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Effect of micronutrients on growth and yield of Aonla (*Emblica officinalis* Gaertn.) CV. NA-7

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Abstract
Aonla (*Emblica officinalis* Gaertn.) is one of the most important minor fruits of India, which is also known as Indian gooseberry, belongs to the family Euphorbiaceae and is native to Central and Southern India. Though it is a hardy crop, growers are experiencing the problem of heavy premature fruit drop which leads to reduced yield and reduced quality which is accompanied with deficiency of nutrients, particularly micronutrients. Hence, to overcome the issue, the present study was conducted to asses the response of foliar application of different micronutrients on growth and yield of aonla *cv*. NA-7. The results revealed that the foliar spray of micronutrient combination of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.25% Borax significantly increased overall growth of plants including plant height, spread in both East-West and North- South directions, reduced the incidence of fruit drop (45.60% as against 79.63% in control) resulting in increased fruit set (53.73% as against 21% in control). The said combination of micronutrients was also associated with increased fruit physical parameters and higher yield levels (24.96 kg/plant).

Keywords: Deficiency, foliar, fruit drop

Introduction
Aonla (*Emblica officinalis* Gaertn.) is one of the most important minor fruits of India, which is also known as Indian gooseberry. It belongs to family Euphorbiaceae (Khan *et al*., 2009) [11] and is native to Central and Southern India. The crop is seen in Sri Lanka, Malaysia and China. In India, aonla is being cultivated on a commercial in the salt affected districts of Uttar Pradesh, arid and semiarid parts of Maharashtra, Gujarat, Rajasthan, and Karnataka. At present, it is being cultivated in an area of about 85,000 ha with an annual production of 1094000 MT in the country (Anon, 2015-16). It is the richest source of Vitamin-C (600 mg/100g) among fruits and ranks second after Barbados cherry (*Malpighia glabra* L.) (Asengo, 1953) [2] and fair source of minerals, carbohydrates, carotene, thiamine and riboflavin. It also contains phyllamblin, gallicacid, ellagic acid and tannins which retard the oxidation of vitamin C (Yadav and Shukla, 2009) [22]. Triphala and chyavanprash are well-known indigenous medicines in Indian ayurvedic system using aonla. It is also considered as 'wonder fruit for health' because of its unique qualities.

The tree is small to medium in size, reaching 1–8 m in height, behaving as evergreen in tropics and as deciduous in sub-tropical conditions. The plants exhibit phyllanthoid branching habit producing short determinate and long indeterminate shoots. The flowers are unisexual flowers are produced as axillary cymules on determinate shoots. Sex ratio in aonla varies from 28.7:1 to 355.5:1 in different cultivars. Fruit is capsular and exhibits zygodormancy. The major factors playing a role in inducing dormancy mechanism of fruit appear to be from auxins (a1-a5). Each seed capsule comprises two to three locules containing two seeds in locule.

Though, it is a very hardy species which can be successfully grown in variable agro-climatic and soil conditions *viz.*, sodic and saline soils upto 35 ESP and EC 9 dSm^{-1} respectively (Pathak and Pande, 1985) [15], the farmers are experiencing the problem of heavy premature fruit drop leading to reduced yield and sometimes reduced quality due to necrosis which is associated with deficiency of boron. The incidence of fruit drop may be due to many reasons, of which micro-nutrients are important because, micronutrients like boron, zinc and iron play a vital role in fruit set, growth and development and their application has been found to address the issue of fruit drop and are more effective for rapid recovery of plant health as per the studies conducted elsewhere.

Hence, keeping this in mind the present study was conducted to assess the response of foliar application of micronutrients on growth and yield of aonla *cv*. NA-7.

The main objective of this study was to see the effect of different micronutrients and their combinations on reducing the incidence of fruit drop and improving its growth, development and yield of fruits.

Material and methods

Geographical location of orchard

The experiment was conducted at the Regional Horticultural Research and Extension Centre (RHREC), University of Horticultural Sciences, GKVK campus, Bengaluru, Karnataka-560065. Six year old uniform plants of aonla *cv*. NA-7 were used which are spaced at 6 m x 6 m (277 plants/ha). Fertilizers are applied uniformly as per the recommendations; FYM 25.00 kg/plant (2.5 tonnes/ha) + 75:50:50 g NPK/ plant (7.5:5.0:5.0 kg/ha).

