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Evaluation of aonla (*Phyllanthus emblica*) genotypes under semi-arid conditions

NARENDRA SINGH[1]*, MUKESH KUMAR[2] and JEET RAM SHARMA[2]

CCS Haryana Agricultural University, Hisar, Haryana 125 004, India

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ABSTRACT

The present study was carried out to evaluate the aonla (*Phyllanthus emblica* L. syn. *Emblica officinalis* Gaertner) genotypes for their growth, yield and fruit quality attributes under the semi-arid condition. The evaluated genotypes had significant variability for the observed parameters. Chakaiya and BSR 1 were found comparatively less vigorous amongst selected genotypes. The number of male flowers, female flowers and total number of flowers, on 10 cm length of indeterminate branch varied from 650.67 to 1488.3, 4.33 to 12.33 and 657.0 to 1499.0, respectively. Sex ratio (male/female) ranged between 96.04 (NA 6) and 262.28 (S 1). Among the genotypes under investigation, NA 20 gave maximum yield, with higher fruit weight (54.96 g) and pulp per cent (93.87). TSS and TSS: acid ratio was observed higher in BSR 1. Total sugars, reducing sugars and non-reducing sugars content was found highest in genotype Krishna. Ascorbic acid and tannin content was recorded highest in Chakaiya and NA 10, respectively.

Keywords: Ascorbic acid, Indian gooseberry, Performance, Physico-chemical

Aonla (*Phyllanthus emblica* L. syn. *Emblica officinalis* Gaertner) is one of the most important indigenous fruit crop of the country. The aonla fruit has high nutraceutical and medicinal value, thus recognized as Amrit-Phal. The fruit could be considered as vitamin C tablet (a rich source of vitamin C). It also contains a wide array of phenolics having antioxidant, antimicrobial, anti-inflammatory, antipyretic, adaptogenic, antiulcerogenic, hepatoprotective, antitumor and antidiarrheal properties (Kuttan and Harikumar 2011). Therefore, aonla has been widely used in the Indian system of medicine (*Ayurveda*). The two important *Ayurveda* products, viz. *Trifla* and *Chavanprash*, are well known for their revitalizing properties. The fruits are processed into various products such as preserves (murabba), candy, dried flecks, etc. These products notably retained the appreciable amount of ascorbic acid. The aonla plant has wider adaptability in diverse agro-climatic and edaphic conditions. The features of the intensive deep rooting system, narrow leaves with sparse foliage density, salt tolerance and fruitlet dormancy of aonla makes it an ideal fruit crop for growing in the fragile ecosystem of the arid and semi-arid region. The large diversity of this indigenous crop is present in the country. Since numerous aonla genotypes have been identified for commercial cultivation, but at the same time, the information about their performance under different agro-climatic conditions is still lacking. Therefore the present investigation was undertaken to evaluate the growth, yield and quality attributes of aonla genotypes under the semi-arid condition.

MATERIALS AND METHODS

The present experiment was conducted at the research orchard of Regional Research Station, Bawal, CCS Haryana Agricultural University during 2017–18. The climate of the experimental site is characterized as hot semi-arid having 450–500 mm mean annual rainfall. In the present investigation, 11 aonla genotypes, viz. CHES 1, BSR 1, Krishna, NA 6, NA 7, NA 10, NA 20, Chakaiya and G 1, along with two seedling selections (S 1 and S 2) were undertaken for the evaluation of their growth, flowering and fruit quality parameters. All the selected genotypes were budded on the seedling rootstocks and planted during July 2006 at a spacing of 6 m × 6 m in square planting system and received uniform cultural practices.

The growth parameters were measured as per norm described by Mahajan *et al.* (2002). Flowering parameters were observed from 10 cm length of tagged indeterminate branche. The fruit physico-chemical attributes were recorded from the mature fruits. Total soluble solids (TSS) were measured using hand refractometer and expressed in °Brix. Titrable acidity (citric acid equivalent %) was determined by titration against 1N NaOH. Ascorbic acid (mg/100 g pulp) and tannins (%) were determined as per the methods outlined

Present Address: [1]ICAR-Indian Agricultural Research Institute, New Delhi; [2]CCS Haryana Agricultural University, Hisar, Haryana. *Corresponding author e-mail: narendrahorti94@gmail.com.

in AOAC (2000). Further, reducing sugars, non-reducing sugars (%) and total sugars (%) were estimated as per the method described by Ranganna (1994). The experiment was conducted in a randomized block design (RBD) with three replications. Statistical analysis for different growth, flowering and fruit physico-chemical parameters were performed using the SAS package (9.3 SAS Institute, Inc., USA) and P-value ≤ 0.05 were considered as significant.

