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Effect of foliar application of PGRs and mineral nutrients on fruiting behaviour, growth and yield of Aonla CV. NA-7

Mahendra Chaudhary, DP Singh, Jagendra Pratap Singh and Krishna Kumar Mishra

Abstract
The present investigation was conducted with aim to assess the effect of plant growth regulators and micro-nutrients on growth, fruiting behaviour and yield of Aonla. The present investigation was carried out during two consecutive years (Y_1=2015-16 & Y_2=2016-17) and pooled analysis was also carried out. The present investigation revealed that maximum fruit set %, fruit retention, fruit length, fruit width, fruit yield was recorded in treatment T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} followed by in T_9 {GA_3 (25 ppm) + NAA (25 ppm)} and T_{12} {Borax (0.75%) + $ZnSO_4$ (0.75%)} during both the years and in pooled analysis. However minimum fruit drop % was also calculated in treatment T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} during both the years and in pooled analysis.

Keywords: aonla, fruit yield, mineral nutrients and PGRs

Introduction
Aonla (*Emblica officinalis* Gaertn.) which belongs to family Euphorbiaceae with a chromosome number of 2n=28. It has various vernacular names such as ‘Amlal’ or ‘Aura’ in Hindi; ‘Amla’ or ‘Amalaki’ in Bengali and Uriya; ‘Nelli’ in Malayalam and Tamil; ‘Dhatri’ in Sanskrit; ‘Amalkumi’ in Telgu; ‘Amolphal’ in Punjabi; ‘Amlay’ in Arabic; ‘Amlet’ in Persian and ‘Emblic Myrobalan’ and ‘Indian Goose Berry’ in English in the various parts of the Worlds (Bajpai and Shukla, 2002) [3].

Aonla trees are hardy in nature, adopt well under varying soil conditions, have low water requirement and exhibit salt tolerance. The wastelands which do not otherwise support arable crops may be put to productive use by planting aonla orchards. Tree characteristics such as deep root system, sparse foliage and dormancy of fruitlets make aonla a promising fruit species for arid and semi-arid regions. In recent past, a set of factors including feasibility of commercial aonla cultivation in marginal lands, availability of improved varieties and huge possibilities for the value-addition of fruits have enabled rapid coverage of vast area under aonla cultivation in many parts of Uttar Pradesh, Haryana, Rajasthan, Maharashtra, Gujarat, Andhra Pradesh and Tamil Nadu states of India (Pathak, 2001) [16]. India ranks first in the world in area and production of aonla crop. In India, Uttar Pradesh is known as home land of aonla cultivation, particularly in the districts of Pratapgarh, Varanasi, Azamgarh, Sultanpur, Raibareli etc. (Bajpai, 1963 and Ram, 1983) [2, 18]. Pratapgarh has been declared as aonla fruit belt and agri-export zone.

Aonla is one of the nutritious fruit and second richest source of vitamin-C (500-750) mg/100 g of pulp) among except Barbados cherry (*Malphigia glabra*) (Asenjo, 1953) [1]. Deficiency of vitamin-C causes various diseases like scurvy, anemia, failure of bound healing, scorbutic bone formation and rough skin. The fruit contain a chemical substance known as gallic acid which retards the oxidation of vitamin-C hence, it has antioxidant property. Aonla has been reported to be hepatoprotective and possesses expectorant, purgative, spasmolytic, antibacterial, hypoglycemic and hypolipidemic activities (Mishra and Rai, 2010) [12]. Fresh aonla is so sour that most people find it intolerable, and hence is preferred in the form of preserves, dried aonla, trifala, jam, juice, pickle and chavyanprash, toffees and fruit bar (Singh and Kumar, 2000).

The role of growth regulators for improving the growth and development, fruit set, control of fruit drops, fruit maturation, fruit quality including of physiological and nutritional disorders has been well established in number of topical, sub-tropical and temperate fruit crops (Singh *et al*., 1976; Bhatia and Yadav, 2003 and Singh *et al*., 2007) [30, 6, 27].

