroughly studied. Furthermore, the physico-chemical characteristics of aonla cultivars have been examined under the rainfed semi-arid conditions of Gujarat.

Post-harvest handling, storage and value-addition

Aonla fruits can be stored on the tree itself for up to 30 days post-maturity without a significant loss in quality

(Singh *et al.,* 2007c). Varieties such as Chakaiya and Anand-2 have a shelf life of 7 days, while Francis, NA-7, and Banarasi*can* last up to 5 days at ambient temperature after harvesting. However, when stored in brine solution, the shelf life can be extended up to 75 days. The fruits of NA-7, Banarasi, and Agra Bold mature by the last week of October, while Kanchan and Chakaiyaare ready for harvest by the last week of November. Additionally, Anand-1 and Anand-2 mature by the last week of November under the semi-arid conditions of Gujarat.

Treating aonla fruits with chemicals and storing them in a zero-energy cool chamber significantly enhance their shelf life (Singh *et al.*, 2010). Effects of post-harvest treatments such as calcium nitrate (1%), GA3 (50 ppm), and Borax (4%) on the shelf life of aonla fruits. They found that physiological weight loss and pathological damage increased with longer storage periods. Calcium nitrate (1%) minimized weight loss, while Borax prevented pathological loss for up to 9 days of storage. Among aonla varieties, NA-10 and Krishnashowed a better shelf life of 10 days, retaining high vitamin C content and a glossy green appearance. In contrast, *NA-7* fruits could be stored for 6-8 days (Scartezzini *et al.*, 2006) under North Indian conditions.

Five aonla varieties (Banarasi, Chakaiya, Francis, Kanchan, and Krishna) were assessed for their yield performance, physico-chemical properties, and sensory quality of processed products. The study revealed that Kanchan and Krishnaare suitable for making candy and jam, while *Banarasi* is best for drying (Pragati *et al.*, 2003). The Chakaiyavariety, known for its desirable attributes, received the highest scores for products such as pickles, chutneys and syrups.

The shelf-life of aonla fruits can be further enhanced by grading, packaging, and using pre- and post-harvest chemical treatments, as well as plant hormone sprays (Singh and Singh, 2006; Kumar *et al.,* 2013). After harvesting, fruits should be graded based on their size and shape. Grade A fruits (with a diameter and length greater than 4.00 cm) are ideal for making *murabba* and candy, Grade B fruits (smaller size) are used for *chavanprash* and *trifla,* while Grade C fruits, which are blemished, are suitable for powder and shampoo production. In the hot semi-arid ecosystem of Gujarat, fruits treated with calcium nitrate (1.5%) or GA3 (50 ppm) and stored in perforated polythene bags showed the least physiological weight loss (2.12-16.00%) and spoilage (2.40-15.60%) and exhibited a shelf life of 11 days (Singh *et al.*, 2007b).

For packaging, wooden crates with a 20-25 kg capacity lined with polyethylene bags and CFB boxes (10 kg capacity) with newspaper liners are most effective for long-distance transportation, while for local markets, fruits are collected and transported in plastic crates lined with newspaper.

Studies on changes in ascorbic acid and total phenols during the processing of aonla products have been conducted by Agarwal and Chopra, (2004). They found that decay loss was lowest (26.56%) under modified storage conditions by the 24th day, while the highest decay loss (48.70%) occurred in the zero-energy chamber. Aonla fruits can also be stored in cold storage for 7-8 days at 0-2°C and 85-90% relative humidity.

Although, aonla is not typically consumed as a table fruit, it has significant commercial value in processing industries. The fruits are used to produce a variety of products such as *murabba,* candy, chutney, toffee, shreds, sauce, pulp, powder, juice, laddu, supari, liqueur, sharbat, and Ayurvedic medicines like *chawanprash, trifla,* syrup, diabetic powder, and aonla powder. Additionally, it is used in the cosmetic industry for products like shampoo, hair oil, and dyes (Goyal *et al.*, 2008).

Pests management

Aonla is generally resistant to serious diseases; however, insect pests can cause significant damage, particularly under favorable environmental conditions. The key pests affecting aonla and their recommended control measures are outlined here. To enhance the production potential of aonla, effective and economical Integrated Pest Management (IPM) strategies have been developed, taking into account the seasonality and peak occurrence periods of these pests.