RESULTS AND DISCUSSION

A perusal of observations for the growth parameters among the selected aonla genotypes exhibited substantial variations (Table 1). The tree shape of the studied genotypes has categorized in three groups, viz. spreading (CHES 1, Chakaiya, Krishna, NA 6, NA 7, NA 10 and BSR 1); drooping (NA 20) and upright type (G 1, S 1 and S 2).

Average plant height, stem girth, plant spread (N-S) and plant spread (E-W) among the studied genotypes varied from 4.83 m to 6.62 m; 46.40 cm to 95.33 cm; 4.39 m to7.47 m and 4.43 to 7.10 m respectively. The genotypes Chakaiya and BSR 1 were found to be comparatively less vigorous amongst selected genotypes. The less vigorous/ dwarf genotypes are considered suitable material for high-density planting. The fresh weight of ten leaves of aonla genotypes varied from 95.3 mg (BSR 1) to 142.0 mg (Krishna). Similarly, the dry weight was recorded maximum (36.3 mg) in Krishna and minimum (19.7 mg) in BSR 1. The results of the present investigation are in accordance with the previous findings in the arid conditions (Shukla *et al*. 2010). However, contrastingly, under the humid conditions of Western Ghats, Tripathi *et al*. (2016) observed lesser vegetative growth in North Indian cultivars (NA 6, NA 10, Krishna and Chakaiya) as compared to BSR 1. These findings suggested that, besides the genetic background of the aonla genotypes, the prevailing agro-climatic conditions are also determining factor for growth characteristics.

The genotypes had significant variations for male, female and total number of flowers, on 10 cm length of indeterminate branches. Among the genotypes, male flowers varied between 650.7 (Krishna) and 1488.3 (NA 10) (Fig 1a). Chakaiya had the highest female flowers (12.33) which were statistically at par with NA 6 (12.0) while lowest female flowers (4.33) was observed in S 2 which was at par with S 1 (5.0) and BSR 1 (7.0) (Fig 1b). The total number of flowers were ranged from 657.0 (Krishna) to 1499.0 (NA 10) (Fig 1c). These findings are quite similar to those reported by the previous workers (Aulakh *et al*. 2013). The sex ratio (male/female) is as an important determining factor for aonla productivity as higher the male/female ratio, lower the yield and vice versa. The sex ratio among the aonla genotypes was recorded between 96.0 (NA 6) and 262.3 (S 1 and S 2) (Fig 1d). Previous studies had also reported similar findings (Kotiyal *et al*. 2015, Bakshi *et al*. 2015). Several environmental variables like temperature fluctuations and edaphic particularly, the nutritional condition of soil influences the sex ratio in aonla (Bajpai 1968). Despite the higher proportion of female flowers (low male/female sex ratio), low yield potential of cultivars, viz. Chakaiya, Krishna and BSR 1 was noticed in the present study which might be due to poor fruit set and high fruit drop.

The evaluated genotypes exhibited significant variation for the different fruit physical attributes (Table 2). The maximum fruit weight (54.96 g) was found in NA 20 while minimum (5.88 g) in BSR 1. The fruit length (3.30 cm) was measured higher in NA 7 and NA 20 which was statistically at par with Chakaiya (3.28 cm), however the minimum fruit length (1.90 cm) was measured in BSR 1. Similarly, fruit breadth was measured maximum (3.70 cm) in Chakaiya while minimum (2.30 cm) in BSR 1. The fruit weight has also been reported to have higher genetic heritability, thus having greater potential for genetic gain and important criterion for selection of new promising cultivar (Singh *et al*. 2012).

The fruit yield is the most important criteria for selection of a genotype for its commercial exploitation. In the present investigation, the yield of aonla genotypes

