

AONLA

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INTRODUCTION

Aonla or Indian gooseberry (*Emblica officinalis* Gaertn. Syn. *Phyllanthus emblica*) is one of the important indigenous fruits of Indian subcontinent, known for its medicinal and therapeutic properties and considered as a wonder fruit for health conscious population. It has been grown and known in India for last more than 3500 years. In fact, it finds a special mention in ancient Indian text 'Ayurveda' by Sushruta, the father of ancient medicine (during 1500 BC-1300 BC). Different vernacular names are associated with aonla in different parts of India such as

Regional names

Amla or Aonla	- Hindi
Dhatri, Dhatriphala, Amalaki	- Sanskrit
Amla or Amalaki	- Bengali and Oriya
Nelli	- Malayalam and Tamil
Amlakamu, Usirikai, Usirika	- Telugu
Amolphal	- Punjabi (Gurmukhi)
Aonla, Myrobalan, Indian gooseberry	- English

ORIGIN

The aonla tree is native to tropical Southeast Asia, particularly central or southern India, Pakistan, Bangladesh, Sri Lanka, Malaya, Southern China and to Mascarene Islands. Seedling trees are of common occurrence in the mixed deciduous dry forests of India, ascending from sea level (Western and Eastern ghats, Aravali and Vindhyan hills) to 1300 m amsl, from northwest Himalayas (Jammu & Kashmir, Himachal Pradesh, Uttranchal) to eastern Himalayas in Assam, Meghalaya, Mizoram, Manipur and Tripura.

DISTRIBUTION

Naturally growing trees of aonla have been reported from India, Sri Lanka, Cuba, Puerto Rico, Hawaii, Florida, Iran, Iraq, Java, West Indies, Trinidad, Singapore, southern Thailand, Pakistan, Malaya and China and Panama Canal regions. However,

its cultivation is more common in India, particularly in the state of Uttar Pradesh where it is cultivated in the districts of Pratapgarh, Raibareli, Jaunpur, Sultanpur, Banda, Kanpur, Agra and Mathura districts. The major concentration of aonla cultivation is in Pratapgarh district. The natural distribution of wild aonla is found on the Himalayas, Chota Nagpur, Bihar, Orissa, West Bengal, North Circars, Deccan, Karnataka and in Western Ghats.

DOMESTICATION

In India, the homeland of aonla, domestication was first started in Varanasi (earlier known as Benaras) district of Uttar Pradesh with the initiative of Maharaja of Kashi. Banarasi, a superior genotype was selected from the wild aonla trees available in large number in the nearby Vindhyan hills. Authentic information regarding its cultivation dates back to 1881-82 in the Partapgarh district of Uttar Pradesh. The ailing state owner of the district (King) was advised for regular consumption of aonla fruit in one way or other. As per information available, few aonla trees were introduced from Varanasi and few from Gujarat. Those brought from Varanasi were named as 'Banarasi' and those brought from Gujarat were known as Francis and later on as *Hathijhool* (because of its drooping branches). A seedling of Banarasi, with prolific bearing and flat fruits was named as Chakla and now it is known as Chakaiya. The new cultivars, agro-techniques and commercial orcharding in the country were promoted based on research and development work at Narendra Dev University of Agriculture and Technology (NDUAT), Kumarganj, Faizabad, Uttar Pradesh, India. Aonla was also included in All India Coordinated Arid Fruit Improvement Project and cultivars developed at NDUAT, Faizabad were planted at the following centres:

- Central Institute for Arid Horticulture, Bikaner, Rajasthan.
- Central Arid Zone Research Institute, Jodhpur, Rajasthan.
- SKN College of Agriculture (RAU), Jobner, Rajasthan.
- Agriculture Research Station, Anantpur, Andhra Pradesh.
- Regional Research Station, Aruppokottai, Tamil Nadu.
- Central Institute of Arid Horticulture, Regional Centre, Godhara, Gujarat.
- Mahatma Phule Krishi Vidyapeeth, Rahuri, Maharashtra.
- Indian Grassland and Fodder Research Institute, Jhansi, U.P.

- Indian Agricultural Research Institute, New Delhi.
- National Bureau of Plant Genetic Resources, New Delhi.
- Central Institute for Subtropical Horticulture, Lucknow, U.P.
- Central Research Institute for Dryland Agriculture, Hyderabad, A. P.
- Central Soil and Water Conservation Research and Training Institute, Dehra Dun and its regional centre, Chandigarh.

PRESENT STATUS

India ranks first in production of aonla. It occupies an area of 103.55 thousand ha with a production of 1221.25 thousand metric tones. Besides India, naturally growing aonla trees are also found in different parts of the world like Srilanka, Cuba, Puerto Rico, USA (Hawaii and Florida), Iran, Iraq, Pakistan, China, Malaysia, Bhutan, Thailand, Vietnam, Phillipines, Trinidad, Panama and Japan. Uttar Pradesh, Gujarat, Rajasthan, Tamil Nadu, Haryana, Maharashtra, Andhra Pradesh, Punjab, Karnataka and Himachal Pradesh are the major aonla growing states in India. Uttar Pradesh ranks first in its area and production.

TAXONOMY

Aonla belongs to new genus *Emblica* (earlier *Phyllanthus*) of the family Euphorbiaceae and order Euphorbiales. A small subgenus, characterized by its usually indehiscent fruits. Section *Emblica* with a species of *P. emblica* is from Asia, shows more advanced pollen grains; its pollen is 4-5colporate, slight oblate but also finely reticulate and circular, the anthers cohering by the connection which end in an apiculus, cells distinct dehiscing longitudinally. Ovary 3 celled; ovules 2 in each cell; styles connate at base with broad recurved twice- branched arms. Fruit depressed-globose, fleshy, with 3 bony 2-valved cocci. Seeds 6, trigonus; albumen fleshy; cotyledon flat broad, cordate or truncate. Leaves on the branchlets many, 100 or more sometimes, linear oblong, apiculate, 10-13 mm long, about 2-3 mm broad; glands small; style arms and twice bifid, sometimes broad, spreading.

Species *officinalis*: Leaves on the branchlets may, up to about 50, elliptic-oblong, round at apex, 10-13 mm long, 2-3 mm broad; glands larger; styles-arms slender, usually twice bifid, recurved.

