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Research Paper

Effect of foliar application of micronutrients on fruit yield, quality and profitability of okra (*Abelmoschus esculentus* L.)

Insha Javeed[1*], Sumati Narayan[1], Khursheed Hussain[1], Farooq Ahmad Khan[2], Rihana Rahman[3], Afroza Akhter[1], Sayed Azrah Indrabi[1], Amreena Sultan[1] and Majid Rashid[1]

[1]*Division of Vegetable Science;* [2]*Division of Basic Sciences and Humanities;* [3]*Division of Soil Science; Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Jammu and Kashmir, India 190025.*
*e-mail: *ratherinsha21@gmail.com*

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ABSTRACT

The experiment was conducted at Vegetable Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir, Shalimar during Kharif 2018 to evaluate the "Effect of foliar application of micronutrients on fruit yield, quality and profitability of okra (*Abelmoschus esculentus* L.)". The experiment was laid out in randomised complete block design (RCBD) with fourteen treatments *viz.*, boric acid @ 100 ppm (T_1), zinc sulphate @ 100 ppm (T_2), ammonium molybdate @ 50 ppm (T_3), copper sulphate @ 100 ppm (T_4), ferrous sulphate @ 100 ppm (T_5), manganese sulphate @ 100 ppm (T_6), mixture of all, T_1 to T_6 (T_7), mixture of all without Boric acid (T_8), mixture of all without zinc sulphate (T_9), mixture of all without ammonium molybdate (T_{10}), mixture of all without copper sulphate (T_{11}), mixture of all without ferrous sulphate (T_{12}), mixture of all without manganese sulphate (T_{13}) and control (T_{14}). All the treatments were replicated thrice. Observations were recorded on fruit yield, fruit dry matter content, crude protein content, Vitamin C and chlorophyll content. Study revealed that treatment comprising of all micronutrients (T_7) resulted in maximum yield/plant (241.74 g) coupled with highest fruit quality in terms of dry matter content (11.46%), crude protein content (9.94%), vitamin C content (13.10 mg/100g) and chlorophyll content (1.80 mg g^{-1}) compared to minimum yield and quality recorded in control (T_{14}). The improved yield under treatment T_7 lead to highest benefit: cost ratio of 4.36 against a benefit: cost ratio of 3.13 in control.

Key words: Economics, micronutrients, okra, quality characters.

Okra (*Abelmoschus esculentus* L.) (2n=2x=130), belonging to family Malvaceae was previously included in the genus *Hibiscus* and section *Abelmoschus* (Linnaeus, 1753). It is grown in many parts of the world, especially in tropical and sub-tropical countries (Saifullah and Rabbani, 2009). This crop can be grown on a large commercial farm or as a garden crop. Okra plants are grown commercially in many countries such as India, Japan, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Myanmar, Malaysia, Thailand, Brazil, Ethiopia, Cyprus and in the Southern United States (Qhureshi, 2007).

Okra has good potential as foreign exchange crop. In India the total area under its cultivation is 531 thousand hectares with annual production of 6466 thousand metric tonnes (Anonymous, 2021a). However in Jammu & Kashmir it is grown over an area of 3.43 thousand hectares with an annual production of 143.68 thousand metric tonnes (Anonymous, 2021b).

Micronutrients are required for optimal growth specifically Zn, B, Fe, Cu, Mo and Mn play vital roles in plant physiology and biochemical processes (Rab and Haq, 2012). Foliar spray of micronutrients is more effective to control deficiency problem than soil application (Torun *et al.*, 2001). Foliar application of these nutrients is generally done to eliminate the effects of soil pH on the availability of these nutrients (Ali, 2012) and being less costly (Ali *et al.*, 2007). Foliar fertilization with multi-nutrients to achieve balanced plant nutrition is considered to play a significant role in modern sustainable vegetable production. This mode of applying fertilizers to the crops provides a valuable supplement to the application of nutrients *via* the soil (Fageria *et al.*, 2009).The particular value of this technique is that it ensures immediate uptake and translocation of nutrients to various plant organs via the leaf tissues and thus enables rapid correction of nutrient deficiencies (Fageria *et al.*, 2009). Moreover, foliar applications has been recommended for integrated plant production since it not only increases crop yield and quality but is also environmentally safe (Fageria *et al.*, 2009; El-Aal *et al.*, 2010; Zodape *et al.*, 2011).