Notable pests of aonla include aphids (*Cerciaphis emblica*), mealy bugs (*Nipaecoccus vastator*), leaf twisters (*Caloptilia acidula*), hairy caterpillars (*Euproctis flava*), shoot gall makers (*Betousa stylophora*), fruit borers (*Virochola isocrates, Meridarchis scyrodes*), and bark-eating caterpillars (*Inderbela terraonis* Moore) (Pathak *et al.*, 2006;Singh *et al.*, 2014f). Orchard sanitation plays a vital role in managing bark-eating caterpillars and borers. Injecting kerosene or petrol, applying Diclorvos, and sealing the holes with mud are effective methods for controlling bark-eating caterpillars.

For general pest management, a tri-weekly application of Dimethoate (0.05%) in the evening is recommended, as it effectively controls a wide range of pests. Based on pest seasonality, a schedule alternating Dimethoate (0.05%) with 5% NSKE (Neem Seed Kernel Extract) every 10 days, from fruit set to fruit development, has proven highly effective in reducing borers in aonla (Pathak *et al.*, 2006; Bajpai,1957; Singh *et al.*, 2010c). For bark-eating caterpillars, spraying Dimethoate at 1.5 ml/l in the evening, every 15 days in January, has also shown significant control (Singh *et al.*, 2007d).

Diseases management

Rust (*Ravenaliia emblicae*), anthracnose (*Colletotrichum* state of *Glomerella cingulata*), and Penicillium fruit rot (*Penicillium indicum*, *P. oxalicum*, *Aspergillus niger*) are significant diseases that cause considerable losses to aonla growers (Singh *et al.*, 2010c). To effectively manage rust, a spray of 2% wettable sulphur or 0.2% Mancozeb 75 WP should be applied at 10-12 day intervals starting in August. For anthracnose control, sprays of 0.2% Mancozeb 75 WP, 0.3% Cuman-L, 0.2% Captaf, 0.2% Chlorothalonil, or 0.3% Copper oxychloride are recommended, along with practices like deep ploughing and healthy cultivation. Penicillium fruit rot, primarily a post-harvest issue, can be controlled by sorting and destroying infected fruits, and avoiding injuries during harvesting, handling, transportation, or storage. Pre-harvest sprays (one week before harvesting) with Blitox, Bavistin, or KH_2PO_4, and post-harvest treatments with 1.5% $CaCl_2$ and 200 ppm GA_3, have also proven effective in managing the disease (Singh *et al.*, 2014f;Singh *et al.*, 2010c).

Physiological disorder

Fruit necrosis, a physiological disorder in aonla, has been associated with boron deficiency. The disorder initially manifests as browning of the mesocarp, which gradually extends to the epicarp, resulting in a brownish-black discoloration of the fruit flesh. This issue can be managed by spraying a 0.6% borax solution three times at 15-day intervals, starting from early September (Pathak, 2003; Pathak *et al.*, 2006).

CONCLUSION AND FUTURE THRUST

Aonla holds immense potential to contribute substantially to India's economy, underscoring the need for its wider popularization. This can be achieved through the development of new self-fruitful cultivars possessing desirable horticultural traits and by expanding its cultivation in arid and semi-arid regions. To enhance the crop's performance, emphasis must be placed on harnessing available genetic resources through extensive exploration and germplasm collection. In addition to selection, further research on the inheritance patterns of specific traits is essential. Advanced breeding techniques, including hybridization, mutation breeding, and molecular approaches, should be adopted to expedite the development of aonla cultivars suited to specific industrial and regional requirements. Furthermore, intensified research on high-density planting systems, value addition, and efficient marketing strategies will be instrumental in boosting the production and productivity of aonla.

REFERENCES

Bajpai, P. N. 1968. Studies on flowering and fruit development in aonla (*Emblica officinalis* Gaertn). *Horticultural Advances,* VII: 38-67.

Bala S, Ram S and Prasad J. 2009. Studies on variability and genetic diversity in selected aonla genotypes. *Indian Journal of Horticulture* **66 (4)**: 433-43.

Baliga M S, Meera S, Mathai B, Rai M P, Pawar V and Palatty P L. 2012. Scientific validation of the ethnomedicinal properties of the *Ayurvedic* drug *Triphala*: a review. *Chinese Journal of Integrative Medicine* **18**: 946-54.

Chatterjee M and Sil P C. 2007. Protective role of *Phyllanthus niruri* against nimusulide induced hepatic damage. *Indian Journal Clinical Biochemistry* **22**:109–116.doi: 10.1007/BF02912892.