BOTANICAL DESCRIPTION

Tree shapes, branching and plant parts (tree, leaves, fruits, seeds) are discussed below:

Tree

Aonla is a medium sized, much-branched tree occupying height of 10-20 m. In the tropical region, it is supposed to be an evergreen tree but behaves as deciduous tree due to complete defoliation of leaves. However, before dropping of determinate shoots, side buds initiate to develop determinate shoots again in February-March. The tree bark is glossy and it cracks irregularly.

Stem

It is smooth, greenish grey to brown, exfoliating bark, which peels off in thin flakes like that of guava.

Branching

Aonla tree is characterized by phyllanthoid branching habit with two types of shoots. On the basis of growth characteristics, these have been characterized as long (indeterminate) and short (determinate) shoots. These are also referred as branch and branchlet. The indeterminate shoots are longer and continue to put new growth in the season. These shoots do not fall from the tree and also do not bear flowers, irrespective of period of their emergence. While on the other hand, determinate shoots appear on the nodes of indeterminate shoots and their number at each node may vary from 3 to 5 in different cultivars. These determinate shoots bear small sized leaves (10-13 mm length, 2-3 mm width), arranged so closely that apparently it appears to be a pinnately compound leaf.

Flowers

The internodes are much shorter in the determinate shoots. These nodes are barren or floriferous with imbricate leaves. First few proximal nodes on the determinate shoots are barren (without leaves), which are reduced to dark brown scarious cataphylls. Succeeding nodes are with green but reduced leaves. Subtending cymules of male flowers are followed by nodes each with cymule of one central female flower (rarely two) and several lateral males, distal half floriferous, determinate, shoots are normally sterile with typical leaves.

Inflorescence

Inflorescence is racemose type, flowers minute, unisexual, with short pedicel. Male flowers appear first in cluster; perianth 6, yellowish green or deep pink in colour with valvate aestivation. Androecium consists of 3 stamens, each profusely branched, and filament attachment is basi-fixed or innate type, short, and cohesion of anther is syngynous. Female flowers have tiny green perianth and number of segments varies from 5 to 7 but commonly six. Ovary hypogynous, carpels 3-4, three chambered placentation axile two ovules perlocule, margin straight to crescent shaped, and ovarian chamber shallow to deep.

Fruit

Nearly pedicel less, fruits depressed, round globose or oblate, indented at the base. A capsular (drupaceous) berry with fleshy exocarp, smooth to obscurely 6 lobed.

COMPOSITION, NATURAL BENEFITS AND MEDICINAL PROPERTIES

Composition

Aonla fruit is rich in vitamin C and pectin. On an average, aonla fruit contains 82.2 per cent water, 0.5 per cent protein, 0.1 per cent fat, 14 per cent carbohydrates and 600 mg vitamin C/ 100g of pulp. The Vitamin C value of aonla increases further when the juice is extracted from the fruit. The dehydrated fruit provides 2428 to 3470 mg of vitamin C per 100 g. Even when it is dried in shade and then turned in to powder, it retains as much as 1780-2660 mg of vitamin C. The fruit contains chemical substance known as leucoanthocyanins (Polyphenol), which retards the oxidation of vitamin C.

It also contains calcium, phosphorus and iron. It is a fair source of vitamin B (30 mg/ 100 g) and nicotinic acid (0.2 mg/ 100 g). The aonla fruit has calorific value of 59 per 100 g of fruit and due to its antiscorbutic, diuretic, laxative, alternative and antibiotic properties, it is regarded as high value having diverse medicinal, industrial and other applications.

Chemical composition of aonla

Constituent	Amount (%)	Constituent	Amount (mg/100g pulp)
Moisture	77.1-82.20	Iron	1-20
Protein	0.50	Nicotinic acid	0-20
Fat	0.10	Vitamin	200-1814
Minerals	0.5-0.70	Carotene	0.01
Fibre	1.9-34	Thiamine	0.03
Carbohydrates	14.10-21.89	Riboflavin	0.05
		Niacin	0.18
Calcium	0.012-0.050	Tryptophan	3.00
Phosphorus	0.020-0.026	Methionine	2.00
		Lysine	17.00

Natural benefits and medicinal properties

Many medicinal virtues have been attributed to aonla. A table spoonful each of fresh aonla juice and honey mixed together forms a valuable medicine for the treatment of tuberculosis of lungs, asthma, bronchitis. It is also beneficial for the treatment of conjunctivitis and glaucoma. It reduces intraocular tension in a remarkable manner. Similarly, a tablespoonful of its juice mixed with a cup of fresh bitter gourd juice, taken daily for two months stimulate the Islet of Lengerhan, thus reduces the blood sugar in diabetes. Aonla is useful in treatment of rheumatism. One tablespoonful of powder of the dry fruit mixed with two teaspoonful of jaggery should be taken twice daily for a month for curing this disease. Similarly, for curing scurvy, one tablespoonful containing equal quantity of powdered aonla and sugar, thrice daily with milk is recommended. Dried fruit is valuable in control of diarrhoea and dysentery. A drink made from aonla mixed with lemon juice and misri is considered highly beneficial in controlling acute bacillary dysentery.

Aonla is considered as an effective remedy for heart disease. It tones up the functions of all organs of the body and builds up health by destroying the

heterogenous elements and renewing the body energy. It has a revitalizing effect. It is said that the great ancient sage Mini chywan rejuvenated himself in his late 70s and regained his virility by the use of aonla.

Aonla is accepted hair tonic in traditional recipe for enriching hair growth and hair pigmentation. It is an important ingredient of *triphala* and *chavanprash* in Ayurvedic medicine system. Besides, fruits are commonly used for preparation of preserve (murabba), pickle, candy, jelly, etc. It can be dried and powdered to be used subsequently. It is also used in the preparation of inks, hair dyes, hair oils. Other parts of the aonla tree are also useful in following ways.

- The seeds and roots are used in medicines.
- The bark, leaves and fruits are used for tanning.
- The wood is hard and can be used for making furniture and agricultural implements.
- The twigs are also used for firewood.

Medicinal properties and uses

Aonla is an antioxidant with the free radical scavenging properties, which may be due to the presence of high levels of super oxide dismutase. It is effective in the treatment of peptic ulcer, dyspepsia, diabetes etc. The fruits exhibit hypolipidaemic and antiathero-sclerotic effects in rabbits and rats. Further reported are hepatoprotective, antioxidant, antimutagenic, cytoprotective, anti-tumour and antimicrobial.