MATERIALS AND METHODS

The present investigation "Effect of foliar application of micronutrients on fruit yield, quality and profitability of okra (*Abelmoschus esculentus* L.)" was carried out at Experimental Farm, Division of Vegetable Science, SKUAST-Kashmir Shalimar campus, during Kharif 2018. The experiment was laid out in Randomized Complete Block Design (RCBD) with 14 treatments and three replications. The various treatments of micronutrients include boric acid 100ppm (T_1), zinc sulphate 100 ppm (T_2), ammonium molybdate 50 ppm (T_3), copper sulphate 100 ppm (T_4), ferrous sulphate 100 ppm (T_5), manganese sulphate 100 ppm (T_6), mixture of all T_1 to T_6 (T_7), mixture of all excluding T_1 (T_8), mixture of all excluding T_2 (T_9), mixture of all excluding T_3 (T_{10}), mixture of all excluding T_4 (T_{11}), mixture of all excluding T_5 (T_{12}), mixture of all excluding T_6 (T_{13}) and control, i.e. no nutrient spray (T_{14}). Basal doses of FYM @ 20-25 t/ ha and NPK @ 120:90:60 kg/ha were also given at the time of field preparation in all the treatments. Foliar application of the micronutrient solutions were done at 30, 45 and 60 days after sowing. Picking of fruits was done at tender edible stage at an interval of 3-5 days.

Observations were recorded on fruit yield, dry matter content (%), crude protein content (%), Vitamin C and chlorophyll content. Fruit dry matter content was measured by drying the fruit samples in Hot Air Oven initially at 80 ±5°C for two hours and then at 60±5°C till the constant weight was obtained. Dry matter was calculated using formula (I). Protein content was calculated by multiplying a factor 6.25 (protein factor) with total nitrogen content in fruits whereas total nitrogen content in fruits was determined by Kjeldhals method as outlined by Tandon (1993). Vitamin C content (mg 100 g^{-1}) was determined by titrating a known weight of sample with 2,6-dichlorophenol indophenols dye using metaphosphoric acid as stabilising agent (AOAC, 1980). Fruit total chlorophyll content was determined spectrophotomerically using dimethyl sulfoxide (DMSO) as extractant.

Amount of chlorophyll (mg g^{-1}) was estimated as using formula given by (Jayaraman 1981):

Dry matter content = (Dry weight / Fresh weight) × 100

$$\text{Total chlorophyll (mg/g)} = \frac{20.2\,(A645) + 8.02\,(A663) \times V}{1000 \times W}$$

where, A= Absorbance at specific wave length (nm); V= Volume of chlorophyll extract in 80% acetone and W= Fresh weight of tissue extracted (g).

Economic analysis of crop treatments

Tabular analysis was performed to assess the economics of the crop. Gross returns were worked out by multiplying yield obtained with the average of current market price. The production cost was subtracted from the gross returns and the results obtained were taken as the net profit. The cost benefit ratio of each treatment was also worked out.

Statistical analysis

The data collected on different traits was statistically analyzed using the standard procedure as given in Gomez and Gomez (1984). The results were tested at five per cent level of significance. The critical difference was used to compare treatment means.

