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RESPONSE OF AONLA (*EMBLICA OFFICINALIS* GAERTN.) PLANTS ON LEAF NUTRIENT STATUS, QUALITY AND YIELD TO FOLIAR APPLICATION OF MICRO-NUTRIENTS IN RED AND LATERITIC REGION OF WEST BENGAL, INDIA

Soustav Datta[1], Susmita Dey[2]*, Chinmoy Mandal[3], Samarpita Roy[1], Tanmoy Mondal[1], Kamal Kr. Mandal[1], (Md.) Abu Hasan[1] and Sarthak Bhattacharya[4]

[1]Department of Fruit Science, Bidhan Chandra Krishi Viswavidyalaya, Mohanpur, Nadia, West Bengal, India.
[2]Faculty of Agriculture, JIS University, 81, Nilgunj Road, Jagarata Pally, Deshpriya Nagar, Agarpara, Kolkata-700 109, W.B., India.
[3]Department of Pomology and Post Harvest Technology, Uttar Banga Krishi Viswavidyalaya, Pundibari, CoochBehar, W.B., India.
[4]Department of Horticulture, School of Agriculture and Allied Sciences, The Neotia University, South 24 Parganas, W.B., India.
*Corresponding author E-mail : susmitadeybckv@gmail.com

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ABSTRACT

Aonla (*Emblica officinalis* Gaertn.) was found highly susceptible to micronutrients deficiency, lead to cause the browning symptoms in fruits. To resolve the issue, an investigation was conducted in consecutive two years at the Regional Research Sub-Station, B.C.K.V., Birbhum-India. Nine treatments such as T_1 - Control (water spray), T_2 - 0.4% $ZnSO_4$, T_3 - 0.8% $ZnSO_4$, T_4 - 0.2% Borax, T_5 - 0.4% Borax, T_6 - 0.4% $ZnSO_4$ + 0.2% Borax, T_7 - 0.4% $ZnSO_4$ + 0.4% Borax, T_8 - 0.8% $ZnSO_4$ + 0.2% Borax and T_9 - 0.8% $ZnSO_4$ + 0.4% Borax were organised in a RBD design and replicated thrice. Two foliar spraying of micronutrients were done as per treatments during the set of fruit (March-April) and pea stages (June-July) of fruit development. According to the findings, the maximum volume (30.10 ml), weight (30.35 g), length (3.75 cm), diameter (3.78 cm), flesh thickness (1.75 cm) of aonla's fruit, TSS (10.92ÚBrix), total sugar (6.62%), juice content (49.45%), ascorbic acid (536.73 mg/100 g of flesh pulp), fruits/plant (1090.00), yield/plant (33.18 kg), leaf zinc and boron (21.23 and 33.75 ppm) and minimum browning symptom (14.42%) were observed with foliar feeding of 0.8% $ZnSO_4$ + 0.4% Borax/plant. After two years of research, this can be summarized that foliar application of 0.8% $ZnSO_4$ + 0.4% Borax/plant could improve yield, quality and leaf micronutrients status and minimizing the browning symptoms in the fruits of Aonla particularly in micronutrients deficit regions such as Red and Laterite zones.

Key words : Aonla, Micro-nutrient, Fruit quality, Browning symptom, Leaf nutrient status.

Introduction

Aonla or Indian goose berry, an indigenous fruit crop of Asia, is commercially cultivated in Rajasthan, Maharashtra, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka and Gujarat. This is one of the most nutritious fruits next to Barbados cherry (Asenjo, 1953) as it includes tannins, phyllamblin, ellagic acid and gallic acid, all of which prevent vitamin-C from oxidising (Yadav and Shukla, 2009). The plant is rather hardy and suitable even for waste land. Besides having nutritional and medicinal values, cultivation of Aonla is also highly remunerative for small and marginal farmers. Aonla cultivation is becoming more common these days due to its high market demand, cheap maintenance costs and adaptability to a variety of agro-climatic conditions.