CLIMATE AND SOIL

Aonla is a hardy subtropical fruit crop and is being cultivated in variable soil conditions but its cultivation in tropical climate is quite successful. Aonla plant can withstand almost all types of climate, however, it prospers in dry subtropical climate. Its susceptibility to frost during winters and desiccating winds in summer makes it necessary to protect young plants, at least up to 3-4 years. Annual rainfall of 630-800 mm is ideal for its growth. A mature aonla tree can tolerate high temperature up to 46°C. Warm weather is conducive for the initiation of fruit growth during July-August.

Well drained fertile loamy soil is ideal for aonla cultivation although, it can be successfully grown in light as well as heavy soils except very sandy one. Slightly acidic to saline soils (pH 6.5-9.5, EC 5dsm⁻¹, ESP 30-40) are suitable for its cultivation. Heavy soils with high water table are not suitable for its cultivation. In recent years, aonla has been identified as an ideal plant for various kinds of wastelands viz., moisture stress, eroded, ravines, upland, riverbeds and areas with undulated topography. Its deep root system and deciduous nature is helpful in providing vertical drainage and improving physical, chemical and biological soil properties. Introduction of aonla in the natural rangelands has shown its suitability for rehabilitation, particularly through popularization of agri-silvihorticulture land use system. Aonla can also be planted on roadsides, strip lands. Experiments on salt tolerance of aonla showed that the aonla has immense possibility for commercial growing on salt affected wasteland which covers an area of 7.0 million hectares in India.

CULTIVARS

Most of the plantations have been raised from seed, therefore exhibit great variability. There has been no standardization of cultivars up to mid seventies and were mostly known on the basis of size, colour and after the names of places viz., Green tinged, Red tinged, Pink tinged, Bansi Red and White-streaked, etc. However, some named cultivars like Banarasi, Francis, Chakaiya are known to be cultivated in Uttar Pradesh. Anand 1, Anand 2 and Anand 3 from Gujarat. They have been adapted to northern climatic conditions of India too. The description of few important varieties, suitable for growing in different parts of the country is:

Banarasi: It is a seedling selection from Varanasi district of Uttar Pradesh. It is popular variety having upright growth habit with three branchlets per node. Inflorescence is deep pink and moderate in length. Fruits are large in size, flattened, oblong, skin smooth yellowish, segment raised in three parts. The flesh is moderately fibrous, soft and semi-transparent. Flowering starts from fourth week of March. It has high number of male flowers and has self incompatibility, hence it is shy bearer. It contains high amount of ascorbic acid. It is used for making preserves. It is early bearer with fine keeping quality. Mildly susceptible to necrosis.

NA-4 (Krishna): Chance seedling of Banarasi from Partapgarh. Tree is semi tall with spreading growth habit and bears moderately. The fruit is medium to large in size, flattened, conical, angular in shape. Skin is very smooth, yellowish in colour with red blush on the surface. Flesh is fibreless, hard and semi-transparent and highly astringent. Early maturing and shy bearing with no evidence of fruit necrosis.

NA-5 (Kanchan): It is also a seedling selection form Chakaiya. It is a heavy and regular bearing cultivar with medium sized, high fibre content fruits. It is more preferred by industries for pulp extraction and manufacturing of various products. Fruit is small to medium (30-40 g), skin smooth, yellowish in colour and ideally suited for preparation of pickles. The variety has been adopted very well in the semi-arid regions and produce 150-200 kg fruits per tree. Late maturity, fruit has a good keeping quality and is free from necrosis.

NA-6: It is a seedling selection from Chakaiya which assumes an ideal tree shape with prolific and heavy bearing. Owing to low fibre content, it is an ideal cultivar for preserve and candy. This is the most promising variety of aonla so far available for plantation.

NA-7: It is a precocious, prolific and regular bearer clone of Francis. The fruit is free from incidence of necrosis. This variety has adopted well in the state of Bihar, Jharkhand, Rajasthan, Madhya Pradesh, Andhra Pradesh, Tamil Nadu and Jammu and Kashmir. The major constraint of NA-7 is brittleness of branches, which often breaks due to its own fruit load. This is an ideal variety for processing and holds a great promise. The fruit is medium to large in size. The surface is smooth and yellow in colour.

NA-10: Chance seedling developed from cultivar Banarasi, locally known as 'Agra Bold'. Semi-tall and semi-spreading growth habit with deep pink and long inflorescence. Fruits are round and brown in colour, growth initiates early in season, at pea stage appears pinkish yellow, which disappeared gradually later on. Fruit is flattened round with moderate size. Fruit skin rough, yellowish green with pink tinge. Flesh is slightly fibrous, whitish green, soft, juicy and highly astringent. It is the earliest maturing variety with good keeping quality. Mildly susceptible to fruit necrosis

Francis: It is also known as ‘*Hathijhool*’ and has originated from Pratapgarh (U.P.). The branches have drooping habit. It is prolific bearer. Fruit is large, flattened, oval, skin smooth, greenish yellow in colour. The flesh is soft, nearly fibreless. Keeping quality is very poor. It is highly susceptible to fruit necrosis thus not suitable for preserve making.

Chakaiya: It is a seedling selection having tall upright growth habit. It bears profusely and is regular bearer. Fruit is small to medium, flattened, smooth skin, greenish in colour. Flesh is fibrous and hard. Keeping quality is very good. It is a late maturing variety having fruits with good keeping quality suitable for pickles and other products. Free from necrosis.

Laxmi-52: This is being cultivated in the private orchard as superior chance seedling of Francis i.e. Laxmi-52. Its tree has semi-erect growth and branches do not droop like its parent Francis. Fruit size large, 40-60 g, diameter 4.0-4.5 cm with 6 ridges. In early part of fruit growth, fruit colour is light pink which disappears on full development. Leaves are longer, broader, dark green than other aonla cultivars. It is mid season maturing (mid November to December) and is free from necrosis with yielding potential of 2-2.5 q/tree (after 10 years). Owing to larger fruit size and attractive colour, it fetches higher price in the market. The fruit has been found suitable for preparation of segments in syrup, candy and preserve.