RESULTS AND DISCUSSION

Findings of the present study with regard to fruit yield indicated that fruit yield was maximum (179.06q/ha) when all the micronutrients are applied together followed by T_{10}, T_9 and T_{11} with fruit yield value of 175.44, 173.06 and 171.00q/ha against the minimum fruit yield (135.56q/ha) recorded in control. Study further revealed that foliar application of micronutrients either alone or in combination affected fruit quality parameters significantly in relation to control (Table 1). Dry matter is one of the most important attribute that gives an idea about photosynthetic ability and food accumulation in edible fruits. During present investigation, treatment, T_7 [Mixture of all (T_1 to T_6)] recorded the highest dry matter content of 11.46% followed by treatment T_{10} [Mixture of all without Ammonium molybdate (T_7 minus T_3)] *viz.*, 10.43% whereas lowest dry matter content (8.43%) was noticed in treatment T_{14} (control). Optimum application of micronutrients in continuous intervals increases availability of essential micronutrients for carrying out efficient physiological and biochemical processes. Addition of micronutrients have significant role in promoting the synthesis of active photosynthetic pigments by increasing the amounts of stomatal and thylakoid proteins in leaves which helps in providing better root biomass and release of nutrients continuously so that they are adequately absorbed by the plants for production of useful biochemical components which are reflected in the form of enhanced dry matter content. Nilesh *et al.* (2015) also reported variations in the concentration of dry matter in tomato due to different levels of nutrients and their content increased with increase in nutrient levels.

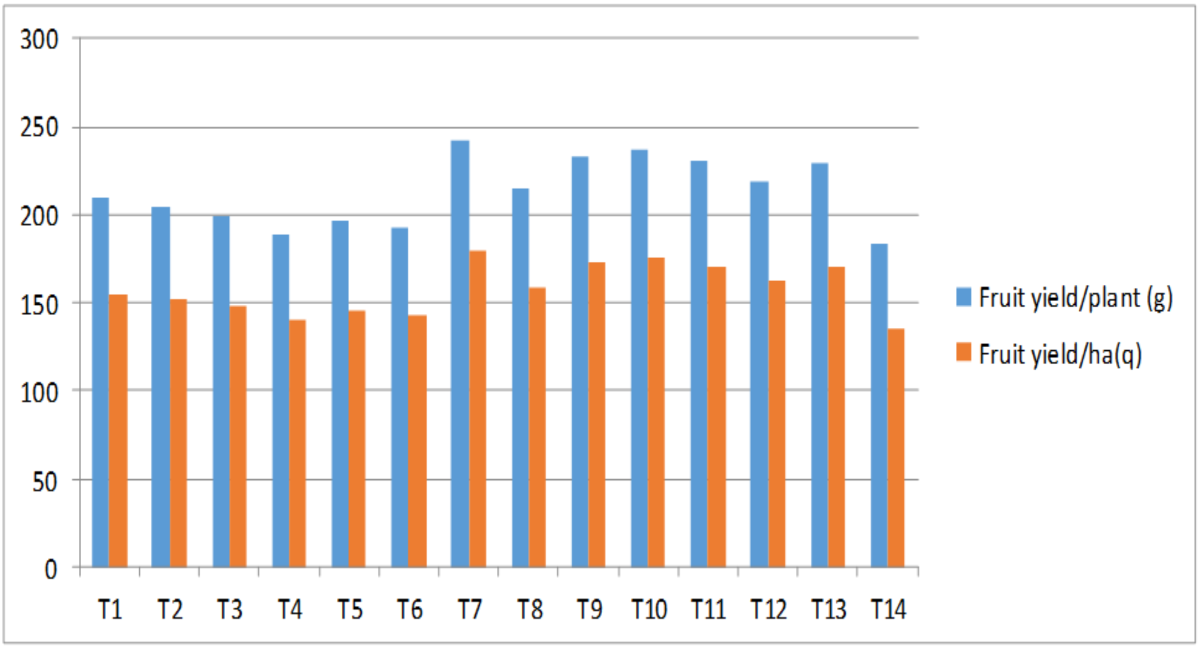

Fig. 1. Effect of foliar application of micronutrients on fruit yield of okra (*Abelmoschus esculentus* L.)

Among all the treatments, T_7 [Mixture of all (T_1 to T_6)] recorded maximum crude protein content of 9.94% followed by treatment T_{10} [Mixture of all without Ammonium molybdate (T_7 minus T_3)] *viz.*, 8.77% whereas minimum crude protein content (5.94%) was recorded in treatment T_{14} (control) The higher values of protein content with treatment T_7 may be attributed to application of optimum levels of micronutrients which improved nutrient availability and uptake and improved source and physiological activities resulting in greater assimilation and translocation of primary and secondary metabolites in plant parts (Broadley *et al.*, 2007).