Among plant nutrients, the role of micronutrients is crucial in numerous aspects of plant metabolism i.e., cell wall construction, photosynthesis, respiration, chlorophyll synthesis, enzymatic activities, nitrogen reduction and fixation as well as hormone synthesis (Das, 2003). Several earlier findings revealed that Aonla is highly susceptible to micronutrients deficiency and the deficiency micronutrients are a major cause of browning of fruits. Therefore, a sufficient supply of micronutrients is important for optimal plant development and greater development, better blooming and higher fruit set lead to higher yield (Ram and Bose, 2000). Micronutrients affected the fruit's quality (Shekhar *et al*., 2010). It's possible that the significant improvement in fruit quality is because of the catalytic impact of micronutrients, especially when they're present in higher concentrations. For ensuring crop quality and productivity, the micro-nutrients zinc and boron are crucial in orchard plant nutrition programmes. The processes of N metabolism, flowering and fruiting, hormone transport as well as cell division are all significantly influenced by zinc and boron (Babu and Singh, 2001). Fruit physico-chemical characteristics are raised when higher quantities of zinc and boron are applied together. Boron is thought to cause the inactivation of excess growth hormone by forming a complex molecule. Although, the role of this element in increasing plant physiological activities is well recognized. Synthesis of tryptophan, prerequisite for auxin synthesis, is the cause of zinc's significant impact on fruit yield. Greater fruit retention and less fruit drop are associated with auxin synthesis, resulting in higher fruit production. Foliar spray of boron and zinc improves plant nutrition as well as photosynthetic capacity, which results in faster metabolite synthesis, mainly carbohydrates and their transfer to fruits. Zinc is required for protein synthesis, seed formation and fruit maturity, whereas boron is required for cell division and elongation, which increases fruit weight. Since little information is available regarding micro-nutrient management of Aonla, particularly in red and lateritic tracts of India. The current investigation was undertaken to progress a foliar spray schedule of micronutrients for quality production of Aonla in Red and Lateritic region of West Bengal.

Materials and Methods

Location of research plot and treatment specifications

This current research was carried out at Bidhan Chandra Krishi Viswavidyalaya's Regional Research Sub-Station, Birbhum, India during the period from 2019 to 2021. The site of the experiment, Regional Research Sub-Station is situated at $23^0$68'N latitude and $87^0$69'E longitude with average altitude of 30m above MSL. These trees are uniform in height and of 12 years old. A Randomised Block Design (RBD) was used to set up the experiment and it was replicated thrice with nine treatments (T_1 - Control as water spray; T_2 - 0.4% $ZnSO_4$; T_3 - 0.8% $ZnSO_4$; T_4 - 0.2% Borax; T_5 - 0.4% Borax; T_6 - 0.4% $ZnSO_4$ + 0.2% Borax; T_7 - 0.4% $ZnSO_4$ + 0.4% Borax; T_8 - 0.8% $ZnSO_4$ + 0.2% Borax and T_9 - 0.8% $ZnSO_4$ + 0.4% Borax).

Time and method of application of micro-nutrients

Two foliar spraying of micro-nutrients was done at fruit set (March-April) and pea stage (June-July) of fruit development. In 50-100 ml of warm water, the indicated amount of borax was dissolved and spray volume was adjusted by mixing it in normal water. Lime weighing half of the measured weight of $ZnSO_4$ was added in solution for adjusting neutral pH of spray solution.

Recommended package of practices

Recommended package of practices including application of recommended dose of fertilizer (N:P:K @ 600:300:600 g/plant), weed control and plant protection measures were practiced accordingly.

Measurement of plant growth parameters

Per cent enhancement in height of the plant as well as canopy spread in E-W and N-S direction was evaluated using a measuring tape before fertilizer application and at harvest, was calculated in meters (m) and represented as percent increase during the investigation period.

Calculation of fruit physical parameters

Browning symptoms of fruits were observed visually up to the harvesting time and calculated in percentage, volume of fruit was measured utilizing the water displacement procedure using a measuring cylinder, fruit length and diameter were evaluated with the help of slide callipers, thickness of the pulp was measured using a centimeter scale, fruit and stone weight were calculated using an electronic balance.

Calculation of fruit bio-chemical parameters

Among the bio-chemical parameters, TSS was evaluated by utilizing Hand Refractometer, titratable acidity and total sugar were measured by the method detailed in A.O.A.C. (1980) and lastly, ascorbic acid content was measured by Rangana (2002).

Estimation of leaf nutrient status

Leaf zinc content was determined using di-acid digested material and an Atomic Absorption Spectrophotometer (Lindsay and Norvell, 1978). Leaf boron content was determined spectrophotometrically by Azomethine-H method (Wolf, 1971 and Gupta, 1979).

Statistical analysis

Statistical analysis was carried out following the process detailed by Panse and Sukhatme (1985).