Morphological characteristics of aonla genotypes

Cultivars	Tree height	Tree shape	Foliage	Leaf shape	Leaf apex	Leaf surface
Banarasi	Semi-tall	Spreading	Sparse	Oblong	Obtuse	Glabrous
Chakaiya	Tall	Upright	Sparse	Oblong	Acute	Glabrous
Francis	Tall	Erect drooping	Dense	Oval	Obtuse	Moderately glabrous
Promising selections						
NA-4 (Kanchan)	Tall	Semi-spreading	Sparse	Oval-oblong	Acute	Non-globuse
NA-5 (Krishna)	Tall	Semi-spreading	Sparse	Oval-oblong	Acute	Non-globuse
NA-6	Tall	Upright	Sparse	Oval-oblong	Acute	Glabrous

Cultivars	Tree height	Tree shape	Foliage	Leaf shape	Leaf apex	Leaf surface
NA-7	Tall	Spreading	Dense	Elliptical	Obtuse	Non-glabrous
NA-8	Tall	Upright	Sparse	Oblong	Acute	Glabrous
NA-9	Tall	Semi-spreading	Dense	Oblong	Obtuse	Non-glabrous
NA-10	Semi-tall	Semi-spreading	Dense	Oblong	Obtuse	glabrous

Flowering, sex ratio and fruit set in aonla genotypes

Characters	Cultivars/promising selections									
	Banarsi	Francis	Chakaiya	NA-4 (Kanchan)	NA-5 (Krishna)	NA-6	NA-7	NA-8	NA-9	NA-10
Initial bloom	26/3	18/3	25/2	03/3	02/4	18/3	20/3	20/3	24/3	15/3
Full bloom	10/4	02/4	16/3	23/3	18/4	02/4	05/4	11/4	11/4	02/4
Fruitlet shape	Round	Round	Elliptic	Round	Elliptic	Elliptic	Round	Round	Round	Round
Fruitlet colour	Light brown	Dark brown	Dark brown	Brown	Light brown	Light brown	Dark brown	Light brown	Dark brown	Reddish brown
Sex ratio	254:1	61:1	64:1	356:1	67:1	29:1	61:1	241:1	90:1	-
Pollen viability (%)	93.96	92.79	88.32	93.96	93.66	96.40	92.79	95.97	93.55	-
Pollen germination (%)	27.76	34.03	25.28	24.65	36.90	29.00	34.03	16.80	16.71	31.40
Fruit set (%)	27.01	58.94	52.55	29.67	50.79	51.87	58.94	36.80	28.57	4.28
Fruit retention (%)	6.22	9.12	8.44	8.13	12.28	9.02	12.37	8.28	6.26	4.22
Female flowers/branchlet	530.29	570.58	358.73	597.04	329.64	294.40	503.60	220.70	594.34	413.19
Male flowers/branchlet	2.33	4.84	7.86	2.00	7.77	10.83	9.79	3.57	2.84	4.64

Physical characteristics of aonla genotypes

Cultivars/promising selections	Fruit length (cm)	Fruit width (cm)	Fruit weight (g)	No. of segments/ fruit	Fruit size	Fruit shape	Fruit colour
Banarasi	3.60	4.44	49.83	6	Large	Triangular	Whitish green to straw yellow
Chakaiya	3.40	4.10	30.66	6	Medium	Flattened round	Light green
Francis	3.91	4.29	42.73	6	Large	Flattened oval	Light green
NA-4 (Kanchan)	3.30	3.53	29.84	6-8	Small	Flattened oblong	Light green
NA-5 (Krishna)	3.60	4.20	44.66	6-8	Large	Triangular	Whitish green to apricot yellow
NA-6	3.60	4.03	35.33	6	Medium	Oval round	Light green
NA-7	3.80	4.00	43.05	6	Medium	Flattened oval	Light green
NA-8	2.90	3.50	26.91	6	Small	Flattened round	Light green
NA-9	3.75	4.50	50.55	6-8	Large	Flattened round	Light green
NA-10	3.40	4.15	41.50	6	Medium	Flattened round	Yellow green with pink tinged

Fruit quality parameters of aonla genotypes

Cultivars/Promising selections	Fibre (g)	Juice (%)	Pulp (g)	TSS (°Brix)	Acidity (%)	Vit. C (mg/100g)	Astringency
Banarasi	0.32	47.00	39.80	13.00	2.19	484.00	Medium
Chakaiya	0.85	52.25	31.80	10.33	2.15	527.00	High
Francis	0.65	50.92	32.70	9.16	1.92	566.50	Medium
NA-4 (Kanchan)	0.95	42.92	22.17	11.00	2.47	504.70	Medium
NA-5 (Krishna)	0.39	50.75	34.00	11.00	2.32	549.20	High
NA-6	0.86	47.00	31.87	9.50	2.11	422.70	High

Cultivars/ Promising selections	Fibre (g)	Juice (%)	Pulp (g)	TSS (*Brix)	Acidity (%)	Vit. C (mg/100g)	Astringency
NA-7	0.61	44.90	33.10	7.83	2.11	500.20	High
NA-8	0.82	31.20	19.22	10.00	2.33	427.00	High
NA-9	0.56	52.50	47.58	11.50	2.52	499.00	High
NA-10	0.52	56.10	39.08	9.90	2.17	528.00	High

The varieties recommended for cultivation are Banarasi, Chakaiya, Francis, NA-4 (Kanchan), NA 5 (Krishna), NA-6, NA-7, NA-10, BSR-1 (Bhavanisagar) and Goma Aishwarya (released by CIAH, Bikaner).

PROPAGATION

Seed Propagation

Aonla can be raised from seeds but it produces small sized fruits of inferior quality as well as such trees have prolonged juvenile period. Plants raised from seeds are mainly used as rootstock. For the purpose of seed extraction, fruits are collected from local seedling (*Desi aonla trees*) and used for rootstock raising. Mature fruits should be collected during November-December. Fruits are dried in open and seeds are extracted by applying light pressure. On an average, there are six seeds per fruit. One kg seed can be obtained from one quintal of *Desi* aonla fruits. Average test weight of aonla seed varies from 30,000-50,000 per kg or 300-500 per 10 g of fresh seed weight. For highest percentage of germination and to obtain seedlings with best root system, seeds should be soaked in 500 ppm GA₃ for 24 hours.