However, it has been studied that the physiological, biochemical and biological activities in plant system are highly influenced due to interaction of micro nutrients. Among the foliar application of different level of growth regulators, viz. GA_3, 2,4-D, NAA have been found more effective in improving flowering, fruit set, fruit size, fruit yield and fruit quality in number of fruit crops. Similar studies on foliar application of growth regulators have earlier been undertaken to find out their effect on fruit set, fruit size, fruit drop, fruit maturation, fruit yield, and fruit quality of aonla (Ram *et al.*, 1977; Shymal *et al*., 1984; Singh *et al*., 2001; Divya and Prasad, 2006 and Singh *et al*., 2009) [19, 22, 26, 8, 25].

Mineral nutrients are involved in flowering and fruiting process, pollen germination, cell division and metabolism of carbohydrates. They effect water relation in plant and are involved in translocation of sugars. The effect of mineral nutrients on yield, quality and shelf-life of fruits has been established in different crops but there are only few references for aonla (Panwar *et al*., 1995 and Singh, 2002) [15, 24]. Boron has also been found to improve fruit retention and quality of fruit in litchi (Kumar *et al*., 2004) [11]. Boron is also claimed to have a role in the water relation in the cells and needed in traces (i.e. 10-15 ppm). Foliar spray of boron increased the fruit quality in various fruits (Kumar *et al*., 2004 and Chauhan *et al*., 2004) [11, 7].

Material and Methods

Thirty nine well established healthy and uniform trees of aonla cv. NA-7 were selected for the purpose of experimentation. The recommended dose of manure and fertilizer and other orchard management practices were adopted during the course of investigation. Aqueous foliar spray of each treatment was done on single selected tree and replicated thrice.

Details of treatments

Treatments		Treatments combination
T_0	:	Control (water spray)
T_1	:	GA_3 (25 ppm)
T_2	:	GA_3 (50 ppm)
T_3	:	NAA (25 ppm)
T_4	:	NAA (50 ppm)
T_5	:	Borax (0.50%)
T_6	:	Borax (0.75%)
T_7	:	$ZnSO_4$ (0.50%)
T_8	:	$ZnSO_4$ (0.75%)
T_9	:	GA_3 (25 ppm) + NAA (25 ppm)
T_{10}	:	GA_3 (50 ppm) + NAA (50 ppm)
T_{11}	:	Borax (0.50%) + $ZnSO_4$ (0.50%)
T_{12}	:	Borax (0.75%) + $ZnSO_4$ (0.75%)

Preparation of solution

S. No.	Chemical	Rate of chemical	Strength of solution
1.	GA_3	25 mg/litre	25 ppm
2.	GA_3	50 mg/litre	50 ppm
3.	NAA	25 mg/litre	25 ppm
4.	NAA	50 mg/litre	50 ppm
5.	Borax	5 g/litre	0.5 per cent
6.	Borax	7.5 g/litre	0.75 per cent
7.	$ZnSO_4$	5 g/litre	0.5 per cent
8.	$ZnSO_4$	7.5 g/litre	0.75 percent
9.	GA_3 + NAA	50 mg/litre	50 ppm
10.	GA_3 + NAA	100 mg/litre	100 ppm
11.	Borax + $ZnSO_4$	1.0 g/litre	1.0 per cent
12.	Borax + $ZnSO_4$	1.5 g/litre	1.5 per cent

Methods of spraying

The foliar application of PGRs and mineral nutrients were applied once after flowering time and second after fruit set and applied during the 15 May and 15 July 2016 and 2017. Each tree was sprayed with 10 litres of solution which was found adequate to drench entire foliage and spraying was done in the afternoon from 3.00 PM and 5.00 PM by using Pneumatic foot sprayer fitted with nozzle. High legged stool was used for top of the tree and it was ensured that all sides of tree branches was drench completely.

Result and Discussion

The flowering and fruiting parameters viz., fruit set %, fruit drop % and fruit retention % were significantly influenced due to the plant growth regulators and micronutrients during both the years and in pooled analysis.

The data recorded on per cent fruit set, fruit drop and fruit retention % due to foliar spray of different micro-nutrients and plant growth regulators during different stages of fruit development of aonla clearly indicate that the maximum fruit drop was observed in the month of September followed by October and minimum in the month of November. Maximum fruit set %, fruit retention and minimum fruit drop % were calculated in treatment T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} followed by T_9 {GA_3 (25 ppm) + NAA (25 ppm)} and T_{12} {Borax (0.75%) + $ZnSO_4$ (0.75%)} however, minimum fruit set %, fruit retention and maximum fruit drop were recorded in T_0 (Water spray) during both the years and in pooled analysis. The treatment T_{10} found significantly superior than rest of the treatments during both the years of experimentation. It is clear from the results that spraying of plant growth regulator GA_3 in combination with NAA have shown beneficial effects in reducing fruit drop. The application of these chemicals supplemented the additional nutrients required during the development of fruits. On the other hand, the maximum fruit drop was caused due to the deficient level of nutrients in plant and soil.