Table 1 Growth attributes of aonla genotypes under semi-arid conditions

Genotype	Tree shape	Plant height (m)	Stem girth (cm)	Plant spread N- S (m)	Plant spread E-W (m)	LFW (mg)	LDW (mg)	Length of determinate branchlets (cm)
CHES 1	Spreading	5.58^{ed}	46.40^{h}	4.39^{d}	4.50^{d}	100.3^{e}	24.7^{bc}	10.67^{cd}
Chakaiya	Spreading	4.83^{f}	59.73^{f}	5.82^{bc}	5.50^{bcd}	100.7^{e}	24.0^{bc}	8.70^{ef}
Krishna	Spreading	5.67^{cde}	62.87^{e}	6.40^{abc}	6.52^{ab}	142.0^{a}	36.3^{a}	7.10^{g}
NA 6	Spreading	6.25^{ab}	67.03^{d}	5.80^{bc}	5.50^{bcd}	122.3^{bc}	26.0^{b}	15.70^{a}
NA 7	Spreading	5.47^{ed}	54.50^{g}	4.40^{d}	4.43^{d}	106.0^{de}	26.0^{b}	15.07^{a}
NA 10	Spreading	5.88^{bcd}	59.20^{f}	5.47^{cd}	5.33^{cd}	118.3^{cd}	26.3^{b}	11.00^{c}
NA 20	Drooping	6.22^{abc}	78.57^{c}	6.00^{bc}	5.77^{bc}	133.7^{ab}	33.3^{a}	13.60^{b}
G 1	Upright	6.62^{a}	95.33^{a}	7.47^{a}	7.10^{a}	103.0^{e}	25.7^{b}	12.53^{b}
BSR 1	Spreading	5.22^{ef}	46.93^{h}	5.50^{cd}	5.22^{cd}	95.3^{e}	19.7^{c}	7.57^{fg}
S 1	Upright	6.42^{ab}	86.56^{b}	6.91^{ab}	6.50^{ab}	102.3^{e}	25.3^{bc}	10.70^{cd}
S 2	Upright	6.18^{abc}	76.15^{c}	6.10^{bc}	6.20^{abc}	97.7^{e}	22.7^{bc}	9.47^{de}