Budding

Of various methods of vegetative propagation, budding has been found to be most practical. Shield budding and patch budding are the commercial methods of aonla propagation. One year old seedlings with a girth of about 1 cm should be shield budded in early July with healthy and plump buds from new growth. Shield budding gives a success of 70-80 per cent. Higher percentage of bud-take has been recorded with patch methods under Jammu conditions.

Grafting

Grafting is also one of the methods for raising good propagules. Soft wood grafting has been attempted with 70 per cent success at the site of terminal shoot of the rootstock raised *in situ*. It would be advisable to raise seedling rootstocks *in situ* and graft them with superior types of scion particularly in dry areas where mortality of budded plants is usually high. Besides, veneer and cleft grafting has also been attempted successfully.

Top working

The poor returns from old trees of inferior types have been the main cause for the limited aonla cultivation so far. These inferior types can be rejuvenated and easily changed into superior type by adopting top working. Top working can be easily adopted in rejuvenated trees to upgrade the old/senile plantations of seedling progeny with superior commercial cultivars.

Top working involves two steps

- (a) beheading of the tree to be top worked and
- (b) budding with a elite material on the new flushes emerging out on the stumps of beheaded tree.

The plants are headed back during December-January to the extent of 2.5 to 3.0 m above the ground level. Four to six shoots from the outer directions on main limbs should be allowed to develop. During June-July, scion of desired variety is budded on these shoots. After bud sprouting, the top portion of the shoot is removed. Numerous side shoots, which emerge on the pruned branches after budding operation should be removed regularly as and when they emerge, so that the tree of pure commercial variety is obtained. Since aonla is self incompatible, the pollens of same variety cannot fertilize its own ovary, the production from mono-culture orchards without appropriate pollinizer varieties, suffers adversely as a result of problem of fruit set. Consequently, pollinizer varieties are budded on developing shoots of pruned trees to strengthen pollination process and enhancement of fruit set and productivity. Budding with mixed varieties results in better yield. The best combination is NA-6 with NA-7; NA-7 with NA-10 and Kanchan with Krishna. Adequate care should be taken to

manage the insect-pest problems as these plants are prone to insect and some times wind damage. Frost damaged older plants of aonla are also rejuvenated by T-budding.

NURSERY PREPARATION

Seedling can also be raised in the seed bed. Nursery should be raised 10-15 cm with FYM, compost or leaf mould. Partial shade is required for nurserybed. Before sowing, seeds are soaked in clear water for 2 days and water should be changed every day during soaking. In spring or rainy seasons, seeds are sown in nursery at 2-3 cm depth maintaining a spacing of 15 cm between row to row. 2-3 seeds are sown per hill. After germination, only healthy plants should be kept per hill and remaining plants should be discarded from the nursery bed. The plants ready for final planting can also be used for budding as rootstock.

Rootstock: Six months to one year old seedling raised from 'Desi' aonla seed is being used as rootstock. Mature aonla fruits during November-December are obtained and their seeds are extracted after drying the fruits. Seeds are sown in raised bed from April onwards and further transplanted in separate bed for subsequent budding. Propagation of aonla in polybag, polytube, root trainer or *in situ* orchards establishment has also been standardized and commercialized.

ORCHARD ESTABLISHMENT

A budded /grafted aonla tree starts bearing after 3-4 years and attains commercial production after 10-12 years which may continue up to 60-70 years under well managed conditions of orchard. The performance of orchard depends on its management which includes water and nutrient management, selection of right cultivars, planting system, care and maintenance of young and bearing trees, stature and canopy management of plants.

Selection of site: Selection of location for the establishment of any aonla orchard is vital for optimum production. Warm weather and dry period during flowering and humidity during fruit growth are considered ideal for successful aonla cultivation.

Land preparation and layout: Before layout, the land should be cleared of bushes, weedy vegetation, leveled and ploughed deeply. To improve fertility of the soil, organic matter should be added. Green manure crop such as dhaincha (*Sesbania aculeata*) or sunhemp (*Crotolaria juncea*) should be grown and incorporated into the

soil which will improve the fertility, moisture holding capacity and physical condition of the soil.

Planting: Aonla should be planted during rainy season which provides optimum soil moisture and better atmospheric humidity for better survival of aonla plants. Hence, under north Indian conditions, planting should be done from mid to end of August. Early planting provides longer rainy period for the success in initial establishment and growth of young transplant in the field.

Planting System: Aonla is an evergreen, spreading plant which attains the height of about 8-10 meters at its full grown stage. The light penetration on its canopy is also desirable for proper fruiting. Hence, planting in square system at the distance of 8-10 meters within and between the rows has been advised. This will also help in cultural operations to be performed conveniently. The canopy needs to be managed through regular and proper pruning in order to avoid overcrowding of branches and twigs for obtaining good fruiting and high yield. Hedge-row planting is also being tried keeping line to line distance of 8 meters, while plant to plant distance is reduced to 4-5 meters. In order to establish aonla orchards under adverse soil conditions, it is advisable to grow the seedlings directly in the field or raise them in suitable container and transplant at permanent site and perform budding *in situ*, subsequently. Since, self-incompatibility appears to be a common problem with aonla cultivars, two cultivars in alternate rows need to be planted. The plants usually shed their leaves after planting inspite of their best care, but this is not a sign of failure, they again put-forth new leaves very soon.

Before planting, the field should be laid out and marked according to system of planting to be followed. The pit of 1 x 1 x 1 m³ size should be dug at marked place during summer season in the month of April-May and kept open for about 15 days. By this process, the harmful insect pests will be destroyed. The pit should then be filled with top soil mixed with about 3-5 baskets (15-20 kg) of well decomposed FYM/compost, 1 kg neem/karanj cake, 500 g bone meal/single super phosphate, 200-300 g muriate of potash, 50 g Heptachlor per 20 g, Furadan 3G per 20 g just before the onset of monsoon. Then, the soil may be allowed to settle properly during first few rains and get leveled properly. At the time of planting, a hole of the size of ball of the earth should be made in the centre of the pit at the marked point and planting should be done. After proper fixing of the plant, watering should be done immediately

for proper establishment of plant. Plants should be regularly irrigated till they are properly established.

ORCHARD MANAGEMENT

The orchard management includes the management of canopy architecture, nutrient, water, field sanitation and plant protection.

