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Mahendra Chaudhary
Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

DP Singh
Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Jagendra Pratap Singh
Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Saurabh Tomar
Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Correspondence
Mahendra Chaudhary
Department of Horticulture, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India

Effect of foliar application of PGRs and mineral nutrients on physico-chemical characteristics of Aonla fruit cv. NA-7

Mahendra Chaudhary, DP Singh, Jagendra Pratap Singh and Saurabh Tomar

Abstract
The present study was conducted with aim to assess the effect of plant growth regulators and micro-nutrients on physical and biochemical properties 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 physical and biochemical characters of fruit viz., specific gravity, fruit pulp weight, fruit juice content, fruit pulp stone ratio, acidity, TSS, ascorbic acid, reducing sugars, non-reducing sugars, total sugars and stone weight were significantly varied due to foliar spray of micronutrients and plant growth regulators during both the years and in pooled analysis. The maximum specific gravity, fruit pulp weight, fruit juice content, fruit pulp stone ratio, acidity, TSS, ascorbic acid, reducing sugars, non-reducing sugars, total sugars and stone weight were recorded in treatment of GA_3 (50 ppm) + NAA (50 ppm) (T_{10}) followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9) as compared with other treatments. However, the lowest reducing, non-reducing and total sugars were obtained in control during both the years and in pooled analysis.

Keywords: Aonla, quality traits, mineral nutrients and PGRs

Introduction
Indian gooseberry (Aonla) is one of the most important fruits of arid tropics, which has high medicinal and nutritional values and has vast potential to grow under diverse soil-agro-climatic conditions. The aonla trees are hardy in nature, adopt well under varying soil (sodic and saline) and climatic conditions (arid and semi arid to dry hot and cold arid regions, rain fed to rainfall area), 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) [13]. 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) [1, 14]. Pratapgarh has been declared as aonla fruit belt and agri-export zone.

The aonla fruits are fleshy, yellowish green in colour having six vague perpendicular furrows enclosing seeds. Nutritional, commercial and medicinal significance of aonla fruit makes it popular all over world (Goyal *et al*., 2007) [7]. The aonla is an excellent source of ascorbic acid (300-900 mg/100 g), amino acid and minerals along with phytochemicals such as polyphenols, tannins, emblicol, linoleic acid, corilagin, phyllemblin and rutin (Ghorai and Sethi, 1996; Jain and Khurdiya, 2004; Murthy and Joshi, 2007; Baliga and Dsouza, 2011) [6, 8, 11, 2].

The plant growth regulators play a vital role for improving the growth and development of plant, fruit set, control of fruit drops, fruit maturation, fruit quality including of physiological and nutritional disorders has been well established in number of tropical, sub-tropical and temperate fruit crops (Singh and Singh, 1976; Bhati and Yadav, 2003 and Singh *et al*., 2007) [22, 3, 21]. 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 and Chonkar, 1984; Singh *et al*., 2001; Divya and Prasad, 2006 and Singh *et al*., 2009) [15, 16, 20, 5, 19].

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) [12, 18].

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 significant variations have been recorded with respect to pulp weight under the different treatments. The maximum pulp weight was observed in T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9) and the minimum was in control. The maximum pulp: stone ratio was recorded in treatment T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9) and the lowest in control (T_0). The increase in pulp: stone ratio might be due to the acceleration in biochemical activities and accumulation of metabolites in plant parts, which is probably due to synergistic effect of micro-nutrients and plant growth regulators on conversion and translocation of total sugars and minerals during the process of fruit development and fruit maturation. Similar observations were recorded by Yadav *et al*. (2010) [23], Mishra *et al*. (2017) [10] and Kumar *et al*. (2017) [9].

An appraisal of data recorded on per cent of juice clearly indicate that there was significant increase in juice content of fruits due to different treatments over control. The maximum juice content was recorded in T_{10} {GA_3 (50 ppm) + NAA (50 ppm)} followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9) and the minimum juice content was noted in control during both the years and pooled analysis.