Fruit drop is an abscission phenomenon controlled by the inter play of hormones (Krishnamoorthy, 1993) [9]. The abscission of immature fruit is correlated with their lower auxin content and is prevented by the exogenous supply of synthetic auxins like NAA. Effectiveness of gibberellins in controlling fruit drop appears to be indirect, mediated through the formation of auxin. The role of zinc in reducing fruit drop also seems indirect. Zinc is required for the synthesis of tryptophan, a precursor of auxin, thus helps in reducing fruit drop. Similar observations on heavy fruit drop have also been reported Sharma *et al*. (2005) [21], Painkra *et al*. (2012) [14], Singh *et al*. (2012) and Singh and Singh (2015) [23].

The yield attributing characters in aonla fruits are number, size and weight of fruit, which are highly influenced by nutritional levels of tree and soil. The supplementary doses of nutrients applied through basal application and foliar sprays of nutrients through use of different chemicals and organic manures have been well established in number of fruits for improving the yield. The foliar spray of micro-nutrients and plant growth regulators have shown better responses in improving the fruit yield in aonla. The highest fruit yield per tree was recorded with the spray of T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} followed by T_9 {GA_3 (25 ppm) + NAA (25 ppm)} and T_{12} {Borax (0.75%) + $ZnSO_4$ (0.75%)} however, minimum fruit set %, fruit retention and maximum fruit drop were recorded in T_0 (Water spray) during both the years and in pooled analysis. The treatment T_{10} found significantly superior than rest of the treatments during both the years of experimentation. The present findings have also been supported by Bhati and Yadav (2003) [5], Singh *et al*. (2007) [28] and Mishra *et al*. (2017) [13].

The maximum number of fruits per kg were calculated in treatment T_0 (water spray) followed by T_7 {$ZnSO_4$ (0.50%)} and T_8 {$ZnSO_4$ (0.75%)} however, minimum number of fruits per kg were recorded in T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} during both the years and in pooled analysis. The treatment T_0 recoded significantly more number of fruits per kg than rest of the treatments during both the years and in pooled analysis.

The physical characters of fruit viz., fruit length, fruit width, fruit weight and fruit volume were significantly varied due to foliar spray of micronutrients and plant growth regulators during both the years and in pooled analysis.

Data recorded on size of fruit (length and breadth) indicate that the size of fruit was significantly influenced by different chemicals.

The maximum fruit length and breadth were recorded with the foliar application of T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} followed by T_9 {GA_3 (25 ppm) + NAA (25 ppm)} and T_{12} {Borax (0.75%) + $ZnSO_4$ (0.75%)} and minimum in T_0 (Water spray) during both the years and in pooled analysis. The treatment T_{10} found significantly superior than rest of the treatments during both the years of experimentation. The results are in close conformity with the findings of Bhati *et al*. (2016) [4], Kumar *et al*. (2017) [10] and Mishra *et al*. (2017) [13].

The increase in size of fruit might be due to the fact that gibberellic acid plays a dominant role in cell enlargement during the fruit development. The beneficial effects of zinc sulphate might be due to the fact that it improves the availability of indole acetic acid and other growth stimulating compounds, thereby increasing the availability of photosynthates. A direct correlation between auxin content and fruit growth have been advocated in various fruit crops (Krishnamoorthy, 1993) [9]. This might have been possible because of increased photosynthetic activity and accumulation of greater amounts of photosynthates.