Maximum vitamin C content (13.10 mg/100g) was recorded in treatment T_7 [Mixture of all (T_1 to T_6)] followed by treatment T_{10} [Mixture of all without Ammonium molybdate (T_7 minus T_3)] *viz.*, 13.04 mg/100g. Whereas lowest vitamin C content (12.05 mg/100g) was noticed in treatment T_{14} (control). The increase in ascorbic acid content is attributed to continuous availability of nutrients at shorter and frequent intervals making the plants photosynthetically active resulting in higher assimilation of primary and secondary metabolites like ascorbic acid, sugars etc. The increase in ascorbic acid was further due to enhancement of enzymatic activity of ascorbic acid oxidase which enhances the ascorbic acid content in fruits. Ascorbic acid content (mg/100g) was recorded significantly more in treatments receiving micronutrients then control alone. The results obtained are in conformity with the findings of Swetha *et al*. (2018) in tomato.

Chlorophyll is the most important photosynthetic parameter to determine synthesis of metabolites during photosynthesis. The highest chlorophyll content of 1.80 mg g^{-1} was recorded in treatment, T_7 [Mixture of all (T_1 to T_6)] followed by treatment T_{12} [Mixture of all without Ferrous sulphate (T_7 minus T_5)] *viz.*, 1.78 mg g^{-1}. Whereas the lowest chlorophyll content (1.31 mg g^{-1}) was recorded in treatment T_{14} (control). It was evident from the present study, that the chlorophyll, a vital basic pigment for augmenting the available light for photosynthetic function, was conditioned by the foliar application of micronutrients. Chlorophyll synthesis is dependent upon mineral nutrition. Increased chlorophyll content is due to the optimum availability of micronutrients which plays a vital role in cell division and formation of active photosynthetic pigments including chlorophyll while the facilitation of biochemical characteristics and biosynthesis of pigment molecules especially chlorophyll also depends on uptake of optimal micronutrient levels. Micronutrients especially Cu, Mn, Zn and Fe functions as cofactors for NAD and NADP thus taking part in many oxidation reduction reactions. Mn, Fe (Iron porphyrins) are part of chlorophyll molecules and their optimum availability aid in photosynthesis especially building of chloroplast.

Therefore from the above, it is evident that higher chlorophyll content in treatment T_7 had positive influence on chlorophyll content thereby enhancing photosynthetic rate resulting in higher fruit yield and associated traits. These results get supported from the findings of Karthick *et al.* (2017).

Table 1: Effect of foliar application of micronutrients on quality parameters of okra (*Abelmoschus esculentus* L.)

Treatments		Dry matter content (%)	Crude protein content (%)	Vitamin C content (mg/100g)	Chlorophyll content (mg g^{-1})
T_1	Boric acid (H_3BO_3)	9.66	7.55	12.66	1.67
T_2	Zinc sulphate ($ZnSO_4$)	9.93	7.54	12.53	1.75
T_3	Ammonium molybdate [$(NH_4)_6Mo_7$]	9.79	7.34	12.59	1.79
T_4	Copper sulphate ($CuSO_4$)	9.59	6.80	12.13	1.73
T_5	Ferrous sulphate ($FeSO_4$)	9.60	7.12	12.41	1.72
T_6	Manganese sulphate ($MnSO_4$)	9.66	7.05	12.32	1.66
T_7	Mixture of all (T_1 to T_6)	11.46	9.94	13.10	1.80
T_8	Mixture of all without Boric acid (T_7 minus T_1)	10.13	7.73	12.74	1.77
T_9	Mixture of all without Zinc sulphate (T_7 minus T_2)	10.36	8.57	12.98	1.65
T_{10}	Mixture of all without Ammonium molybdate (T_7 minus T_3)	10.43	8.77	13.04	1.57
T_{11}	Mixture of all without Copper sulphate (T_7 minus T_4)	10.20	8.55	12.87	1.77
T_{12}	Mixture of all without Ferrous sulphate (T_7 minus T_5)	10.22	8.10	12.81	1.78
T_{13}	Mixture of all without Manganese sulphate (T_7 minus T_6)	10.26	8.56	12.92	1.68
T_{14}	Control	8.43	5.94	12.05	1.31
C.D ($p \leq 0.05$)		**0.65**	**0.25**	**0.01**	**0.03**