Treatment details

Treatment included; T_1 (Control, water spray), T_2 (0.5% $ZnSO_4$), T_3 (0.5% $FeSO_4$), T_4 (0.25% Borax), T_5 (T_2+ T_3), T_6 (T_2+ T_4), T_7 (T_3+ T_4), T_8 (T_2 + T_3 + T_4). The foliar sprays were given two times, one at the time of flushing and second at sixty days after flushing which coincided with flowering.

Morphological features

Plant height (distance from soil level to growing point), stem circumference (at 30 cm above soil level), plant spread (both in East-West and North-South directions) were recorded using measuring tape during the time of foliar application and subsequent measurements were taken at the time of harvest and the total increment in vegetative characters during the period of experimentation was calculated.

Reproductive parameters

Four shoots in all four directions were tagged and total number of fruits set, fruit drop and fruit retention were calculated using formulae; fruit set (%) = (Number of set fruits/ Number of flowers) x 100; fruit drop (%) = (Initial fruit set – Total number of fruits at harvest time)/ Initial fruit set x 100; fruit retention (%) = (Number of fruits at harvesting time/ Initial fruit set) x 100. The fruit, pulp and seed weights of five randomly collected individual fruits from each tree were recorded using weighing balance and expressed in grams. Pulp weight was recorded by subtracting the weight of the seeds from total weight of the fruit and expressed in grams.

Fruit yield

The fruits were harvested at commercially ripe stage when the skin of the fruit changes to light greenish or yellowish in colour. Yield per tree was recorded at the time of final harvest and expressed in kilo grams.

Experimental design and statistical analysis

The experiment was laid out in a completely randomized block design with three replications. Three plants for each treatment were sampled for plant growth, reproductive and yield components. Five fruits were randomly selected for evaluating fruit physical and chemical features. The data were analysed in a completely randomized block design using analysis of variance (ANOVA).

Results and discussion

The data pertaining to effect of different micronutrients on increment in total vegetative growth of the plants *viz*., plant height, spread and girth is depicted in Table 1 and are significant over control. The maximum increment in plant height (0.79 m), plant spread in East-West (0.90 m), North-South (0.92 m) and stem diameter (4.73 cm) were recorded with foliar spray of $ZnSO_4$ + $FeSO_4$ + Borax 0.25% which was markedly better than other treatments. The increment in vegetative growth of plants is might be due to stimulative effect of zinc and iron. Zinc and iron are the elements involved in synthesis and formation of chlorophyll and hence total photosynthetic activity is increased in plant (Meena *et al*., 2014) [13]. The earlier report of Singh *et al*. (2002) [18] also indicated that combined application of zinc, borax and copper increased plant height, spread and trunk girth in aonla which was due to stimulatory effect of zinc and boron in cell division and cell elongation, which is also close conformity with results of Shekar *et al.* (2010) [17].

The data pertaining to total number of flowering panicles, total fruit set, drop and fruit retention were depicted in Table 2. The highest number of flower panicles (1205 m^{-2}) was obtained from the treatment combination of $ZnSO_4$ 0.5% and Borax 0.25% which is 40.05 per cent higher over control. Initial fruit setting of aonla did not differ significantly due to foliar feeding of micro-nutrients. The minimum fruit drop percentage (45.60%) and maximum retention (53.73%) were recorded with the application of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + Borax 0.25% followed by 0.5% $ZnSO_4$ + 0.25% Borax whereas maximum fruit drop (79.63%) and minimum retention were noticed in control (water spray) (Table 2).

Increase in total number of flowering panicals during the period of investigation was might due to fact that zinc and boron, being important elements involved in reproduction, play an important role in enhanced flower bud initiation which leads to increased number of flowers and flowering panicles. Similar findings were reported by Chandra and Singh (2015) [6] who opined that zinc is the element present in activating several dehydrogenase and proteinase enzymes and involved in the biosynthesis of auxin, which promotes flowering and fruit setting of many plants.

Maximum fruit retention and minimum fruit drop is might be due to zinc and boron being main constituent of cell wall which plays an important role in strengthening of pedicel attached to proximal end of fruit resulted in less fruit drop (Singh *et al*., 2007) [20]. Similarly, reduction in fruit drop by spray of borax is might due to the indirect action of boron in auxin synthesis that delayed the formation of abscission layer during early stages of fruit development (Guardiola and Garcia, 2000) [10]. According to Krishnamoorthy (1992) [12] and Awasthi *et al*. (1975) [3] fruit drop is an abscission phenomenon controlled by the inner play of hormones. Zinc application ultimately encourages the endogenous production of auxin thereby reducing the formation of abscission layer and less incidence of fruit drop.