A perusal of observations recorded on chemical composition of aonla fruit, determining its quality, due to effect of micro-nutrients and plant growth regulators clearly indicate that there was slight improvement in quality of fruits by combined application of $ZnSO_4$, Borax, GA_3 and NAA. The highest TSS content was observed due to 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), while lowest TSS content was recorded in control during both the years and in pooled analysis. The increase in TSS content of aonla fruit might be due to the higher levels of water soluble compounds viz. sugars, vitamins and minerals, which were translocated and accumulated in mature fruit due to chemical changes taking place during the fruit maturation stage. Similar observations in accordance to present finding have been reported by Singh and Singh (2015) [17], Bhati *et al*. (2016), Kumar *et al*. (2017) [9] and Mishra *et al*. (2017) [10].

During the fruit maturation and harvesting stage, the concentration of acidity in aonla fruits was also affected by changes in sugars and other compounds due to increasing levels of nutrients in plant parts, which might have shown beneficial role in improving the quality of fruit by reducing the acidity per cent. It is clear from the results that the per cent acidity was significantly reduced due to foliar spray of GA_3 (50 ppm) + NAA (50 ppm) (T_{10}) followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9), while the maximum acidity was recorded in control (T_0) during both the years and in pooled analysis. The present observations are in conformity with the findings of Singh and Singh (2015) [17] and Bhati *et al*. (2016).

Vitamin-'C' (Ascorbic acid) is a major active chemical constituent of aonla fruit, responsible for its medicinal properties. The vitamin-'C' content of aonla fruits is significantly affected by variable genotype, nutritional status of plant and soil and environmental temperature. The foliar application of micro-nutrients and plant growth regulators after fruit set have been found to play beneficial role in improving the ascorbic acid content of fruits. The observations recorded in present investigation clearly exhibit that the vitamin-'C' (Ascorbic acid) content in aonla fruits was influenced by foliar application of different treatments.

The maximum vitamin 'C' content (675mg/100g pulp) was obtained with the combined spray of GA_3 (50 ppm) + NAA (50 ppm) (T_{10}) followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9), while, the lowest content of vitamin-'C' was found in control (water spray) during both the years and in pooled analysis. The results are in conformity with the observations recorded by Bhati and Yadav (2003) [4] with NAA in ber and Mishra *et al*. (2017) [10] with $ZnSO_4$, $CuSO_4$ and Borax in aonla. It is evident from the results that vitamin-'C' content in fruits might be improved with the application of micro-nutrients and plant growth regulators.

A similar pattern as for total soluble solids was recorded with respect to reducing, non-reducing and total sugars of fruit due to different treatments. The maximum reducing, non-reducing and total sugars were recorded in treatment of GA_3 (50 ppm) + NAA (50 ppm) (T_{10}) followed by spray of GA_3 (25 ppm) + NAA (25 ppm) (T_9) as compared with other treatments. However, the lowest reducing, non-reducing and total sugars were obtained in control during both the years and in pooled analysis. The increase in sugar fraction by the foliar spray of zinc, copper, GA_3 and NAA might be due to their stimulatory effect on increasing the photosynthetic efficiency and metabolic activity in plant system, which would be helpful in translocation and accumulation of chemical metabolites in matured fruits. Similar observations have also been reported by Singh and Singh (2015) [17] Bhati *et al*. (2016) and Mishra *et al*. (2017) [10].

Table 1: Effect of foliar application of PGRs and mineral nutrients on physical and biochemical parameters