Young non-bearing orchard: Management and upkeep of young non-bearing orchards is essential which accelerate growth of the young plant and minimize juvenile period up to 3 years of age. The main aim of the aonla orchard management is to accelerate the plant growth so as to develop better frame work which will make platform for the higher production throughout the life span of the plant. Generally, young aonla plant sprouts once in a year to form canopy with a certain quantity of vegetative growth. Therefore, newly planted young saplings should be properly nourished to promote better vegetative growth. It has been anticipated that after attaining the age of 2 years, the plant develops good canopy and become ready for bearing few fruits. But it is advisable to remove the flowers and fruit of the first two years. Other management practices like weeding, hoeing, cleaning of plant basins, plant protection and water management, etc. should be done from time to time to facilitate better growth.

Young bearing orchard: This is a very delicate stage of orchard management where more visionary approach should be followed in skillful manner. During this stage (2-7 years), plant needs more nutrients for proper growth and bearing. At this stage, the tree keeps enlarging its canopy and produces fruits. Therefore, the management should be aimed to balance both vegetative and reproductive growths. It is more important because excessive vegetative growth adversely affects fruit setting, while excessive fruit load reduces proper development of tree canopy as well as leads limb breakage and encourages fruit drop. Skillful orchard management at this stage includes maintenance of optimum number of bearing branches as per the nutritional status and health of the plant. Young trees tend to have more vegetative growth and the fruit production is suppressed by excessive vegetative flush. Therefore, proper training and pruning is needed.

Training and Pruning: As the branches of aonla trees often break off due to heavy crop load and brittle nature of the wood, aonla plant should be encouraged to form a shape of medium headed tree. The main branches should be allowed to appear at a height of 0.75 to 1.0 meter above the ground level. Plants should be trained to modified central leader system. Two to four branches with wide crotch angle, appearing in the opposite directions should be encouraged in early years. The unwanted branches need to be pinched off during March-April. In the subsequent years, 4-6 branches should be allowed to develop. Regular pruning of bearing aonla tree is not required as per growth habit, shedding of all determinate shoots (branchlets) encourages new growth in coming season. However, dead, broken, infested, overlapping or weak branches should be removed regularly.

Nutrient management: Inadequate nutrition has very often been attributed as the cause of lower yields in aonla. Therefore, balanced nutrition is important, both for young growing plants as well as grown up fruit bearing trees. However, a bearing tree requires balanced nutrient application for maintenance of vegetative growth along with fruit production.

Schedule of manure and fertilizer application in aonla

Age of plant (Year)	Manure and fertilizer per plant				
	FYM (kg)	Neem/Karanj Cake (kg)	N (g)	P (g)	K (g)
At planting	10	1	100	50	100
1	10	1	100	50	100
2	20	2	200	100	200
3	30	3	300	150	300
4	40	4	400	200	400
5	50	5	500	250	500
6	60	6	600	300	600
7	70	7	700	350	700
8	80	8	800	400	800
9	90	9	900	450	900
10 or above	100	10	1000	500	1000

The dose of manure and fertilizers depend upon soil fertility, age of plant and production. 10 kg FYM, 100 g nitrogen, 50 g phosphorus and 100 g potash should be given to one year old plant. This dose should be increased yearly i.e. double in second year and triple in third year of the initial dose of manure and fertilizers and so on up to

10 years. Thereafter, a constant dose should be given in the subsequent years. Full dose of FYM and phosphorus and half of nitrogen and potash should be given in tree basin during December-January. The remaining half should be applied in August. In problematic land, 100-500 g boron, zinc sulphate and copper sulphate each per tree should also be incorporated along with fertilizers as per tree age and vigour.

Water Management: Established aonla orchards generally do not require irrigation in normal soils. No irrigation is required during rainy and winter season. Irrigation at 15-20 days interval is desirable in dry summer particularly during early years of orchard establishment under wasteland conditions. Brackish water should not be used for irrigation purpose. In bearing plant, first irrigation should be given just after manure and fertilizer application (January-February). Irrigation should be avoided during flowering period (mid March to mid April). Among the various systems of irrigation, basin system has been found to be the best suited for aonla. The initial information obtained with drip irrigation has shown promising response. In water scarcity areas, pitcher irrigation can also be successfully done for aonla orchard establishment.

ORCHARD FLOOR MANAGEMENT

Mulching: Mulching is a practice, which helps in proper growth and development of the plants by modifying soil temperature, by providing better nutrient availability and by better moisture conservation. The uses of mulches help to reduce water consumed. The main functions that mulches provide including: weed suppression, soil water conservation, moderation of soil temperature fluctuations (daily and seasonal), increased infiltration of water droplets from precipitation or irrigation, soil protection from traffic compaction, improved soil structure for organic mulches and the slow release of nutrients. Mulches not only conserve soil moisture but also impart manifold beneficial effects, like suppression of extreme fluctuation of soil temperature and reduction of water loss through evaporation, resulting in more stored soil moisture, maintenance of soil fertility. The requirement of water through mulch can further be reduced by using locally available organic materials as mulches which not only save irrigation water but also conserves soil moisture. Various studies have indicated that in fruit crops like apple, sapota and acid lime, mulching improves soil moisture status, growth, yield and quality of these fruits, besides reducing weed growth. Continuous

uses of organic mulches in aonla orchards have been found to be very effective for its establishment and are also found to be helpful in improving the physico-chemical properties, microbial flora and soil aeration. Moreover, mulching with plastic polyethylene is found effective in conserving the soil moisture and increasing the growth, yield and quality in different fruit crops.

Inter-cropping: During initial 3-4 years of planting, aonla orchards present an excellent opportunity for utilizing vacant interspaces in the orchard. Vegetables like bottle gourd, okra, coriander, cauliflower, pea, and turmeric; flowers like gladiolus and marigold have been found well suited for intercropping in aonla orchards. In salt affected or marginal soils, intercropping of Dhaincha for a few years is beneficial for improving the physico-chemical properties of the soil. The trunks of fruit plants should be saved from injury. Leave a space of one meter diameter around the plants uncultivated. After the plants attain 5 years of age, no crop should be grown. The basins should be kept free of weeds, manually, throughout the year. Aonla being a deep-rooted, deciduous tree with sparse foliage, proved to be an ideal plant for 2 or 3 or multi-tier cropping system. Short statured fruit plants, vegetables, flowers and medicinal and aromatic plants have been found suitable for inter-cropping in aonla orchards. Cropping system models such as Aonla + ber or guava (Two tier), Aonla + phalsa (Two tier), Aonla + dhaincha + wheat or barley, Aonla + dhaincha + onion/garlic or brinjal, Aonla + dhaincha + German chamomile (Three tier), etc. have been found much remunerative.