It is obvious from the data recorded on weight, fruit volumes influence by different chemicals, these were significantly increased with the foliar application of GA_3 (50 ppm) + NAA (50 ppm) (T_{10}) followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9), respectively. Foliar application of GA_3 (50 ppm) + NAA (50 ppm) found significantly superior to rest of the treatments during both the years and in pooled analysis. The minimum weight, fruit volume was recorded in control (T_0) during both the years of investigation and also in pooled analysis. Increase in weight and fruit volume was mainly due to the fact that GA_3, NAA and $ZnSO_4$ are known as growth promoting chemicals, playing a significant role in development of fruits. (Krishnamoorthy, 1993) [9]. Pollen grains are a rich source of auxin. Pollination supplies the necessary stimulus, in the from of auxin, for the development of ovary into fruits. Additional supply of the auxin comes from the fertilized ovules. Further developing seeds inside the fruit constitute a rich source of auxin. There are a number of evidences to implicate the developing seeds as a rich source of auxin in the development of fruits. Generally, the size of the fruit is proportional to the number of seeds it contain. This is evident in strawberry (*Fragaria* spp.) where fruit size is markedly reduced when the developing achenes inside the fruit are removed after pollination. In the case of apple, the development of fruit is symmetric when it contains seeds distributed all round. Auxin causes an isodiametric enlargement of ovary cells leading to fruit development. Further, auxins induce translocation and accumulation of food reserves from vegetative plant parts towards the developing fruits. A direct correlation between the endogenous gibberellin content of developing fruits and their growth rate has been established in many fruit crops. Although exactly not known, there may be two possibilities regarding the role of gibberellin in fruit development. Firstly, gibberellins may trigger auxin production, which in turn may control fruit development (Sastry and Muir, 1963) [20]. Secondly, like auxin, gibberellins may also preferentially direct the flow of metabolites from vegetative parts to developing fruits (Pereto and Beltran, 1987) [17]. The results are also in conformity with the observations recorded by Uniyal and Mishra (2015) [31], Bhati *et al*. (2016) [4] and Mishra *et al*. (2017) [13].

Table 1: Effect of foliar application of PGRs and mineral nutrients on fruiting behaviour, growth and yield.

Treatments		Fruit set (%)			Fruit drop (%)			Fruit retention (%)		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_0	Control (water spray)	67.44	67.82	67.63	77.56	76.88	77.22	22.44	23.12	22.78
T_1	GA_3 (25 ppm)	72.48	72.71	72.60	74.43	73.98	74.21	25.57	26.02	25.80
T_2	GA_3 (50 ppm)	74.58	75.10	74.84	73.46	73.18	73.32	26.54	26.82	26.68
T_3	NAA (25 ppm)	71.88	72.13	72.01	74.67	74.22	74.45	25.33	25.78	25.56
T_4	NAA (50 ppm)	72.13	72.36	72.25	74.52	74.15	74.34	25.48	25.85	25.67
T_5	Borax (0.50%)	69.77	70.11	69.94	76.94	76.27	76.61	23.06	23.73	23.40
T_6	Borax (0.75%)	71.66	71.98	71.82	76.68	76.18	76.43	23.32	23.82	23.57
T_7	$ZnSO_4$ (0.50%)	67.67	67.94	67.81	77.25	76.84	77.05	22.75	23.16	22.96
T_8	$ZnSO_4$ (0.75%)	69.97	70.17	70.07	77.13	76.82	76.98	22.87	23.18	23.03
T_9	GA_3 (25 ppm) + NAA (25 ppm)	75.34	75.78	75.56	70.35	70.12	70.24	29.65	29.88	29.77
T_{10}	GA_3 (50 ppm) + NAA (50 ppm)	75.65	75.98	75.82	69.64	68.97	69.31	30.36	31.03	30.70
T_{11}	Borax (0.50%) + $ZnSO_4$ (0.50%)	74.82	75.22	75.02	73.26	72.92	73.09	26.74	27.08	26.91
T_{12}	Borax (0.75%) + $ZnSO_4$ (0.75%)	75.13	75.54	75.34	73.37	73.16	73.27	26.63	26.84	26.74
C.D. (P=0.05)		0.174	0.182	0.184	0.186	0.163	0.165	0.158	0.158	0.160
SEm±		0.059	0.062	0.063	0.063	0.059	0.060	0.054	0.054	0.055

Table 2: Effect of foliar application of PGRs and mineral nutrients on fruiting behaviour, growth and yield

Treatments		Fruit yield (kg/tree)			Number of fruits/kg			Fruit length (cm)		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_0	Control (water spray)	35.30	38.80	37.05	41.20	39.43	40.32	2.77	2.96	2.87
T_1	GA_3 (25 ppm)	52.50	54.10	53.30	27.12	26.53	26.83	3.36	3.59	3.48