Economics of okra: The results presented in Table 2, 3 and 4 revealed that capital investment exhibited variation with different treatments in okra cultivation. The maximum gross returns of Rs 537180 ha^{-1} was obtained from treatment T_7 [Mixture of all (T_1 to T_6)] with highest net returns of Rs 437013.39 ha^{-1} in okra cultivation. From the entire study, it can be concluded that combined application of micronutrients *i.e.*, Boric acid @ 100 ppm + Zinc sulphate @ 100 ppm + Ammonium molybdate @ 50 ppm + Copper sulphate @ 100 ppm + Ferrous sulphate@ 100 ppm + Manganese sulphate @ 100 ppm is most optimum for getting highest yield resulting in very high net returns with B:C ratio of 4.36 for every rupee spent and can be recommended for commercial cultivation of okra under open conditions.

These results are in agreement with the findings of Kumar *et al.* (2010) in cauliflower and Bharati *et al.* (2018) in bitter gourd.

Table 2: Treatment-wise added cost

Treatment		Cost involved (Rs.)		No. of labourers involved @ Rs.225 labour^{-1}	Amount involved on labour (Rs.)	Added cost (Rs. ha^{-1})
		Fertilizer	Manure			
T_1	Boric acid (H_3BO_3)	6781.65	12500	16	3600	22881.65
T_2	Zinc sulphate ($ZnSO_4$)	6791.53	12500	16	3600	22891.53
T_3	Ammonium molybdate [$(NH_4)_6Mo_7$]	6732.88	12500	16	3600	22832.88
T_4	Copper sulphate ($CuSO_4$)	6748.32	12500	16	3600	22848.32
T_5	Ferrous sulphate ($FeSO_4$)	6720.54	12500	16	3600	22820.54
T_6	Manganese sulphate ($MnSO_4$)	6836.99	12500	16	3600	22936.99
T_7	Mixture of all (T_1 to T_6)	7641.91	12500	18	4050	24191.91
T_8	Mixture of all without Boric acid (T_7 minus T_1)	7454.26	12500	17	3825	23779.26
T_9	Mixture of all without Zinc sulphate (T_7 minus T_2)	7444.38	12500	17	3825	23769.38
T_{10}	Mixture of all without Ammonium molybdate (T_7 minus T_3)	7503.03	12500	17	3825	23828.03
T_{11}	Mixture of all without Copper sulphate (T_7 minus T_4)	7487.59	12500	17	3825	23812.59
T_{12}	Mixture of all without Ferrous sulphate (T_7 minus T_5)	7515.37	12500	17	3825	23840.37
T_{13}	Mixture of all without Manganese sulphate (T_7 minus T_6)	7398.92	12500	17	3825	23723.92
T_{14}	Control	6594.00	12500	15	3375	22469.00

Rate of fertilizers, Urea @ Rs. 6/kg, DAP @ Rs. 22/kg, MOP @ Rs. 12/kg, FYM @ Rs. 500/ton

Rate of micronutrients (Boric acid @ Rs. 304/500g, Ammonium molybdate @ Rs. 900/kg, Zinc sulphate @ Rs. 320/500g, Ferrous sulphate @ Rs. 205/500g, Copper sulphate @ Rs. 250/500g, Manganese sulphate @ Rs. 390/500g.