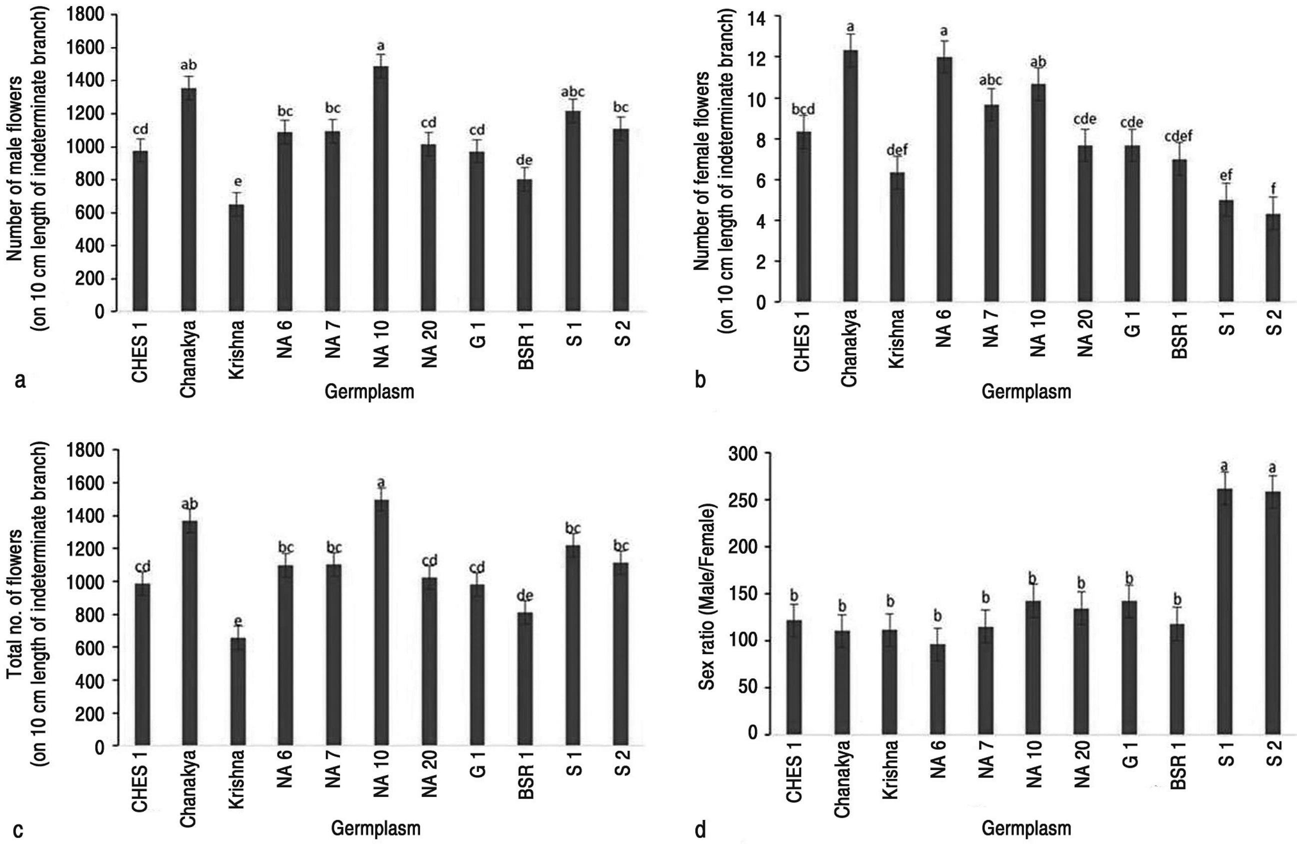

Fig 1 Flowering characteristics of aonla genotypes under semi-arid conditions (a) Number of male flowers (on 10 cm length of indeterminate branch); (b) Number of female flowers (on 10 cm length of indeterminate branch); (c) Total no. of flowers (on 10 cm length of indeterminate branch); (d) Sex ratio (male/ female).

varied from 27.0 to 97.2 kg tree. It was recorded highest (97.2 kg/tree) in NA 20, being at par with NA 6 (90.8 kg/ tree) while lowest (27.0 kg/tree) in BSR 1. These findings are comparable with previous findings (Aulakh *et al*. 2013, Bakshi *et al*. 2015). However, BSR 1 has been reported as productive aonla genotype under the tropical region of the country (Kumar *et al*. 2011b). Thus, it seems that semi-arid conditions are a hindrance for fruit growth and yield of BSR 1. The stone weight was observed lowest (0.86 g) in BSR 1 while highest (3.36 g) in NA 20. The aonla genotype, NA 20 had the highest pulp per cent (93.87%) which was at par with Chakaiya (92.37%) and NA 6 (91.80%) whereas, lower pulp per cent was recorded in G 1 (84.63 %), BSR 1 (85.42%), S 1 (85.40%) and CHES 1 (86.45%). The results pertaining to pulp and stone parameters during the present experiment were in consonance with previous studies in aonla (Shukla *et al*. 2005, Bakshi *et al*. 2015). Time of fruit maturity was recorded early (i.e. before 15 November) in cultivar Krishna and NA 10; mid (i.e. 15 November to 15th December) in CHES 1, NA 6, NA 7, NA 20, G 1 and S 2, and late (i.e. after 15th December) in S 1, Chakaiya and BSR 1. These results are comparable with previous studies about the maturity period of aonla genotypes under the subtropical conditions (Bakshi *et al*. 2015, Singh *et al*. 2015).

The aonla genotypes had significant variations for their fruit quality parameters (Table 2). Total soluble solids (TSS) value of the studied aonla genotypes varied from 8.4-18.3 °B. It was recorded highest in genotype, BSR 1 while lowest (8.4 °B) in S 1, which was statistically at par with S 2 (8.7 °B). The titrable acidity was recorded lowest (1.87%) in NA 6 and highest (2.67%) in S 2. TSS: acid ratio was observed higher in BSR 1 (7.67), G 1 (7.07) and CHES 1 (7.07), and lowest (3.29) in S 2. The present findings on TSS, acidity TSS: acid ratios are corroborated with those of Pandey *et al*. (2008). The value of total sugars, reducing sugars and non-reducing sugars among aonla genotypes varied from 3.89–8.51%, 1.75–4.68% and 2.14– 3.89%, respectively (Table 2). The genotype, Krishna contains higher reducing sugars (4.68%), non-reducing sugars (3.89%) and total sugars (8.51%). These results are in similar range with previous findings in aonla (Pandey *et al*. 2008, Bakshi *et al*. 2015). The aonla fruits are known for its high ascorbic acid content which plays an important role in antioxidant activities along with different bioactive compounds. The significant differences for ascorbic acid content were estimated among aonla genotypes and it was recorded highest (565.88 mg/100 g pulp) in Chakaiya while lowest (308.74 mg/100 g pulp) in S 1, which was statistically at par with BSR 1 (321.88 mg/100 g pulp) and S 2 (327.51 mg/100 g pulp). The range of ascorbic acid content among the aonla genotypes in the present study is comparable with earlier findings under subtropical conditions (Bakshi *et al*.