Drury, H. 1873. The useful plants of India (2nd ed.), Wm. H. Allen & Co., London.

Gaire BP and Subedi L. 2015. Phytochemistry, pharmacology and medicinal properties of *Phyllanthus emblica* Linn. *Chinese Journal of Integrative Medicine* DOI: 10.1007/s11655-014-1984-2

Ghosh G N, Roy S and Bera B. 2013. Study on performance of aonla cultivars in laterite soil of West Bengal. *Journal of Crop and Weed* **9 (2)**: 36–38.

Golechha M, Bhatia J, Ojha S and Arya D S. 2011. Hydroalcoholic extract of Emblica officinalis protects against kainic acid-induced status epilepticus in rats: evidence for an antioxidant, anti-inflammatory, and neuroprotective intervention. *Pharmaceutical Biology* **49**: 1128-36.

Goyal R K, Patil R T, Kingsly A R P, Walia H and Kumar P. 2008. Status of post harvest technology of aonla in India -A review. *American Journal of Food Technology* **3** : 13-23.

Hiwale, S. 2015. Aonla In: Sustainable Horticulture in Semi-arid drylands. Springer India Pvt. Ltd. pp. 83-96.

Hiwale S S and Singh A K. 2014. Aonla based cropping system. *Technical Bulletin,* Pub. CHES (ICAR-CIAH), Godhra, pp. 1-29.

Korwar G R, Pratibha G, Ravi V and Palanikumar D. 2006. Influence of organic and in organics on growth, yield of aonla (*Emblica officinalis* Gaertn) and soil quality in semi-arid tropics. *Indian Journal of Agricultural Sciences* **76** : 457-61.

Krishna H, Saroj P L, Jatav M K and Awasthi O P. 2018. Fruit based cropping models to increase farmer's income- An experience of arid region. CIAH/ Tech./ Pub. No. 70, Pub. ICAR-CIAH, Bikaner, Rajasthan, India pp. 61.

Krishna H, Singh I S, Bhargava R and Sharma S K. 2013. Fruit-based cropping systems for sustainable production. ICAR News **19 (2)**: 9.

Kumar, A. D. 2007. Pharmacognostical investigations on *Triphala churnam*. *Ancient Science of Life* **26**: 40-44.

Kumar R, Syamal M M, Dwivedi SV, Anand R K and Vishwanath. 2013. Studies on variability in physico-chemical properties of aonla (*Emblica officinalis* Gaertn) genotypes *The Asian Journal of Horticulture* **8 (2)**:706-8.

Kumar S G, Nayaka H, Dharmesh SM and Salimath P V. 2006. Free and bound phenolic antioxidants in amla (*Emblica officinalis*) and turmeric (*Curcuma longa*). *Journal of Food Composition and Analysis* **19**:446–52. doi: 10.1016/j.jfca.2005.12.015.

Malik S K, Chaudhury R, Dhariwal O P and Bhandari D C. 2010. *Emblica officinalis* (aonla) In: Genetic Resources of Tropical Underutilized Fruits in India. NBPGR, New Delhi, pp. 70-73.

Meshram D T, Appa Rao V V, Singh A K and Mittal H K. 2009. Low cost earthen dam for maximization of fruit crops production in semi-arid region. *Journal of Soil and Water Conservation* **2 (2)**: 30-34.

Meshram D T, Appa Rao V V, Singh A K, Bagle B G and Dhandar D G. 2008. Planning, designing and construction of series of check dams for soil and water conservation in micro-watershed. *Journal of Agro Meteorology* **10 (1)**: 27-32.

Mishra M, Pati R and Chandra R. 2006. Clonal micro propagation of Indian gooseberry (*Emblica officinalis* Gaertn). *Indian Journal of Genetics and Plant Breeding* **66 (4)**: 359-60.

Mishra R S, Pathak R K and Ojha C B. 2005. Effect of seasonal variation and shoot characteristics on bud induction in Emblica officinalis Gaertn. *Indian Journal of Horticulture* **62(1)**: 52–54.

Mythilypriya R, Shanthi P and Sachdanandam P. 2007. Analgesic, antipyretic and ulcerogenic properties of an indigenous formulation- Kalpaamruthaa. *Phytotherapy Research* **21**: 574-78.