Results and Discussion

Impact of micro-nutrients on plant physical characters

Results showed significant influence of micro-nutrients on plant height as well as canopy spread in North-South (N-S) and East-West (E-W) direction (Table 1). From pooled analysis, highest increase in plant height (23.19%) was observed in T_9 (0.8% $ZnSO_4$ + 0.4% Borax) whereas the minimum value (20.94%) was in control (Water spray). The per cent increase in canopy spread in the E-W direction (14.03%) and in N-S direction (12.23%) were recorded maximum in T_9 whereas the minimum per cent increase in canopy spread in the East-West direction (11.63%) and in North-South direction (9.63%) were recorded under control. Zinc is a necessary mineral for the production of chlorophyll, which is clearly tied to the plant's ability to photosynthesize; hence enhancement in vegetative growth could be attributable to its simulative effect (Khan *et al*., 2009).

Effect of micro-nutrients on fruit physical characters

According to the pooled data, it is clear that maximum percentage of fruits showing browning symptom (24.19%) was recorded in control whereas lowest percentage of fruits showing browning symptom (14.42%) was measured from T_9 that was statistically at par with T_7 (0.4% $ZnSO_4$ + 0.4% Borax), T_8 (0.8% $ZnSO_4$ + 0.2% Borax) and T_6 (0.4% $ZnSO_4$ + 0.2% Borax). The information in Table 2 made it abundantly evident that the significant variation on fruit length and diameter was observed with the application of various combinations of treatments. Fruit length varied between 2.30 cm to 3.75 cm and diameter varied between 2.63 cm to 3.78 cm.

Maximum fruit volume of 30.10 ml, flesh thickness of 1.75 cm and average fruit weight of 30.35 g were obtained from the treatment T_9, whereas the minimum fruit volume (26.27 ml), flesh thickness (1.11 cm) and fruit weight (26.88 g) were in control (Tables 3 and 4). Maximum stone weight (2.05 g) was recorded with 0.2% Borax spray followed by 0.4% Borax and lowest value (1.62 g) was recorded with T_9. Boron has a key function in the accumulation of additional photosynthates, which is linked to fruit size, weight and volume. Since boron is involved in nitrogen metabolism, cell division and cell

Table 1 : Impact of micro-nutrients on per cent enhancement in plant height and canopy spread of Aonla.

Treatments	Increase in canopy spread (%)			Increase in plant height (%)					
				E-W			N-S		
	19-20	20-21	Pooled	19-20	20-21	Pooled	19-20	20-21	Pooled
T_1	19.48 (26.18)	22.40 (28.24)	20.94 (27.22)	10.04 (18.47)	13.21 (21.30)	11.63 (19.93)	8.62 (17.07)	10.64 (19.03)	9.63 (18.08)
T_2	20.39 (26.83)	23.33 (28.87)	21.86 (27.87)	10.98 (19.34)	13.85 (21.84)	12.42 (20.62)	9.65 (18.09)	11.88 (20.15)	10.77 (19.15)
T_3	20.66 (27.02)	23.54 (29.01)	22.10 (28.03)	11.16 (19.51)	14.13 (22.07)	12.65 (20.82)	9.82 (18.26)	12.15 (20.39)	10.99 (19.35)
T_4	19.99 (26.55)	22.77 (28.49)	21.38 (27.53)	10.51 (18.91)	13.38 (21.48)	11.95 (20.21)	9.00 (17.45)	11.16 (19.51)	10.08 (18.50)
T_5	20.15 (26.66)	22.98 (28.63)	21.57 (27.66)	10.73 (19.11)	13.67 (21.69)	12.20 (20.44)	9.33 (17.78)	11.59 (19.90)	10.46 (18.87)
T_6	20.84 (27.15)	23.96 (29.30)	22.40 (28.24)	11.59 (19.90)	14.74 (22.57)	13.17 (21.27)	10.18 (18.60)	12.44 (20.64)	11.31 (19.65)
T_7	21.05 (27.30)	24.23 (29.48)	22.64 (28.40)	11.77 (20.06)	15.24 (22.97)	13.51 (21.55)	10.41 (18.82)	12.74 (20.90)	11.58 (19.89)
T_8	21.31 (27.48)	24.65 (29.76)	22.98 (28.64)	11.93 (20.20)	15.59 (23.25)	13.76 (21.77)	10.76 (19.14)	13.08 (21.19)	11.92 (20.19)
T_9	21.56 (27.66)	24.82 (29.87)	23.19 (28.78)	12.18 (20.42)	15.87 (23.47)	14.03 (21.99)	10.99 (19.35)	13.47 (21.52)	12.23 (20.46)
S.Em (±)	0.043	0.024	0.029	0.037	0.028	0.023	0.025	0.025	0.018
CD (0.05)	0.129	0.074	0.089	0.113	0.084	0.068	0.076	0.077	0.054

*Data in the parenthesis are angular transformed value.