T_2	GA_3 (50 ppm)	55.90	58.90	57.40	25.93	25.15	25.54	3.48	3.69	3.59
T_3	NAA (25 ppm)	46.10	48.70	47.40	30.41	29.60	30.01	3.19	3.36	3.28
T_4	NAA (50 ppm)	48.20	51.60	49.90	29.57	28.03	28.80	3.28	3.47	3.38
T_5	Borax (0.50%)	39.80	41.60	40.70	34.25	32.39	33.32	3.01	3.28	3.15
T_6	Borax (0.75%)	41.00	43.50	42.25	32.59	31.27	31.93	3.04	3.32	3.18
T_7	$ZnSO_4$ (0.50%)	37.50	39.90	38.70	38.71	37.19	37.95	2.85	3.09	2.97
T_8	$ZnSO_4$ (0.75%)	38.60	40.70	39.65	35.92	33.76	34.84	2.94	3.22	3.08
T_9	GA_3 (25 ppm) + NAA (25 ppm)	65.99	67.30	66.65	23.28	22.81	23.04	3.76	3.93	3.85
T_{10}	GA_3 (50 ppm) + NAA (50 ppm)	66.70	68.20	67.45	22.92	21.95	22.43	3.90	4.07	3.99
T_{11}	Borax (0.50%) + $ZnSO_4$ (0.50%)	56.70	59.00	57.85	25.01	24.00	24.51	3.67	3.79	3.73
T_{12}	Borax (0.75%) + $ZnSO_4$ (0.75%)	59.20	62.10	60.65	24.03	23.39	23.71	3.69	3.86	3.78
C.D. (P=0.05)		0.664	0.642	0.643	0.304	0.317	0.315	0.024	0.022	0.023
SEm±		0.226	0.219	0.220	0.103	0.108	0.107	0.008	0.007	0.008

Table 3: Effect of foliar application of PGRs and mineral nutrients on fruiting behaviour, growth and yield.

Treatments		Fruit Width (cm)			Fruit Weight (g)			Fruit volume (cc)		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_0	Control (water spray)	3.26	3.30	3.28	24.27	25.36	24.82	23.56	24.25	23.91
T_1	GA_3 (25 ppm)	3.65	3.68	3.67	36.87	37.69	37.28	33.06	33.19	33.13
T_2	GA_3 (50 ppm)	3.68	3.73	3.71	38.57	39.76	39.17	33.96	34.24	34.10
T_3	NAA (25 ppm)	3.53	3.59	3.56	32.88	33.78	33.33	29.87	30.22	30.05
T_4	NAA (50 ppm)	3.60	3.64	3.62	33.82	35.68	34.75	30.35	31.65	31.00
T_5	Borax (0.50%)	3.38	3.42	3.40	29.20	30.87	30.04	27.09	28.12	27.61
T_6	Borax (0.75%)	3.45	3.48	3.47	30.68	31.98	31.33	28.22	28.85	28.54
T_7	$ZnSO_4$ (0.50%)	3.30	3.33	3.32	25.83	26.89	26.36	24.52	25.12	24.82
T_8	$ZnSO_4$ (0.75%)	3.34	3.37	3.36	27.84	29.62	28.73	26.19	27.10	26.65
T_9	GA_3 (25 ppm) + NAA (25 ppm)	3.83	3.90	3.87	42.96	43.85	43.41	37.18	37.58	37.38
T_{10}	GA_3 (50 ppm) + NAA (50 ppm)	3.86	3.95	3.91	43.63	45.56	44.60	37.22	38.28	37.75
T_{11}	Borax (0.50%) + $ZnSO_4$ (0.50%)	3.72	3.76	3.74	39.98	41.66	40.82	35.12	36.09	35.61
T_{12}	Borax (0.75%) + $ZnSO_4$ (0.75%)	3.77	3.83	3.80	41.61	42.76	42.19	36.12	37.01	36.57
C.D. (P=0.05)		0.014	0.016	0.013	0.406	0.407	0.408	0.294	0.295	0.299
SEm±		0.005	0.005	0.004	0.138	0.139	0.140	0.100	0.100	0.100

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