FLOWERING, FRUIT GROWTH AND DEVELOPMENT

Flowering: Aonla bears two types of flower, male and female which appear on branchlets in late spring. When hot winds blow, fruit set is often a problem. It is observed that flower bud differentiation in Banarasi cultivar takes place in the first week of March. The flowers commence opening from the last week of March and the blooming period lasts for 3 weeks. Male flowers appear in clusters on the axil of leaf all over the branchlet, while female flowers on the upper end of a few branchlets only. The maximum number of male flowers opens between 6 and 7 pm and dehiscence of anthers occurs soon or about 10-15 minutes after anthesis. The female flowers open gradually and it takes 72 hours to open completely. The stigma becomes receptive on the third day of anthesis. Aonla is pollinated mainly by wind and honey bee.

Fruit Growth and Development: Fruits are available from November to December. After fruit set, the embryo lies in dormant condition and does not exhibit any symptom of external growth until middle of August. The diameter and volume of the fruit increases rapidly thereafter, and the maximum growth is achieved by November after which there is not much increase in size. The growth of the fruit is due to the enlargement of the cell of the mesocarp, while endocarp cells form the hard stone cells.

FRUIT MATURITY AND HARVESTING

Fruit Maturity: Increased yield and processing quality of aonla fruits is directly related to its time of maturity. Being an underutilized fruit crop, little attention has been given for establishing reliable maturity indices of aonla. However, commercially used parameters like days from flowering to maturity, heat units, colour of fruit surface and TSS: acid ratio can be used for determining the maturity index of aonla cultivar in a particular region. The colour of fruit changes during ripening. The fruits are normally light green at first but on maturity and ripening, the colour becomes dull, greenish yellow or rarely brick red. Change in seed colour from creamy white to brown is an indication of fruit maturity. The mature fruits are hard and unyielding to the touch and so are well suited for bulk harvesting as well as distant transportation and marketing. For getting attractive price, fruits should be picked at proper stages of maturity and handled properly.

Harvesting: Aonla fruits are ready to harvest during November-December. Maximum ascorbic acid content is observed in mature fruits, while immature fruits are acrid and low in ascorbic acid content and minerals. Fully developed fruits are harvested. Delayed harvesting results in heavy dropping of fruits particularly in Francis and Banarasi. It also adversely affects the following years bearing. Harvesting should be done in early or in late hours of the day. The method of harvesting is hand picking of individual fruits. Individual fruits are plucked by climbing on the tree with the help of pegged bamboo or ladder. Harvesting should be done in early or in the late hours of the day. A budded/grafted aonla tree starts bearing third year onwards after planting, whereas a seedlings tree may take 6-8 years. Vegetatively propagated plants attain full bearing within 10-12 years and may continue to bear for 60-75 years of age

under well managed conditions. An aonla tree may bear 1 to 3 quintal fruits per tree, giving 15-20 tons/ha.

POST HARVEST MANAGEMENT

Grading: Since, very little work on grading in aonla is reported. However, aonla fruits are graded into 3 grades i.e. large sized, small sized and blemished fruits. Large sized, sound fruits are mostly utilized for preserve and candy; small sized for chavanprash and trifala and blemished fruits for powder and shampoo making.

Storage: Aonla fruits can be stored for 6-9 days at ambient temperature. However, with a salt solution it can be stored upto 75 days. Fruits can be cut in to pieces and soaked with salt and ajowan solution and dried under sun. It can be stored for long time without loss of ascorbic acid.

Processing: Some commercially important processed products prepared from aonla are

(i) Aonla preserve

Procedure: Fruits are washed and pricked with a needle and then placed in 2% common salt solution. On subsequent days, the concentration of salt is raised progressively from 2% until final concentration of 8% is obtained. The fruits are then washed and placed in freshly prepared 8% brine for a period of one week. The fruits are again washed and blanched in 2% alum solution prior to placing them in cold water. The fruits and sugar in alternate layers are placed in vessel and left as such for 24 hours. The weight of sugar is almost half the prepared fruits. When fruits and sugar are placed together in a vessel, fruits give out sufficient water and a syrup of 36 to 38°Brix is formed. The mixture is boiled so as to raise the concentration of syrup from 59 to 60°Brix. A small quantity of citric acid (0.2% weight of fruits) is also added. After boiling for few minutes, fruits are kept as such without any disturbance in the syrup for another 24 hours. On the third day, the strength of the syrup is raised to 70°Brix and the product is allowed to stand for a week.

Alternatively, preserve can also be prepared by the following method. After pre-treatment and blanching, fruits are boiled with sugar or in syrup until a syrup of heavy consistency (68°Brix) is obtained. The syrup is drained from the fruits which are filled

in the dry containers. Freshly prepared sugar syrup of 68°Brix is then poured into the containers which are exhausted for 8-10 minutes at about 100°C and then sealed hermetically. Sterilization of can for 25-30 minutes at 100°C is safer to avoid spoilage during storage.

(ii) Aonla candy

Procedure: Fruits are kept in a solution of common salt (15%) to remove astringency. Fruits are then washed thoroughly to remove brine and boiled for 15 minutes and kept in fresh water for 12 hours. The water is changed 4 to 5 times, and then it is subjected to syruing. A syrup of approximately 30°Brix is prepared by using one part glucose, one part cane sugar and water. The prepared fruit is boiled in this syrup and the material is kept in this syrup for 24 hours. Next the strength of syrup is raised to 40°Brix. The process is repeated and the strength of syrup is raised to 65°Brix and then by 5°Brix on alternate days until the final concentration of sugar reaches about 75°Brix. The fruit is removed from the syrup, drained for about half an hour and dipped in boiling water to remove adhering syrup. Then it is dried in shade or in a drier at about 66°C for 8 to 10 hours.

(iii) Aonla pickle

Procedure: The aonla pickles are prepared by first washing the fruit thoroughly and boil them for 15 minutes. Separate 1 kg aonla segments or pieces. Mix 30 g of brown fenugreek seeds with 10 g turmeric powder, 10 g red chillies powder, 10 g nigella seed and 5 number cloves (whole). Fry fruit segments in 350 ml of mustard oil for 5 minutes. Mix 150 g salt and pack pickles in glass jar. Similarly, pickle from whole fruit can be prepared. For better preservation, 15 to 20 ml/kg glacial acetic acid may be added.