Table 2 : Impact of micro-nutrients on per cent of fruits showing browning symptom, fruit length and diameter of Aonla.

Treatments	% fruits showing browning symptom			Fruit length (cm)			Fruit diameter (cm)		
	19-20	20-21	Pooled	19-20	20-21	Pooled	19-20	20-21	Pooled
T_1	24.25 (29.49)	24.12 (29.40)	24.19 (29.45)	2.18	2.41	2.30	2.46	2.79	2.63
T_2	18.02 (25.10)	15.94 (23.52)	16.98 (24.33)	2.66	2.81	2.74	2.96	3.09	3.03
T_3	17.87 (24.99)	15.76 (23.36)	16.82 (24.20)	2.78	2.95	2.87	3.10	3.28	3.19
T_4	17.62 (24.80)	15.39 (23.08)	16.51 (23.96)	2.31	2.53	2.42	2.67	2.86	2.77
T_5	17.41 (24.65)	15.11 (22.85)	16.26 (23.77)	2.45	2.67	2.56	2.78	3.00	2.89
T_6	16.78 (24.16)	13.94 (21.90)	15.36 (23.05)	2.94	3.17	3.06	3.22	3.40	3.31
T_7	16.14 (23.64)	13.23 (21.31)	14.69 (22.52)	3.09	3.42	3.26	3.35	3.58	3.47
T_8	16.53 (23.97)	13.59 (21.61)	15.06 (22.82)	3.40	3.68	3.54	3.47	3.77	3.62
T_9	15.96 (23.52)	12.88 (20.99)	14.42 (22.29)	3.58	3.92	3.75	3.61	3.94	3.78
S.Em (±)	0.630	0.624	0.437	0.024	0.022	0.017	0.032	0.062	0.038
CD (0.05)	1.906	1.887	1.320	0.072	0.066	0.052	0.096	0.189	0.116

*Data in the parenthesis are angular transformed value.

Table 3 : Impact of various micro-nutrients on fruit volume and flesh thickness of Aonla.

Treatment	Fruit volume (ml)			Flesh thickness (cm)		
	19-20	20-21	Pooled	19-20	20-21	Pooled
T_1	25.54	26.99	26.27	1.01	1.20	1.11
T_2	26.67	28.68	27.68	1.23	1.43	1.33
T_3	26.95	29.07	28.01	1.30	1.51	1.41
T_4	26.01	27.74	26.88	1.09	1.28	1.19
T_5	26.24	28.19	27.22	1.16	1.36	1.26
T_6	27.27	29.55	28.41	1.41	1.60	1.51
T_7	27.69	30.00	28.85	1.49	1.68	1.59
T_8	28.00	30.97	29.49	1.56	1.79	1.68
T_9	28.61	31.59	30.10	1.62	1.88	1.75
S.E.m(±)	0.040	0.037	0.031	0.030	0.026	0.018
CD (0.05)	0.122	0.110	0.093	0.091	0.078	0.055

elongation, foliar nutrient feeding may have resulted in enhanced fruit size and volume. The findings are in accordance with results of Singh *et al*. (2009) and Shukla *et al*. (2008) in Aonla. This improvement in the size as well as volume of fruit could be owing to zinc's direct involvement in growth or it could be just because of higher accumulation and translocation of food ingredients. The reduced stone weight might be attributed to the nutrients' role in the fruit's build-up of more flesh which decreased finally stone weight.

Impact of various micro-nutrients on fruit bio-chemical characters

Perusal of the data presented in Tables 5 and 6 revealed significant variation in TSS, total sugar, titratable acidity as well as ascorbic acid content of the pulp due to application of various micro-nutrient combinations.

From the pooled analysis, maximum TSS content (10.92^{0}Brix), ascorbic acid content (536.73 mg/100 g of pulp), juice percentage (49.45%) were observed from the treatment T_9 (0.8% $ZnSO_4$ + 0.4% Borax) compared with minimum TSS content (9.43^{0}Brix), ascorbic acid content (475.89 mg/100 g of pulp) as well as juice percentage (46.16%) in plants under control. Significant reduction in acidity content (1.46%) was observed from plants treated with treatment T_9 compared to 2.05% in control. Highest total sugar content (6.62%) was recorded

Table 4 : Impact of various micro-nutrients on fruit weight and stone weight of Aonla.

