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Effect of micronutrients on fruit quality, shelf life and economics of tomato (*Solanum lycopersicum* L.) cv. pkm-1

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Abstract
The present investigation entitled "Effect of micronutrients on fruit quality, shelf life and Economics of Tomato (*Solanum lycopersicum* L.) cv. PKM-1" was under taken at vegetable research field, Department of Horticulture, Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology & Sciences (SHIATS), Allahabad during rabi season (2015-2016). The experiment was laid out in Randomized block design with 13 treatments and each replicated thrice. The treatments consists of different combinations of micronutrients i.e., zinc, boron, copper and iron. Among these thirteen treatments, treatment T_{12} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm) was recorded the maximum maximum fruit yield per ha (33.62t) followed by treatment T_{11} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm). Among the quality parameters TSS (5.0^0B^{rix}) was found maximum in treatment T_{11}($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm) followed by treatment T_{12}($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm) whereas juiciness (31.24%), titrable acidity (1.06%), Ascorbic acid content (26.67mg/100 g fruit juice) and shelf life (11.39) days at normal room temperature was recorded maximum in treatment T_{11}($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm) followed by T_{12}($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm). Maximum gross returns (Rs.3, 37,700 ha^{-1}), net returns (Rs. 2,14,925 ha^{-1}) and B: C ratio (2.75:1) was found to be best with treatment with T_{12} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm)

Keywords: Tomato, PKM-1, micronutrients, yield, and quality

Introduction
Tomato (*Solanum lycopersicum* L.) is an important vegetable crop in India, occupies an area of 8,65,000 ha with an annual production of 1,65,26,000 metric tones/ha and productivity of 19.1metric tonnes/ha (Anon., 2011). It belongs to the family Solanaceae having chromosome number (2n=24). It is a self-pollinated crop and Peru-Equador region is considered to be the centre of origin. Tomato is one of the popular vegetable with great medicinal value and is used in various forms of salad, soup, ketchup, sauce, chutney, pickles, powder, paste, juice, puree, whole canned fruits and also forms an important ingredient in the cocktails known as "Bloody Mary". It is believed that consumption of one tomato per day enhances the health status of individuals and considered to be important in diet as it is quite high in nutritive value. It contains higher quantity of total sugar (2.5-4.5%), starch (0.6-1.2%) and minerals like potassium, calcium, sodium, magnesium, phosphorus, boron, manganese, zinc, copper, iron, etc. Apart from these, it also contains organic acids such as citric, malic and acetic acids which are known as health acids in fresh tomato fruit. The flavor of tomato fruits is controlled by various volatile compounds like ethanol and acetaldehyde. Tomato juice promotes gastric secretion, acts as a blood purifier and works as intestinal antiseptic.
Micronutrients have an important role in the plant activities and foliar application can improve the vegetative growth, fruit set and yield of tomato (Adams, 2004) [1] by increasing photosynthesis of green plants (Mallick and Muthukrishnan, 1980) [7]. Among micronutrients, Zn and B are important for plant nutrition. Tomato requires both major and micronutrients for its proper plant growth (Sainju *et al*., 2003) [14]. Zn plays important role on growth and development as well as carbohydrates, protein metabolism and sexual fertilization of plant (Imtiaz *et al*., 2003; Vasconcelos *et al*., 2011) [5, 18] while B deficiency reduced yield and quality in tomatoes (Davis *et al*., 2003) [4]. Balanced fertilization of macro and micro nutrients can increases production (Swan *et al*., 2001; Ali *et al*., 2008) [17, 3] but foliar application of micronutrients is the not only efficient but also secured way (Aghtape *et al*., 2011) [2].
Thus micronutrients as their requirement is low but they are essential as the larger amount of primary and secondary nutrients for plant growth and development. Keeping in view all the above facts an experiment has been conducted to access the effect of micronutrients on plant growth, yield and fruit quality of tomato along with the comparative study of economics of various treatment combinations.