Pahak R K Ram R A and Shukla S K. 2005. Cultivating aonla organically. *Indian Horticulture* **50**:4-9.

Pandey D, Pandey G and Tripathi M. 2013. Variability in aonla (*Emblica officinalis* Gaertn.) accessions collected from Madhya Pradesh. *The Asian Journal of Horticulture* **8 (2)**: 706-7.

Pathak, R. K. 2003. Status Report on Genetic Resources of Indian Gooseberry-Aonla (*Emblica officinalis* Gaertn.) in South and Southeast Asia. IPGRI Office for South Asia National Agriculture Science Centre (NASC) DPS Marg, Pusa Campus, New Delhi, India, pp.1-96.

Pathak R K and Pathak S. 2001. Fruit production in problematic soil. *Indian Journal of Horticulture* **58** :16-22.

Pathak R K and Tiwari R K. 2002. Cost effective comprehensive technology for aonla cultivaion in sodic soils. (In) Workshop on Recent Advances in Sodic Land Reclamation Technology, UPCAR, Lucknow, pp. 55-60.

Pathak R K, Singh S and Saroj P L. 2006. Aonla (*Emblica officinalis*). In: Advances in Arid Horticulture (Eds P. L. Saroj and O. P. Awasthi), IBD Co. Lucknow.

Patidar D K, Tripathi M K, Tiwari R, Baghel B S and Tiwari S. 2010. *In-vitro* propagation of *Emblica officinalis* from nodal segment culture. *Journal of Agricultural Technology* **6 (2)**: 245- 256.

Poltanov E A, Shikov A N, Dorman H J, Pozharitskaya O N, Makarov V G and Tikhonov VP.2009. Chemical and antioxidant evaluation of Indian gooseberry (*Emblica officinalis* Gaertn, syn. Phyllanthus emblica L.) supplements. *PhytotherapyResearch* **23** :1309-1315.

Pragati S, Dahiya and Dhawan SS. 2003. Effect of drying method on nutrition composition of dehydrated aonla fruit. *Plant Food for Human Nutrition* **58**: 921-928.

Sahu G D, Singh P and Singh A K. 2010. Studies on the physico chemical changes in aonla preserve (*murabba*) of three cultivars during storage. *Research Journal of Agricultural Sciences* **1 (4)**: 419–25.

Sandhya T, Lathika KM, Pandey BN and Mishra K P. 2006. Potential of traditional *Ayurvedic* formulation, Triphala, as a novel anticancer drug. *Cancer Letters* **231**: 206-214.

Saroj PL, Nath V and Vashishtha VV. 2001. Effect of poly containers on germination, seedling vigour, root characters and budding success in aonla. *Indian Journal of Horticulture* **57 (4)**: 300-4.

Scartezzini P, Antognoni F, Raggi MA, Poli F and Sabbioni C. 2006.Vitamin C content and antioxidant activity of the fruit and of the Ayurvedic preparation of *Emblica officinalis* Gaertn. *Journal of Ethnopharmacology* **104** : 113-18.

Sharma, O. C. 2003. Intra-specific variability and selection of promising type of aonla (*Emblica officinalis* L.) in Solan area of Himachal Pradesh. *Himachal Journal of Agricultural Research* **29 (1&2)**: 52-58.

Shukla A K, Samadia D K, Shukla AK and Dhandar D G. 2005. Genetic Resources of Aonla (*Emblica of ficinalis* Gaertn.). *Indian Journal of Plant Genetic Resources* **18 (2)**: 188-193.

Singh A K, Singh P P, Singh S, Bhargava R and Makwana P. 2014. Variability in morphological and physico-chemical traits of aonla (*Emblica officinalis* genotypes collected from north-eastern region of India. *Indian Journal of Agricultural Sciences* **86(8)**: 992-97.

Singh, A. K. 2007.Effect of alkalinity on aonla buddlings cv.Chakaiya as influenced by gupsum. *Orissa Journal of Horticulture* **35(2)**:78-83.

Singh A K and Singh R S. 2014a. Aonla. In: Propagation of Horticultural plants of Arid and Semi-Arid regions (Eds. R. S. Singh and R. Bhargava). New India Publishing Agency, New Delhi, pp.177-88.

Singh A K and Singh S. 2007. Preliminary studies on high density planting system in NA-7 Aonla (*Emblica officinalis* Gaertn). *Orissa Journal of Horticulture* **35 (1)**: 81-85.