Treatment	Fruit weight (g)			Stone weight (g)		
	19-20	20-21	Pooled	19-20	20-21	Pooled
T_1	25.58	28.17	26.88	1.84	1.89	1.87
T_2	26.98	29.82	28.40	1.80	1.82	1.81
T_3	27.35	30.12	28.74	1.74	1.78	1.76
T_4	26.29	29.09	27.69	1.98	2.11	2.05
T_5	26.77	29.56	28.17	1.88	1.93	1.91
T_6	27.69	30.67	29.18	1.76	1.81	1.79
T_7	28.42	31.29	29.86	1.69	1.74	1.72
T_8	28.04	30.86	29.45	1.64	1.70	1.67
T_9	28.89	31.80	30.35	1.59	1.65	1.62
S.Em (±)	0.075	0.158	0.081	0.035	0.027	0.016
CD (0.05)	0.227	0.479	0.245	0.106	0.082	0.049

in T_9, that was found statistically at par with T_7 (0.4% $ZnSO_4$ + 0.4% Borax), while the lowest was observed from the treatment T_1 (5.63%). This enhancement in sugars fraction caused by foliar boron and zinc supplementation could be owing to their roles in metabolite photosynthesis as well as sugar translocation from plant's other parts to the developing fruits (Singh *et al.*, 2012). It could also be attributable to micronutrients, which have been linked to fruit quality in both direct and indirect ways (Kumar and Shukla, 2005). Zinc supplementation raised ascorbic acid levels, possibly due to enhanced growth as well as the availability of additional metabolites for ascorbic acid production.

Table 5 : Impact of micro-nutrients on TSS, titratable acidity and total sugar content of Aonla.

Treatment	TSS (^{0}Brix)			Titratable acidity (%)			Total sugar (%)		
	19-20	20-21	Pooled	19-20	20-21	Pooled	19-20	20-21	Pooled
T_1	9.17	9.68	9.43	2.09	2.00	2.05	5.60	5.65	5.63
T_2	9.88	10.38	10.13	1.86	1.78	1.82	6.01	6.16	6.09
T_3	10.01	10.55	10.28	1.80	1.74	1.77	6.08	6.29	6.19
T_4	9.51	9.91	9.71	1.99	1.95	1.97	5.84	5.94	5.89
T_5	9.73	10.12	9.93	1.92	1.89	1.91	5.93	6.07	6.00
T_6	10.19	10.71	10.45	1.72	1.68	1.70	6.25	6.46	6.36
T_7	10.49	11.06	10.78	1.59	1.49	1.54	6.41	6.60	6.51
T_8	10.30	10.96	10.63	1.66	1.56	1.61	6.36	6.53	6.45
T_9	10.65	11.19	10.92	1.52	1.40	1.46	6.54	6.69	6.62
S.Em (±)	0.031	0.031	0.018	0.039	0.044	0.035	0.098	0.038	0.043
CD (0.05)	0.095	0.093	0.056	0.117	0.134	0.107	0.295	0.116	0.131

Table 6 : Impact of micro-nutrients on ascorbic acid and juice volume measurement of Aonla.

Treatment	Ascorbic acid (mg/100 g flesh pulp)			Juice (ml)		
	19-20	20-21	Pooled	19-20	20-21	Pooled
T_1	442.08	509.70	475.89	43.19	49.12	46.16
T_2	464.54	526.33	495.44	44.67	50.86	47.77
T_3	470.00	530.48	500.24	44.85	51.18	48.02
T_4	450.17	515.61	482.89	44.13	50.28	47.21
T_5	455.36	519.53	487.45	44.31	50.49	47.40
T_6	488.19	539.81	514.00	45.04	51.61	48.33
T_7	505.16	552.51	528.84	45.62	52.24	48.93
T_8	498.77	546.66	522.72	45.38	51.89	48.64
T_9	512.32	561.13	536.73	45.90	52.99	49.45
S.Em (±)	0.711	0.992	0.807	0.130	0.159	0.123
CD (0.05)	2.149	3.000	2.440	0.393	0.481	0.373

Impact of various micro-nutrient treatments on yield characters of Aonla plants

The information in Table 7 clearly showed the significant variation in number of fruits/tree at harvest due to various micro-nutrient treatments. From the pooled data, highest number of harvestable fruits/tree with 1090 numbers was observed in T_9 and lowest with 865 was observed in control. Finally, application of 0.8% $ZnSO_4$ + 0.4% Borax produced highest yield of 33.18 kg fruits per tree compared with 23.32 kg fruits per tree in control. Results regarding fruit yield are in accordance with those of other various researchers (Meena *et al.*, 2014) and (Chandra and Singh, 2015) in Aonla cv. NA-7.