Table 2 Fruit physico-chemical attributes of aonla genotypes under semi-arid conditions

Genotype	Fruit weight (g)	Fruit length (cm)	Fruit breadth (cm)	Yield (kg/tree)	Stone weight (g)	Pulp (%)	Fruit maturity group	TSS (°B)	Acidity (%)	TSS:Acid ratio	Total sugars (%)	Reducing sugars (%)	Non-reducing sugars (%)	Ascorbic acid (mg/100 g pulp)	Tannin (%)
CHES 1	14.76^{g}	2.44^{g}	3.00^{d}	47.2^{de}	2.00^{c}	86.45^{cd}	Mid	15.0^{c}	2.13^{bc}	7.07^{a}	4.90^{f}	2.76^{f}	2.14^{f}	442.00^{e}	2.30^{g}
Chakaiya	34.80^{b}	3.28^{ab}	3.70^{a}	65.3^{c}	2.65^{b}	92.37^{ab}	Late	10.5^{e}	2.33^{ab}	4.52^{de}	6.48^{d}	3.89^{c}	2.59^{d}	565.88^{a}	3.30^{b}
Krishna	27.60^{d}	3.18^{bc}	3.50^{b}	70.5^{c}	2.54^{b}	90.80^{b}	Early	10.6^{e}	2.17^{bc}	4.93^{cd}	8.51^{a}	4.68^{a}	3.83^{a}	491.74^{bc}	3.10^{c}
NA 6	29.40^{c}	3.10^{c}	3.38^{bc}	90.8^{ab}	2.41^{b}	91.80^{ab}	Mid	11.1^{e}	1.87^{c}	6.01^{b}	6.93^{c}	3.66^{d}	3.27^{bc}	373.49^{f}	2.85^{d}
NA 7	28.20^{cd}	3.30^{a}	3.44^{bc}	87.0^{b}	2.65^{b}	90.61^{b}	Mid	9.0^{f}	2.33^{ab}	3.86^{ef}	7.72^{b}	4.56^{b}	3.16^{bc}	515.20^{b}	2.15^{h}
NA 10	21.60^{e}	2.96^{d}	3.30^{c}	88.3^{b}	2.56^{b}	88.13^{c}	Early	14.2^{c}	2.63^{a}	5.40^{bc}	3.89^{h}	1.75^{h}	2.14^{f}	473.91^{cd}	3.60^{a}
NA 20	54.96^{a}	3.30^{a}	3.50^{b}	97.2^{a}	3.36^{a}	93.87^{a}	Mid	13.0^{d}	2.23^{b}	5.92^{b}	5.69^{e}	3.32^{e}	2.37^{e}	451.39^{de}	2.70^{ef}
G 1	13.56^{g}	2.50^{fg}	2.90^{ed}	85.0^{b}	2.08^{c}	84.63^{d}	Mid	17.4^{b}	2.47^{ab}	7.07^{a}	4.45^{g}	2.31^{g}	2.14^{f}	425.11^{e}	2.80^{de}
BSR 1	5.88^{h}	1.90^{h}	2.30^{g}	27.0^{f}	0.86^{d}	85.42^{d}	Late	18.3^{a}	2.40^{ab}	7.67^{a}	7.94^{b}	4.56^{b}	3.38^{b}	321.88^{g}	2.80^{de}
S 1	20.41^{e}	2.76^{e}	2.83^{e}	41.3^{e}	2.43^{b}	88.10^{c}	Late	8.4^{f}	2.37^{ab}	3.60^{f}	4.68^{fg}	2.20^{g}	2.48^{de}	308.74^{g}	3.10^{c}
S 2	17.40^{f}	2.60^{f}	2.57^{f}	52.8^{d}	2.54^{b}	85.40^{d}	Mid	8.7^{f}	2.67^{a}	3.29^{f}	6.70^{cd}	3.55^{d}	3.16^{bc}	327.51^{g}	2.60^{f}

2015, Singh *et al*. 2016). Notably, the ascorbic acid content in aonla genotypes was reported lower in the humid tropical conditions compare to the subtropical conditions which could be due to high soil moisture and atmospheric humidity at the time of fruit maturation that leads to increased enzymatic metabolism (Singh and Dhaliwal 2004). The maximum tannin content (3.60%) was recorded in aonla genotype, NA 10 whereas, it was observed minimum (2.15%) in NA 7. These results were in agreement with those of investigated by Pandey *et al*. (2008). The tannins play important role in retention of ascorbic acid and also possess antioxidant properties (Kuttan and Harikumar 2011).

The present investigation deciphered significant variability among the aonla genotypes for their growth, flowering and fruit-related parameters under the semi-arid conditions of Indian state Haryana. The aonla genotypes NA 20, NA 6 and Chakaiya found comparatively superior to other studied genotypes for yield and fruit biochemical attributes. Thus, these selected genotypes have the potential for commercial cultivation in the semi-arid region of India to achieve the higher yield and high-quality aonla production.

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