Treatments		Specific gravity			Fruit juice content (%)			Pulp weight of fruit		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_0	Control (water spray)	1.03	1.05	1.04	43.14	44.64	43.89	22.62	23.68	23.15
T_1	GA_3 (25 ppm)	1.12	1.14	1.13	48.65	49.25	48.95	34.79	35.58	35.19
T_2	GA_3 (50 ppm)	1.14	1.16	1.15	49.57	50.07	49.82	36.46	37.63	37.05
T_3	NAA (25 ppm)	1.10	1.12	1.11	47.64	48.94	48.29	30.92	31.82	31.37
T_4	NAA (50 ppm)	1.11	1.13	1.12	48.28	48.97	48.63	31.84	33.61	32.73
T_5	Borax (0.50%)	1.08	1.10	1.09	45.76	47.10	46.43	27.32	28.96	28.14
T_6	Borax (0.75%)	1.09	1.11	1.10	46.34	47.46	46.90	28.77	30.04	29.41
T_7	$ZnSO_4$ (0.50%)	1.05	1.07	1.06	44.18	45.53	44.86	24.12	25.17	24.65
T_8	$ZnSO_4$ (0.75%)	1.06	1.09	1.08	44.26	45.88	45.07	25.99	27.75	26.87
T_9	GA_3 (25 ppm) + NAA (25 ppm)	1.16	1.17	1.17	51.24	52.33	51.79	40.77	41.64	41.21
T_{10}	GA_3 (50 ppm) + NAA (50 ppm)	1.17	1.19	1.18	51.56	52.77	52.17	41.42	43.32	42.37
T_{11}	Borax (0.50%) + $ZnSO_4$ (0.50%)	1.14	1.15	1.15	50.29	50.13	50.21	37.84	39.52	38.68
T_{12}	Borax (0.75%) + $ZnSO_4$ (0.75%)	1.15	1.16	1.16	50.72	51.22	50.97	39.45	40.58	40.02
C.D. (P=0.05)		0.006	0.007	0.006	0.171	0.163	0.164	0.395	0.396	0.395
SEm±		0.002	0.002	0.002	0.058	0.055	0.056	0.134	0.135	0.134

Table 2: Effect of foliar application of PGRs and mineral nutrients on physical and biochemical parameters

Treatments		Fruit pulp stone ratio			Fruit stone weight (g)			Total Soluble solids (°B)		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_0	Control (water spray)	13.71	14.10	13.91	1.65	1.68	1.67	11.08	10.92	11.00
T_1	GA_3 (25 ppm)	16.73	16.86	16.80	2.08	2.11	2.10	12.97	11.46	12.22
T_2	GA_3 (50 ppm)	17.28	17.67	17.48	2.11	2.13	2.12	13.20	11.55	12.38
T_3	NAA (25 ppm)	15.78	16.23	16.01	1.96	1.96	1.96	12.45	11.96	12.21
T_4	NAA (50 ppm)	16.08	16.24	16.16	1.98	2.07	2.03	12.70	11.50	12.10
T_5	Borax (0.50%)	14.53	15.16	14.85	1.88	1.91	1.90	11.64	11.82	11.73
T_6	Borax (0.75%)	15.06	15.48	15.27	1.91	1.94	1.93	11.79	12.95	12.37
T_7	$ZnSO_4$ (0.50%)	14.11	14.63	14.37	1.71	1.72	1.72	11.22	13.94	12.58
T_8	$ZnSO_4$ (0.75%)	14.05	14.84	14.45	1.85	1.87	1.86	11.30	12.62	11.96
T_9	GA_3 (25 ppm) + NAA (25 ppm)	18.62	18.84	18.73	2.19	2.21	2.20	14.25	13.46	13.86
T_{10}	GA_3 (50 ppm) + NAA (50 ppm)	18.74	19.34	19.04	2.21	2.24	2.23	14.40	14.60	14.50
T_{11}	Borax (0.50%) + $ZnSO_4$ (0.50%)	17.68	18.47	18.08	2.14	2.14	2.14	13.75	13.50	13.63
T_{12}	Borax (0.75%) + $ZnSO_4$ (0.75%)	18.26	18.61	18.44	2.16	2.18	2.17	13.80	13.70	13.75
C.D. (P=0.05)		0.111	0.109	0.110	0.011	0.012	0.011	0.073	0.074	0.074
SEm±		0.038	0.037	0.037	0.004	0.004	0.004	0.025	0.025	0.025

Table 3: Effect of foliar application of PGRs and mineral nutrients on physical and biochemical parameters