PLANT PROTECTION

Disease

Aonla rust: It is also known as ring rust of aonla. It is caused by *Ravenelia emblicae* var. *fructoidae*. The conspicuous black pustules appear on leaflets and fruits which later form a ring, join together covering a large area. Pustules rupture exposing black spore mass. Pinkish pustules develop on leaves which may be isolated or in group.

The affected fruits drop off prematurely. *Desi* variety is highly affected but Chakaiya and Banarasi are free from it.

Control: 3-4 sprays of wettable sulphur @ 5 g/l of water at an interval of one month or mancozeb @ 2.5 g/l of water at an interval of 15 days.

Anthracnose: It is caused by *Colletotrichum* sp. The symptom is minute, circular, grayish spots with yellow margins appear on leaflets, central area remaining grayish with dot-like fruit bodies. Lesions on fruits are depressed, turn dark in the centre, acervuli formed which are arranged in rings. Lesions may vary in size and shape, spore mass appear on fruiting bodies at high humidity. Infected fruits become shriveled and rot.

Control: Spray mancozeb @ 2 g/l of water or copper oxychloride @ 3 g/l of water or carbendazim @ 0.5 g/l of water at 15 days interval. Repeat sprays as per severity.

Fruit rot: It is caused by *Phoma* sp. i.e. *Phomopsis phyllanthi*, *Nigrospora sphearica*, *Cladosporium tenuissium*, *Pestalotia creenta*, *Alternaria alternata*, *Cytospora* sp. The disease appears as small, pinkish brown necrotic spots. Smoke brown to black round lesions, black ring spots or colourless soft areas appear resulting in partial or complete rotting of fruit.

Control: Give post harvest treatment to the fruit with difolaton @ 1.5 g/l of water or mancozeb @ 1 g/l of water or carbendazim @ 0.5 g/l of water.

Blue mold rot: It is caused by *Penicillium islandicum*. Brown patches with water soaked areas are formed on fruit. With the progress of the disease, three different colours i.e. bright yellow, purple brown and bluish green develop. Yellowish drops of liquid exude from the diseased patches, fruit emits a bad smell, finally giving a bluish green or beaded look.

Control: Handle fruit carefully avoiding wounds. Manage good sanitary conditions in storage by gas treatment with NCl_3 and ozone. Treat fruit with borax @ 0.5 g/l of water.

Pests

Bark-eating caterpillars (*Indarbela quadrinotata*, *Indarbela tetraonis*): It affects the main trunk of the plant and makes tunnels. Feed on the bark under silken ribbon-shaped webs. It causes damage up to 80 per cent.

Control: It can be managed through clean cultivation, avoiding the over crowding of branches. Spraying 0.03% endrin or furadan or injecting kerosene oil or petrol in the holes and plugging them with cotton or wet soil during September-October or February-March.

Shoot-gall maker (*Betanosa stylophora*): The young caterpillars bore into tender shoots and feed in pits during August-September. The damaged region develops gall like formation. All varieties are susceptible.

Control: Pruning and burning the affected parts minimizes the infestation. Killing the larvae by inserting iron or spoke or injecting dichloroovas or endosulphon @ 0.05% in the holes whereas collection and destruction of gall affected shoots. Spraying of monocrotophos @ 0.05% during July-August is effective.

Fruit borer (*Deudorix isocrates*): It is most serious pest in India. Newly hatched caterpillars bore into the fruits and feed on developing seeds. Hole made by the caterpillar facilitates the entry of pathogens and induce fruit rot and drop. It causes considerable damage to fruits.

Control: Collect all infested fruits at least twice a week. Bag fruits after single spray of dimethoate @ 0.045 % or deltamethrin @ 0.003 % with muslin cloth or butter paper bags.

Aphids (*Schoutedenia emblica*): It is a serious pest on new flush. The aphids infest tender shoots, leaves, flower bud and fruits.

Control: Single spray of neem seed kernel extract @ 2 % at the initiation of new flush. Spray dimethoate @ 0.03 % or phosalone @ 0.05 %.

Physiological disorders

Internal fruit necrosis: Necrosis is a physiological disorder. It is characterized by browning of innermost part of mesocarpic tissues followed by browning of the epicarp. In severe cases, mesocarp of affected fruit turns black and becomes corky and gummy pockets develop. This is due to deficiency of boron.

Control: Spray of 0.4-0.6% borax or zinc sulphate (0.4 %) + copper sulphate (0.4 %) thrice during September and October at 10-15 days interval.

Fruit drop: Fruit drop occurs at different stages. The first fruit drop commences from June to September due to lack of pollination and fertilization. Pre-harvest fruit drop is of economic importance and begins from third week of August until October.

Researchable issues

The work on following aspects is to be undertaken on priority in order to stabilize the production in India:

- i. Emphasis on the collection and evaluation of newly released varieties of aonla under rainfed conditions of Jammu.
- ii. Special attention is to be given on crop improvement for better qualitative and quantitative traits.
- iii. Development of efficient water use technology.
- iv. Development of aonla tree based cropping system.
- v. Standardization of techniques for faster multiplication of planting material and for rejuvenation of old/unproductive plantations.
- vi. Developing suitable technologies for reduced post harvest losses.
- vii. More work on utilization of aonla fruits for value addition.

RECOMMENDATIONS OF SKUAST-J

Cultivar evaluation: Out of various aonla cultivars evaluated under Jammu subtropics, Neelam (NA-7) cultivar has been recommended on the basis of qualitative and quantitative traits under rainfed conditions. Maximum female flower percentage with minimum female: male flower ratio, highest fruit set and least fruit drop, better fruit size, weight, yield and quality can be obtained NA-7 as compared to other cultivars of aonla grown in Jammu subtropics.

Chakaiya and Banarasi aonla cultivars were found to be best for making of osmo air dried slices.

Mulching: Black polythene is most suitable mulching material for aonla cv. NA-7 to have improved plant growth, flowering, fruit production with significant mean for weed control.

Maturity indices: The ideal time for harvesting of aonla cv. NA-7 is last week of December, whereas for NA-6 and NA-10 cultivars of aonla should be harvested during first week of January.