Materials and Methods

An experiment was carried out at vegetable research field, Department of Horticulture, Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology & Sciences (SHIATS), Allahabad, during Rabi season (2015-16). The experiment was laid out in Randomized block design with 13 treatments and each replicated thrice.

Treatment details

Treatment Symbol	Treatment Combinations
T_0	Control
T_1	$ZnSO_4$@250ppm
T_2	$ZnSO_4$@500ppm
T_3	$B3HO_3$@250ppm
T_4	$B3HO_3$@500ppm
T_5	$CuSO_4$@100ppm
T_6	$CuSO_4$ @250ppm
T_7	$FeSO_4$@250ppm
T_8	$FeSO_4$@500ppm
T_9	$ZnSO_4$+B_3HO_3+$CuSO_4$@250ppm
T_{10}	$ZnSO_4$+B_3HO_3+$CuSO_4$@500ppm
T_{11}	$ZnSO_4$+B_3HO_3+$CuSO_4$+$FeSO_4$@250ppm
T_{12}	$ZnSO_4$+B_3HO_3+$CuSO_4$+$FeSO_4$@500 ppm

Results and Discussion

Table 1: Performance of Quality and shelf life parameters of Tomato PKM-1 Variety due to effect of different micronutrients combinations

S. No	Treatments	Juiciness	TSS	Titrability	Ascorbic acid	Shelf life	Yield per ha
1	Control	19.20	3.14	0.87	23.24	5.16	19.08
2	ZincSulphate@250ppm	22.42	3.71	0.92	24.80	7.00	23.41
3	ZincSulphate@500ppm	25.94	4.05	0.96	25.24	8.28	27.15
4	Boricacid@250ppm	23.49	3.82	0.92	25.03	7.53	24.97
5	Boricacid@500ppm	27.42	4.08	0.94	25.71	9.26	29.01
6	CopperSulphate@100ppm	20.62	3.50	0.9	24.48	6.53	21.60
7	CopperSulphate@250ppm	21.97	3.62	0.91	24.84	6.77	22.42
8	FerrousSulphate@250ppm	19.94	3.17	1.03	23.93	5.66	20.35
9	FerrousSulphate@500ppm	20.24	3.24	1.05	23.99	6.07	20.96
10	Zinc+Boron+Copper@250ppm	28.89	4.09	0.97	25.93	10.14	30.77
11	Zinc+Boron+Copper@500ppm	30.14	4.33	1.02	26.15	10.77	31.44
12	Zinc+Boron+Copper+Ferrous@250ppm	30.71	5.03	1.05	26.68	11.71	33.14
13	Zinc+Boron+Copper+Ferrous@500ppm	31.24	4.68	1.03	26.48	11.18	33.62
CD		1.42	0.21	0.02	0.20	0.50	1.12
SED		0.68	0.10	0.01	0.097	0.25	0.55

Yield parameters

The data revealed that the combination of different micronutrients were also affected the yield parameters of tomato. In the present study, among the various treatment combinations T_{12} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm) was recorded maximum yield per hectare (33.62 t/ha) followed by T_{11} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm) and the minimum were recorded with Treatment T_0(Control). Maximum photosynthetic activity and accumulation of number of fruits is also found to be highest with T_{12} ($ZnSO_4$+B_3Ho_3+$CuSO_4$+$FeSO_4$ @500ppm). The increase in yield per plant, per plot and per hectare is might be due to the increase in growth and flower attributes which in turns and lead to increase photosynthesis and dry matter production. Minimum number of fruits and yield in Control might be due to non-availability of micronutrients during its development stage. Similar findings were also reported by Naidu *et al.*, (2002) [8], Rafi *et al.*, (2002) [11], Poul *et al.*, (2004) [10], Rodge and Yadlod (2009) [13] and Suge *et al.*, (2011) [16] in tomato and brinjal.