Singh A K, Singh P P, Singh S and Makwana P. 2016a. Biodiversity in aonla for future. *Indian Horticulture* **61 (2)**:17-18.

Singh A K, Singh P P, Singh S, Bhargava R and Makwana P. 2014b.Variability in morphological and physico-chemical traits of aonla (*Emblica officinalis* Gaertn) genotypes collected from north-eastern region of India. *Indian Journal of Agricultural Sciences* **86 (8)**: 992-97.

Singh A K, Singh S, Appa Rao V V, Singh R S and Makwana P. 2013b. Production potential and economics of aonla based cropping system under rainfed semi-arid ecosystem of western India. *Indian Journal of Arid Horticulture* **8 (1&2)**:18-20.

Singh A K, Singh S and Appa Rao V V. 2011a. Double hedgerow planting system in aonla production. *Rashtriya Krishi* **6 (2)**:75-79.

Singh A K, Singh S and Appa Rao V V. 2012b. Influence of organic and inorganic sources of nutrients on soil properties and quality of aonla under hot semi-arid ecosystem. *Indian Journal of Horticulture* **69 (1)**:50- 54.

Singh A K, Singh S and Joshi H K. 2013a. More aonla in lesser area. *Indian Horticulture* **58 (2)**:17-18.

Singh A K, Singh S and Makwana P. 2015a. Characterization of aonla varieties under zero irrigation semi-arid conditions. *Indian Journal Agricultural Sciences* **85 (10)**: 217-21.

Singh A K, Singh S, and Appa Rao V V. 2014c. Mulching enhances aonla yield in rainfed areas. *Indian Horticulture* **59 (2)**:29-31.

Singh A K, Singh S, Appa Rao V V, Hiwale S S, Joshi H K and Sharma S K. 2012a. Effect of organic manure and biofertilizers on soil properties and growth of aonla under rainfed condition of hot semi-arid environment. *Indian Journal of Arid Horticulture***7 (1&2)**: 45-48.

Singh A K, Singh S, Appa Rao V V and Meshram D T. 2008d. Effect of mulching on soil properties, growth and yield of aonla (*Emblica officinalis* Gaertn) in semi-arid ecosystem. *Indian Journal of Agricultural Sciences***78 (3)**:193-97.

Singh A K, Singh S, Appa Rao V V, Hiwale S S and Joshi H K. 2014h. Dynamics of vegetative morphomatrix, productivity and economics of NA-7 aonla (*Emblica officinalis* Gaertn) in different planting systems under rainfed conditions. *Indian Journal of Agricultural Science* **84 (9)**: 21-26.

Singh A K, Singh S, Appa Rao V V, Bagle B G and More T A. 2010b. Efficacy of organic mulches on soil properties, earthworm population, growth, and yield of aonla cv. NA-7 in semi-arid ecosystem. *Indian Journal of Horticulture* **67(special issue)**: 124-28.

Singh A K, Singh S, Appa Rao V V, Bagle B G and More T A. 2007b. Effect of organic and inorganic sources of nutrients on soil properties, growth, yield and quality of aonla (*Emblica officinalis* Gaertn).2nd Indian Horticultural Congress, on Opportunities and Linkage for Horticulture Research and Development (North-East region), 18-21 April, ICAR, Complex for NE Region, Barapani, Meghalaya, pp.155.

Singh A K, Singh S, Appa Rao V V, Hiwale S S and Joshi H K. 2014a. Long term effect of INM on aonla and soil quality under rainfed hot semi-arid environment. *Indian Journal of Agricultural Sciences***84 (5)**: 37-40.

Singh A K, Singh S, Appa Rao V V, Meshram D T and Bagle B G. 2007c. Influence of organic mulch on soil and nutrient concentration of aonla shoots cv. NA 7 under semi arid ecosystem. *Orissa Journal of Horticulture* **35 (2)**: 87-91.

Singh A K, Singh S, Appa Rao V V, Meshram D T and Bagle B G. 2007e. Influence of organic mulches on soil, temperature, moisture and growth of aonla cv. NA- 7 under rainfed conditions. *The Horticultural Journal* **20 (2)**: 71-75.

Singh A K, Singh S, Appa Rao V V, Meshram D T, Bagle B G and More T A. 2010c. High density planting system in aonla. Pub. CHES (ICAR-CIAH), pp.1- 15.