The physical parameters (Table 3) of fruit and seed were significantly influenced by foliar application of micronutrients. Among the treatments, higher fruit weight (43.69 g) and pulp weight (43.03 g) were associated with the combined application of $ZnSO_4$ 0.5%, $FeSO_4$ 0.5% and Borax 0.25% (T_8). The increase in physical attributes might be due to the combined effect of all the three micronutrient where in iron increases the photosynthetic activity there by increases the accumulation of metabolites in the system; boron as a constituent of cell membrane is essential for cell division and

elongation and zinc being an essential trace element for plants is involved in many enzymatic reactions and is necessary for good growth and development. These findings are in agreement with the observations of Babu and Singh (2001) [4] who reported that increased fruit size and weight might be due to increased rate of cell division and cell enlargement leading to accumulation of more metabolites in the fruit. These results are also in close conformity with the findings of Ghosh *et al*. (2009) [8] who have also reported that foliar spray of zinc sulphate increased the fruit weight of aonla, while Singh *et al*. (2012) [21] found similar effect with combined application of boron, zinc and copper in aonla fruit *cv*. Banarasi. Further, similar findings were reported in guava (Goswami *et al*., 2012) [9] and mango (Banic *et al*., 1997) [5] where translocation of food material from source to sink under the influence of micronutrients like boron and zinc increased the size of the fruit.

The lower values for seed weight (1.51 g) was recorded with the application of $FeSO_4$ 0.5% (T_3), whereas, the higher pulp: seed ratio (22.18) was recorded with the combined application of $ZnSO_4$ 0.5%, $FeSO_4$ 0.5% and Borax 0.25% (T_8) which is the most desired character (Table 3). The increase in pulp: seed ratio is might be due to acceleration in biochemical activities and accumulation of metabolites in plant parts including fruits, which is probably due to synergistic effect of zinc on conversion and translocation of total sugars and minerals during the process of fruit development and fruit maturation (Chandra and Singh, 2015) [6]. Further, role of boron in cell division and cell elongation leading to higher fruit weight in well-established plants and similar observations were reported by Singh *et al*. (1993) [19] in aonla. The increase in yield (Table 3) might due to direct or indirect involvement of micronutrients in photosynthesis, fruit setting, retention, reduction in drop which ultimately gives the higher yield levels. Similarly Singh *et al*. (2012) [21] reported that application of zinc and boron might have caused rapid synthesis of auxins, protein and translocation of carbohydrate which ultimately led to increase in fruit retention and its growth which is directly correlated with total yield. Similar results have been reported in aonla (Ram *et al*., 1977; Dashora *et al*., 2005; Panwar *et al*., 1995) [16, 7, 14] and in litchi (Babu and Singh, 2001) [4].

Table 1: Effect of foliar application of micro-nutrients on morphological parameters of aonla *cv*. NA-7.

Treatments	Plant height (m)	Plant spread (m)		Stem diameter (cm)
		E-W	N-S	
T_1	0.65	0.64	0.63	2.83
T_2	0.67	0.66	0.66	3.10
T_3	0.77	0.73	0.70	4.13
T_4	0.68	0.70	0.72	3.60
T_5	0.69	0.67	0.67	4.40
T_6	0.68	0.72	0.75	3.90
T_7	0.66	0.71	0.74	4.67
T_8	0.86	0.90	0.92	4.73
S. Em. ±	0.01	0.02	0.03	0.12
CD @ 5%	0.04	0.07	0.08	0.36

Table 2: Effect of foliar application of micro-nutrients on reproductive parameters of aonla *cv*. NA-7.

Treatments	Flower panicles/ m^2	Fruit set (%)	Fruit drop (%)	Fruit retention (%)	Decrease in fruit drop over control (%)	Increase in fruit retention over control (%)
T_1	860.67	72.63	79.63	21.00	-	-
T_2	966.00	75.87	78.30	21.97	1.67	4.61
T_3	971.00	72.47	74.80	26.37	6.06	25.57
T_4	968.00	73.67	68.70	32.10	13.72	52.85
T_5	973.33	73.20	71.40	28.07	10.33	33.66
T_6	1205.33	74.27	49.80	50.27	37.46	139.38
T_7	928.67	74.48	63.70	35.70	25.00	70.00
T_8	1043.00	75.47	45.60	53.73	42.73	155.85
S. Em. ±	43.54	-	2.84	1.42	-	-
CD @ 5%	132.06	NS	8.61	4.30	-	-

Table 3: Effect of foliar application of micro-nutrients on fruit weight, pulp weight, seed weight, pulp: seed ratio and yield parameters of aonla *cv*. NA-7.