Quality parameters

The data revealed that the combination of different micronutrients were also affected the quality parameters of tomato. In the present experimental findings it shows that treatment T_{11} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm) were recorded maximum TSS (5.03^0B^{rix}) followed by T_{12} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm) with 4.68^0B^{rix}. The juiciness of tomato (31.24%), acidity (1.06%) and ascorbic acid (26.67 mg/100g of fruit juice) was also found to be maximum with treatment T_{11} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm) followed by T_{12} ($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm). The increase in quality of tomato parameters is might be due to increase in availability of micronutrients especially zinc, boron, which plays vital role in enhancing the fruit quality. The Similar findings were also reported by Krishna and Krishnappa (2002) [6], Patil *et al.* (2004) [4], Singh *et al.* (2010) [15] in tomato.

Shelf life

The data reveals that the maximum shelf life of tomato fruits at normal room temperature were recorded best with the treatment T_{11}($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm) with 11.39 days followed by T_{12}($ZnSO_4$+B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm) with 11.08 days. Application of zinc and iron might have reduced the rate of respiration and transpiration resulting in reduced ethylene production during storage of tomato fruits which results in increasing the shelf-life of the fruits. Similar findings were also reported by Patil *et al.*, (2004) [4] and Ranjit *et al.*, (2013) [2] in tomato.

Economics

The present investigation revealed that Maximum gross returns (Rs.3, 37,700 ha^{-1}), net returns (Rs. 2,14,925 ha^{-1}) and B: C ratio (2.75:1) was found to be best with treatment with T_{11}($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm) followed by T_{12}($ZnSO_4$ +B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm)

Table 1: Performance of Quality and shelf life parameters of Tomato PKM-1 Variety due to effect of different micronutrients combinations

S. No	Treatments	**Total fixed cost Rs**	**Total variable cost**	**Total cost of cultivation Rs**	**Fruit Yield $ha^{-1(kgs)}$**	**Sale rate Rs kg^{-1}**	**Gross return Rs/ha**	**Net return Rs/ha**	**Cost Benefit ratio**
1	Control	1,19,229	00	119229	19080	10	190800	71571	1:1.60
2	ZincSulphate@250ppm	1,19,229	600	119829	23410	10	234100	114271	1:1.95
3	ZincSulphate@500ppm	1,19,229	1200	120429	27150	10	271500	151071	1:2.25
4	Boricacid@250ppm	1,19,229	500	119729	24970	10	249700	129971	1:2.09
5	Boricacid@500ppm	1,19,229	1000	120229	29010	10	290100	169871	1:2.41
6	CopperSulphate@100ppm	1,19,229	400	119629	21600	10	216000	96371	1:1.81
7	CopperSulphate@250ppm	1,19,229	800	120029	22420	10	224200	104171	1:1.87
8	FerrousSulphate@250ppm	1,19,229	1250	120479	20350	10	203500	83021	1:1.69
9	FerrousSulphate@500ppm	1,19,229	2500	121729	20960	10	209600	87871	1:1.72
10	Zinc+Boron+Copper@250ppm	1,19,229	1500	120729	30770	10	307700	186971	1:2.55
11	Zinc+Boron+Copper@500ppm	1,19,229	3000	122229	31440	10	314400	192171	1:2.57
12		1,19,229	2750	121979	33140	10	331400	209421	1:2.72
13		1,19,229	5500	124729	33620	10	336200	211471	1:2.70

Conclusion

On the basis of present experimental findings, it is concluded that the application of treatment T_{12}($ZnSO_4$+B_3HO_3 +$CuSO_4$ +$FeSO_4$ @500ppm) were resulted in maximum plant height, yield and TSS where as the Juiciness, Acidity, Ascorbic acid content and Shelf-life was recorded with treatment T_{11} ($ZnSO_4$+B_3HO_3 +$CuSO_4$ +$FeSO_4$ @250ppm) and the minimum was recorded with T_0 (Control) respectively.

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