Singh A K, Singh S, Appa Rao V V, Meshram D T, Bagle B G and Dhandar D G. 2007g. Efficacy of planting system on productivity and economics of aonla cv. NA-7 under rainfed conditions. *The Horticultural Journal* **20 (2)**: 67-70.

Singh A K, Singh S, Appa Rao VV, Hiwale S S, Bagle B G and More T A. 2008c. Response of young aonla trees to drip irrigation. Paper presented in Third Indian Horticulture Congress on New R & D Initiatives in Horticulture for Accelerated Growth and Prosperity, organized by The Horticultural Society of India, New Delhi, during 06-09 November, Bhubaneswar p.16.

Singh A K, Singh S, Hiwale S S, Appa Rao V V, and Joshi H K. 2014f. Production technology of aonla under rainfed conditions of western India. *Technical Bulletin*, Pub. CHES (ICAR-CIAH), pp.1-36.

Singh A K, Singh S, Makwana P and Contractor K. 2014g. Characterization of aonla (*Emblica officinalis* Garten) varieties under rainfed semi arid condition of western India. Global Conference on Technological Challenge and Human Resources for Climate Smart Horticulture- Issue and Strategies during May, 2014, NAU, Gujarat, pp. 50.

Singh A K, Singh S, Mishra D S and Saroj P L. 2016c. More crop with minimal water. *Indian Horticulture* **61(6)**: 86-91.

Singh A K, Singh S, Mishra D S and Saroj P L. 2018a. Aonla for economic and health security in dryland. *Indian Horticulture* **63 (1)**: 36-40.

Singh AK, Pandey D, Gangadhara K, Yadav L P, Rane J, Krishna H, Devanand G, Anil P, Sahil A and Ravat P. 2024a. Descriptors for characterization and evaluation of Indian gooseberry (*Emblica officinalis* Gaertn) germplasm for utilization in crop improvement. *Genet Resour Crop Evol* (2024). https://doi.org/10.1007/s10722-024-02135-8.

Singh AK, Singh S, Appa Rao V V, Bagle B G and More T A. 2011b. Effect of high density planting systems on the productivity of NA-7 aonla (*Emblica officinalis* Gaertn) under rain fed conditions of semi-arid ecosystem. *Indian Journal of Horticulture* **68 (4)**: 461-65.

Singh B P, Pandey G, Sarolia D K, Pandey M K and Pathak R K. 2005. Shelf life evaluation of aonla cultivars. *Indian Journal of Horticulture* **62(2)**:137-40.

Singh, I. S. 1998. Aonla production technology- A Bulletin, Deptt. of Hort. N.D.U.A.&T., Faizabad, Uttar Pradesh.

Singh I S and Pathak R K. 1987. Evaluation of aonla (*Emblica officinalis* Gaertn) varieties for processing. *Acta Horticulturae* **208**:173-78. DOI: 10.17660/ *Acta Hortic*. 1987.208.19.

Singh I S, Babita and Rajan S. 2009. Influence of climate on flowering and fruiting behaviour of aonla (*Emblica officinalis* Gaertn.). Indian Journal of Horticulture **66(1)**: 100–4.

Singh S and Singh A K. 2006a. Effect of size grading on quality and shelf life of aonla. *Progressive Horticulture* **38 (2)**:218-23.

Singh S, Singh A K and Joshi H K. 2003. Storage behaviour of Indian gooseberry (*Emblica officinalis* Gaertn) cultivars under semi-arid ecosystem of Gujarat. *Indian Journal of Agricultural Sciences* **73 (10)**: 530-34.

Singh S, Singh A K and Joshi H K. 2005b. Prolonging storability of Indian gooseberry under semi-arid ecosystem of Gujarat. *Indian Journal of Agricultural Sciences* **75 (10)**: 647-50.

Singh S, Singh A K and Joshi H K. 2006b. Standardization of maturity indices in Indian Gooseberry (*Emblica officinalis* Gaertn) under semi-arid conditions of Gujarat. *Indian Journal of Agricultural Sciences* **76 (10)**: 591-95.

Singh S, Singh A K and Joshi H K. 2008a. Standardization of maturity indices in aonla (*Emblica officinalis* Gaertn) under semi-arid environment of Western India. *Annals of Arid Zone* **47 (2)**: 209-12.