Treatments	Fruit weight (g)	Pulp weight (g)	Seed weight (g)	Pulp: Seed ratio	Yield (kg. $tree^{-1}$)
T_1	35.44	33.99	1.61	21.04	14.91
T_2	39.52	37.82	1.83	20.71	18.56
T_3	34.60	33.10	1.51	21.99	15.96
T_4	39.82	37.82	2.01	18.60	18.28
T_5	38.53	36.93	1.87	19.85	19.63
T_6	41.27	39.12	2.14	18.29	22.21
T_7	35.27	33.48	1.79	18.70	21.07
T_8	43.69	43.03	1.94	22.18	24.96
S. Em. ±	1.41	1.26	0.06	0.74	1.66
CD @ 5%	4.28	3.82	0.17	2.26	5.04

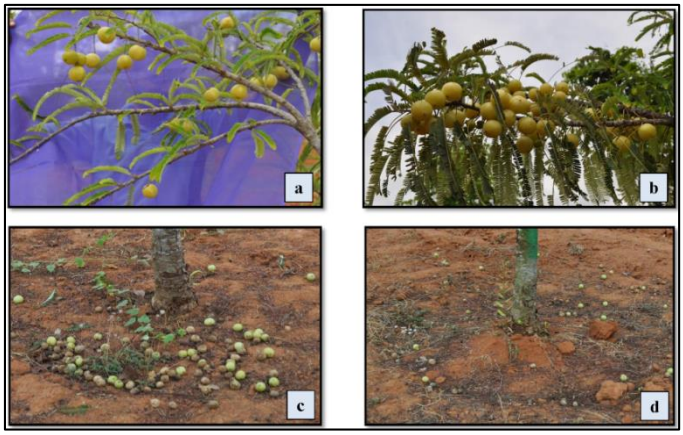

Plate 1: General view of fruit drop and fruit retention in the orchard a. Fruit retention (T_1) b. Fruit retention (T_8) c. Fruit drop (T_1) d. Fruit drop (T_8)

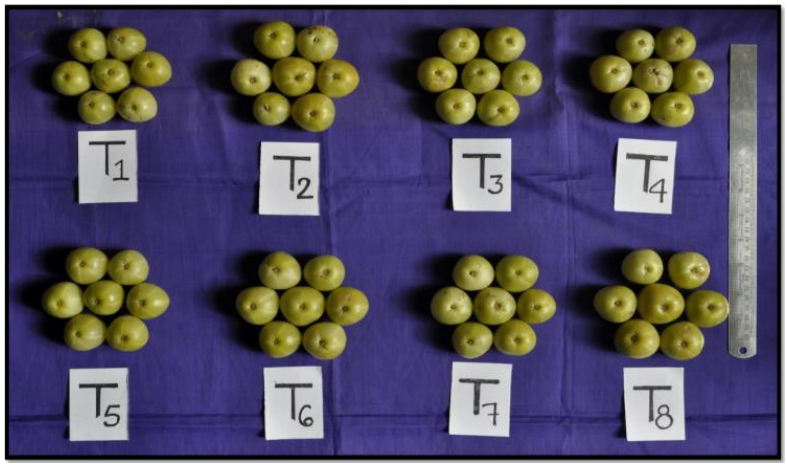

Plate 2: Fruit characteristics influenced by foliar application of micronutrients on aonla *cv*. NA-7.

T_1 - Control (Water spray)	T_5 - $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 %
T_2 - $ZnSO_4$ 0.5 %	T_6 - $ZnSO_4$ 0.5 % + Borax 0.25 %
T_3 - $FeSO_4$ 0.5 %	T_7 - $FeSO_4$ 0.5 % + Borax 0.25 %
T_4 - Borax 0.25 %	T_8 - $ZnSO_4$ 0.5 % + $FeSO_4$ 0.5 % + Borax 0.25 %

Conclusion

Foliar application of micronutrients is an ideal way for improving vegetative growth and yield in case of aonla. Our results shows that the fruit yield was almost double as compared to control in the treatment combination of $ZnSO_4$ 0.5% + $FeSO_4$ 0.5% + Borax 0.25% as a result of doubling up of fruit retention. Hence, the micronutrient combination of 0.5% $ZnSO_4$ + 0.5% $FeSO_4$ + 0.25% Borax holds immense potential as a foliar spray in arresting fruit drop and doubling up the yield in aonla under rain-fed conditions of southern dry zone of Karnataka.

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