Table 7 : Impact of various micro-nutrients on number of fruits/tree and yield of Aonla.

Treatment	Number of fruits/tree			Yield (kg/tree)		
	19-20	20-21	Pooled	19-20	20-21	Pooled
T_1	810	920	865	20.72	25.92	23.32
T_2	900	980	940	24.28	29.22	26.75
T_3	910	990	950	24.89	29.82	27.35
T_4	860	950	905	22.61	27.64	25.12
T_5	880	960	920	23.56	28.38	25.97
T_6	950	1030	990	26.31	31.59	28.95
T_7	970	1070	1020	27.57	33.48	30.52
T_8	1000	1100	1050	28.04	33.94	30.99
T_9	1020	1160	1090	29.47	36.89	33.18
S.Em (±)	4.907	4.031	3.301	0.154	0.184	0.108
CD (0.05)	14.838	12.188	9.981	0.466	0.556	0.326

Table 8 : Impact of micro-nutrients on leaf zinc and boron content of Aonla.

Treatment	Leaf zinc (ppm)			Leaf boron (ppm)		
	19-20	20-21	Pooled data	19-20	20-21	Pooled data
T_1	19.66	17.87	18.77	10.75	9.69	10.22
T_2	30.11	31.94	31.03	11.05	10.03	10.54
T_3	30.38	32.04	31.21	11.21	10.19	10.70
T_4	19.84	18.05	18.95	19.27	21.06	20.17
T_5	19.96	18.16	19.06	19.59	21.24	20.42
T_6	31.07	33.99	32.53	19.83	21.68	20.76
T_7	31.55	34.22	32.89	20.09	22.02	21.06
T_8	31.98	34.81	33.40	19.97	21.85	20.91
T_9	32.47	35.03	33.75	20.36	22.10	21.23
S.Em (±)	0.608	0.988	0.714	1.442	1.068	1.227
CD (0.05)	1.840	2.988	2.159	4.360	3.229	3.711

Impact of micro-nutrients on nutrient status of leaf of Aonla plants

The information in Table 8 clearly showed that there were significant variation in leaf zinc and boron content due to various micro-nutrient treatments.

From the pooled analysis, highest zinc content (33.75 ppm) was observed in T_9 (0.8% $ZnSO_4$ + 0.4% Borax) and that was statistically at par with T_8, T_7 as well as T_6, whereas lowest value (18.77 ppm) was observed in T_1 followed by T_4 (0.2% Borax). Maximum leaf boron content (21.23 ppm) was recorded from T_9 whereas the minimum boron content (10.22 ppm) was observed under control. These observations are in confirmation with the findings of Singh *et al.* (2007). It was found that Zn is transferred through the phloem to another location of use based on the rise in Zn concentration in the petiole (Kurešová *et al.*, 2010). Zn applied foliarly raised leaf Zn concentration by 50 per cent compared to control and B applied foliarly raised leaf B concentration by 75 per cent compared to control (Jeyabaskaran and Pandey, 2008).

Conclusion

In the present investigation, micro-nutrient spray was done at fruit set (March-April) and pea stage (June-July) of fruit development. There were nine treatments with different dose of $ZnSO_4$ and borax. The micro-nutrient treatments had a substantial impact on plant growth parameters, physico-chemical parameters of fruits, yield parameters and leaf nutrient status of Aonla plants, in comparison to the controlled plants. Finally, this can be summarised from the investigation that application of either 0.8% $ZnSO_4$ + 0.4% Borax per plant or 0.8% $ZnSO_4$ + 0.2% Borax per plant improves yield as well as quality of Aonla plants in the Red-Laterite zone of West Bengal.

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Author's contribution

Conceptualisation and designing of the research work (SD and KKM); Execution of field or lab experiments and data collection (SD, SD, SR and TM); Analysis of data and interpretation (SD, CM and SB); Preparation of manuscript (SD, MAH and KKM).

Declaration

The authors do not have any conflict of interest.

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