Singh S, Singh A K, Joshi H K and Appa Rao V V. 2007d. Effect of various post harvest treatments on shelf life of aonla (*Emblica officinalis*) cv. Chakaiya. *Orissa Journal Horticulture* **36 (1)**:8-15.

Singh S, Singh A K, Joshi H K and Bagle B G. 2007a.Post harvest management in aonla. *Asian Science* **2(2)**:18-20.

Singh S, Singh A K, Joshi H K, Bagle B G and Dhandar D G. 2008b. Evaluation of packages for transportation and storability of aonla (*Emblica officinalis* Gaertn) under semi-arid environment of western India. *Journal of Food Science and Technology* **46 (2)**: 127-31.

Singh S, Singh A K, Joshi H K, Bagle B G and Dhandar D G. 2006.Heat unit summation-an index for predicting fruit maturity in aonla (*Emblica officinalis* Gaertn.) under semi-arid tropics of western India. 8th Indian Agricultural Scientists and Farmers Congress, held at B.H.U., Varanasi 21-22, February, pp.123.

Singh S, Singh A K, Joshi H K, Bagle B G and More T A. 2010. Effect of zero energy cool chamber and post harvest treatments on shelf life of fruits under semi- arid environment of western India Part-2 Indian gooseberry fruits. *Journal of Food Science and Technology* **47 (4)**: 450-53.

Singh S, Singh A K, Joshi H K, Bagle B G and More T A. 2007b. Prolonging shelf-life of Indian Gooseberry (*Emblica officinalis* Gaertn) under semi-arid environment. 2nd Indian Horticultural Congress, on Opportunities and Linkage for Horticulture Research and Development (North-East region), 18-10 April, 2007, ICAR, Complex for NE Region, Barapani, Meghalaya, pp. 298.

Singh S, Singh A K, Joshi H K, Bagle B G and More T A. 2007c. Impact of tree storage on fruit quality attributes of Aonla under semi arid ecosystem of western India. Paper was presented in the National seminar on Recent Advances in Production, Protection and Post Harvest Management of Grape, Mandarin and Arid Fruits during March 17-18,2007 at KNK college of horticulture, Mandasaur, M.P. pp. 106.

Supe V S, Shete MB, Chavan U D and Kaulgud S N. 1997. Physico-chemical analysis of different aonla (*Emblica officinalis*) cultivars under Maharashtra conditions. *Journal of Maharashtra Agricultural Universities* **22(3)**: 310–12.

Tandon D K, Yadav R C, Sood S, Kumar S and Dikshit A. 2003. Effect of blanching and lye peeling on the quality of aonla candy. *Indian Food Packer* **57**: 147-49.

Tandon, P. 2000.Aonla market potential and challenges. Paper presented in National Seminar on 'Uttar Pradesh mein Aonla Vikas' held at Pratapgarh (UP) from 21-22 October, 2000.

Tarai R K and Ghosh S N. 2005. Effect of N level on yield fruit quality and foliar NPK status of aonla grown on laterite soil. *Indian Journal of Horticulture* **62**: 394-95.

Tewari R K and Bajpai C K. 2002. Studies on quality parameters of scion and root stock on success of grafting in aonla. *Indian Journal of Agroforestry* **4 (2)**: 138-40.

Thilaga S, Muthaiah J, Virgin L, Parameswari A, Nair R R and Ganesh D. 2013. High frequency somatic embryogenesis from leaf tissue of *Emblica officinalis* Gaertn - A high valued tree for non-timber forest products. *Australian Journal of Crop Science* **7(10)**:1480-87.

Tiwari J P, Mishra D S, Chand S and Kumar R. 2008. Aonla: A Potential Fruit Crop of India. *Indian Farmar's Digest* **41 (2)**: 12-14.

Tiwari J P, Mishra D S, Misra K K and Mishra N K. 2007. Aonla. In: Singh, Jitendra (ed.). Medicinal and Aromatic Crops. Avishkar Publishers and Distributors, Jaipur, pp. 112-123.

Yadav R, Baksh H, Singh H K and Yadav A L. 2007. Effect of integrated nutrient management on productivity and quality of aonla (*Emblica officinalis* Gaertn.) cv. Narendra Aonla-7. *Plant Arch***7**: 881-883.

Yamdagni, R. 1983 Salt tolerance of arid zone fruits- A review. II. National Workshop on Arid Zone Fruit Research. 8-10 July 1983, Udaipur, Rajasthan.