Treatments		Acidity %			Ascorbic acid (mg/100 g pulp)			Reducing sugar (%)		
		2016	2017	Pooled	2016	2017	Pooled	2016	2017	Pooled
T_0	Control (water spray)	1.84	1.87	1.86	556.88	558.34	557.61	3.66	3.71	3.69
T_1	GA_3 (25 ppm)	1.67	1.70	1.69	561.77	562.43	562.10	4.47	4.56	4.52
T_2	GA_3 (50 ppm)	1.63	1.66	1.65	563.44	564.22	563.83	4.52	4.58	4.55
T_3	NAA (25 ppm)	1.74	1.76	1.75	560.23	561.56	560.90	4.33	4.43	4.38
T_4	NAA (50 ppm)	1.69	1.71	1.70	560.55	562.13	561.34	4.41	4.49	4.45
T_5	Borax (0.50%)	1.76	1.79	1.78	559.12	560.14	559.63	4.12	4.18	4.15
T_6	Borax (0.75%)	1.75	1.78	1.77	559.20	561.32	560.26	4.24	4.29	4.27
T_7	$ZnSO_4$ (0.50%)	1.80	1.84	1.82	557.35	559.17	558.26	3.81	3.88	3.85
T_8	$ZnSO_4$ (0.75%)	1.77	1.81	1.79	558.14	559.66	558.90	3.96	4.05	4.01
T_9	GA_3 (25 ppm) + NAA (25 ppm)	1.52	1.56	1.54	569.22	570.18	569.70	4.76	4.81	4.79

T_{10}	GA_3 (50 ppm) + NAA (50 ppm)	1.49	1.54	1.52	572.30	573.66	572.98	4.84	4.89	4.87
T_{11}	Borax (0.50%) + $ZnSO_4$ (0.50%)	1.59	1.64	1.62	564.11	564.98	564.55	4.63	4.69	4.66
T_{12}	Borax (0.75%) + $ZnSO_4$ (0.75%)	1.55	1.59	1.57	566.33	567.11	566.72	4.71	4.77	4.74
C.D. (P=0.05)		0.007	0.006	0.007	0.288	0.278	0.280	0.024	0.022	0.015
SEm±		0.002	0.002	0.002	0.098	0.095	0.097	0.008	0.008	0.005

Table 4: Effect of foliar application of PGRs and mineral nutrients on physical and biochemical parameters

Treatments		Non-reducing sugar (%)			Total sugars (%)		
		2016	2017	Pooled	2016	2017	Pooled
T_0	Control (water spray)	3.22	3.28	3.25	6.88	6.99	6.94
T_1	GA_3 (25 ppm)	3.41	3.47	3.44	7.88	8.03	7.96
T_2	GA_3 (50 ppm)	3.44	3.49	3.47	7.96	8.07	8.02
T_3	NAA (25 ppm)	3.38	3.45	3.42	7.71	7.88	7.80
T_4	NAA (50 ppm)	3.39	3.46	3.43	7.80	7.95	7.88
T_5	Borax (0.50%)	3.31	3.36	3.34	7.43	7.54	7.49
T_6	Borax (0.75%)	3.35	3.39	3.37	7.59	7.68	7.64
T_7	$ZnSO_4$ (0.50%)	3.25	3.31	3.28	7.06	7.19	7.13
T_8	$ZnSO_4$ (0.75%)	3.28	3.34	3.31	7.24	7.39	7.32
T_9	GA_3 (25 ppm) + NAA (25 ppm)	3.51	3.57	3.54	8.30	8.42	8.36
T_{10}	GA_3 (50 ppm) + NAA (50 ppm)	3.54	3.61	3.58	8.35	8.46	8.41
T_{11}	Borax (0.50%) + $ZnSO_4$ (0.50%)	3.47	3.52	3.50	8.10	8.21	8.16
T_{12}	Borax (0.75%) + $ZnSO_4$ (0.75%)	3.50	3.55	3.53	8.21	8.32	8.27
C.D. (P=0.05)		0.008	0.008	0.007	0.28	0.028	0.028
SEm±		0.003	0.003	0.003	0.010	0.009	0.010

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