Table 3: Treatment-wise comparative economics of cost of cultivation in okra after harvesting

Treatments		Fixed cost (Rs. ha^{-1})	Variable cost (Rs. ha^{-1})	Added cost (Rs. ha^{-1})	Total variable cost (Rs. ha^{-1})	Total cost of cultivation
T_1	Boric acid (H_3BO_3)	22237.20	53737.50	22881.65	76619.15	98856.35
T_2	Zinc sulphate ($ZnSO_4$)	22237.20	53737.50	22891.53	76629.03	98866.23
T_3	Ammonium molybdate [$(NH_4)_6Mo_7$]	22237.20	53737.50	22832.88	76570.38	98807.58
T_4	Copper sulphate ($CuSO_4$)	22237.20	53737.50	22848.32	76585.82	98823.02
T_5	Ferrous sulphate ($FeSO_4$)	22237.20	53737.50	22820.54	76558.04	98795.24
T_6	Manganese sulphate ($MnSO_4$)	22237.20	53737.50	22936.99	76674.49	98911.69
T_7	Mixture of all (T_1 to T_6)	22237.20	53737.50	24191.91	77929.41	100166.61
T_8	Mixture of all without Boric acid (T_7 minus T_1)	22237.20	53737.50	23779.26	77516.76	99753.96
T_9	Mixture of all without Zinc sulphate (T_7 minus T_2)	22237.20	53737.50	23769.38	77506.88	99744.08
T_{10}	Mixture of all without Ammonium molybdate (T_7 minus T_3)	22237.20	53737.50	23828.03	77565.53	99802.73
T_{11}	Mixture of all without Copper sulphate (T_7 minus T_4)	22237.20	53737.50	23812.59	77550.09	99787.29
T_{12}	Mixture of all without Ferrous sulphate (T_7 minus T_5)	22237.20	53737.50	23840.37	77577.87	99815.07
T_{13}	Mixture of all without Manganese sulphate (T_7 minus T_6)	22237.20	53737.50	23723.92	77461.42	99698.62
T_{14}	Control	22237.20	53737.50	22469.00	76206.50	98443.70

Total variable cost (Rs.ha^{-1}) = Variable cost (Rs.ha^{-1}) + Added cost (Rs.ha^{-1}), Total cost of cultivation (Rs.ha^{-1}) = Fixed cost (Rs.ha^{-1}) + Total variable cost (Rs.ha^{-1})

Table 4: Benefit cost ratio (economics of production of okra, Rs. ha^{-1}) after harvesting

Treatments		Total cost of cultivation (Rs. ha^{-1})	Fruit yield (q ha^{-1})	Gross returns (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	Return per Rupee invested
T_1	Boric acid (H_3BO_3)	98856.35	154.86	464580	365723.65	3.69
T_2	Zinc sulphate ($ZnSO_4$)	98866.23	151.64	454920	356053.77	3.60
T_3	Ammonium molybdate [$(NH_4)_6Mo_7$]	98807.58	148.02	444060	345252.42	3.49
T_4	Copper sulphate ($CuSO_4$)	98823.02	139.93	419790	320966.98	3.24
T_5	Ferrous sulphate ($FeSO_4$)	98795.24	145.60	436800	338004.76	3.42
T_6	Manganese sulphate ($MnSO_4$)	98911.69	143.08	429240	330328.31	3.33
T_7	Mixture of all (T_1 to T_6)	100166.61	179.06	537180	437013.39	4.36
T_8	Mixture of all without Boric acid (T_7 minus T_1)	99753.96	159.13	477390	377636.04	3.78
T_9	Mixture of all without Zinc sulphate (T_7 minus T_2)	99744.08	173.06	519180	419435.92	4.20
T_{10}	Mixture of all without Ammonium molybdate (T_7 minus T_3)	99802.73	175.44	526320	426517.27	4.27
T_{11}	Mixture of all without Copper sulphate (T_7 minus T_4)	99787.29	171.00	513000	413212.71	4.14
T_{12}	Mixture of all without Ferrous sulphate (T_7 minus T_5)	99815.07	162.69	488070	388254.93	3.88
T_{13}	Mixture of all without Manganese sulphate (T_7 minus T_6)	99698.62	170.05	510150	410451.38	4.11
T_{14}	Control	98443.70	135.56	406680	308236.30	3.13

Sale price of okra = Rs. 30 kg^{-1}

CONCLUSION

It may be concluded from the present results that the foliar application of micronutrient mixtures (Boron + Zinc + Molybdenum + Copper + Iron + Manganese) enhanced quality attributes of okra, besides improving the economic feasibility of growing okra under temperate conditions of Kashmir.

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