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Effect of foliar spray of zinc sulphate on growth and yield of tomato (*Solanum lycopersicon* L.) under polyhouse

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Abstract
The field experiment was conducted at Horticulture farm, College of Agriculture, Bikaner (Rajasthan) from December, 2016 to June, 2017. The treatment consisted of five levels of zinc sulphate (0, 50, 100, 150, 200 ppm) and number of sprays (first, second and third) making there by 15 treatment combination Which were replicated three times in the Factorial Complete Randomized Design having bed size of 10 m x 1 m with a row to row distance of 45 cm and plant to plant 60 cm. The first, second and third spray of zinc sulphate was done 20, 40 and 60 days after transplanting respectively. The increasing levels of zinc sulphate and number of sprays significantly increased the growth and yield by increasing number of plant height, number of branches, number of flowers, chlorophyll content, length of fruits, weight of fruits, number of fruits per plant, fruits yield per plant, fruits yield q ha.

Keywords: *Solanum lycopersicon***,** factorial complete randomized design, zinc sulphate**,** growth and yield

Introduction
Tomato (*Solanum lycopersicon* L.), comes under family Solanaceae, is said to be native of Tropical America (Thomson and Kelly, 1957) [17]. From tropical America it spread over other parts of the world in the 16th century and became popular in India within last five decades. Tomato occupies an important place among vegetable crops and is grown in almost all parts of India under different agro-climatic conditions. Tomato is one of the most important and remunerative vegetable crop in India. In India, major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh and West Bengal. In India, total production of tomato is approximately 18.74 million tonnes from an area about 0.88 million hectares with an average productivity of 16.1 metric tonnes per hectare. (Anonymous, 2015) [2]. Rajasthan contributes about 7.52 million tonnes productions with an area of 0.16 million hectare and productivity of 4.5 metric tonnes per hectare. To meet out the demand of increasing population, higher yield in all sort of agricultural produce is required; also the idea of quality cannot be overlooked. The higher yield combined with good quality of produce is the demand of the modern day. The aim of the agricultural scientists engaged in researches in fruits and vegetables is to explore the means and methods for high yields along with good quality. Wallace (1957) [20] predicted that due to adaptation of improved agronomic practices for increasing crop production, gradually the reserve of available micronutrients in the soil will be exhausted, and the demand for micronutrients will also increase. The addition micronutrients have become now essential not only to replenish the exhausting pool but also to improve the efficiency of applied macro-nutrients. For the efficient use of major nutrients an adequate supply of micronutrients has been found essential (Trehan and Grewal, 1997) [18]. Micronutrients usually required in minute quantities nevertheless are vital to the growth of plants (Benepal, 1967) [3]. Copper, manganese, zinc and iron are chiefly concerned with the oxidation-reduction reaction (Wallace, 1957) [20]. The micronutrients improve the chemical composition of fruits and general conditions of plant are known to act as catalyst in promoting organic reactions taking place in plants (Ranganathan and Perumal, 1995) [14].
Zinc like other trace elements is known to be present in plant body long before its essentiality was proved. Zinc act as a catalyst and regulator in plant nutrition and plays an important role in oxidation-reduction. It is known to be related to the formation of chlorophyll.

It has been observed that the development of green colour is associated with an increase in the zinc content of leaf. It is considered indispensable for the growth of all living organisms and its deficiency causes abnormalities in growth. Micronutrients are vitally connected with chlorophyll formation and act as an integral part of enzyme system and oxidation-reduction agent in biological system. Zinc deficiency in tomato has been reported to cause serious reduction in yield and quality. Amongst the vegetables, tomato is very responsive to the application of micronutrients (Bose and Tripathi, 1996; Ranganathan and Perumal, 1996) [5, 15]. The objective of the study was to evaluate the effect of foliar application of zinc on growth and yield of tomato cultivated under polyhouse.

Materials and Methods

The experiment was laid out at Horticulture Research Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Beechwal, Bikaner from December, 2016 to June, 2017. The experiment was laid out in Factorial Complete Randomized Design (F-CRD) with three replications. The treatments were randomized by using Fisher's random number table (Fisher, 1950). Variety used in experiment was Arka Rakshak which was procured from ICAR-IIHR, Bengaluru (Karnataka). Paired row planting system was followed for raising the crop under poly house. Zinc Sulphate (Zinc Sulphate heptahydrate) of concentration (0, 50, 100, 150, 200 ppm) was applied as foliar spray at 20, 40 and 60 Days After Transplanting. The experiment was comprised of 15 treatments and total plants under study was 1350.

Data were collected on Growth attributes i.e. plant height, Number of branches per plant, Days to first flowering, Days to first harvest, Number of flowers per plants, Chlorophyll content and yield attributes i.e. Number of fruits per plant, Diameters of fruit (cm), Average fruit weight (g), Fruit yield per plant (Kg) and Fruit yield (kg/ha). Collected data were statistically analyzed as per procedure described by Panse and Sukhatme (1985). The critical difference were calculated to assess the significance of treatment means wherever, the "F" test was found significant at 5 per cent and 1 per cent level of significance. The analysis of variance for all the data discussed has been given in the respective appendices at the end.

Results

Plant Growth Characters

Plant height: The maximum plant height at 70 days (121.84 cm) and 90 days (156.92 cm) was observed in treatment (Zn_4) *i.e.* 200 ppm zinc sulphate which was found to be significantly higher over (Zn_0), (Zn_1) and (Zn_2) but statistically at par with (Zn_3). Data further revealed that three sprays (at 20, 40 and 60 DAT) of zinc sulphate at different concentrations was found significantly better in increasing plant height. The maximum plant height was found under three spray at 70 DAT (118.08 cm) and 90 DAT (150.56 cm) as compared to the minimum (101.33 cm) at 70 DAT and (131.01 cm) at 90 DAT one spray.

Number of branches per plant

The maximum number of branches at 70 and 90 days (9.38) and (14.62) were observed in treatment Zn_4 *i.e.* 200 ppm zinc sulphate these values which were found to be significant higher over other treatments. While zinc sulphate at different concentrations gave significantly higher number of branches per plant at 70 DAT (8.81) and 90 DAT (13.41) as compared to their respective obtained values with single spray (6.81 at 70 DAT) and (11.07 at 90 DAT).

Days to first flowering

The result showed that number of days taken for first flowering were minimum (33.37) days in plants treated with zinc sulphate @ 200 ppm (Zn_4) followed by (33.54) days in plants treated with zinc sulphate @ 150 ppm (Zn_3) However, maximum days were required in control (39.01) for first flowering. The critical examination of data showed that the first flowering in all treatment was observed before 40 DAT, by that time the plants have received only one spray of zinc sulphate (*i.e.* at 20 DAT).

Number of flowers per plant

Mean data clearly indicated that the maximum number of flowers at 70 DAT (86.83) was observed in treatment Zn_4 *i.e.* 200 ppm zinc sulphate which was found to be significantly higher over Zn_0 (65.88) Zn_1 (73.62) and Zn_2 (80.39) but statistically at par with Zn_3 (85.60). The data further indicated that three sprays (at 20, 40 and 60 DAT) of zinc sulphate at different concentrations significantly increased the number of flowers per plant (82.85) at 70 DAT as compared to one spray (73.70).

Days to first harvest

The results showed that the number of days taken for first harvesting were minimum (76.26 days) in plants treated with zinc sulphate @ 200 ppm (Zn_4) followed (76.97 days) taken by plants treated with zinc sulphate @ 150 ppm (Zn_3). The result showed that minimum numbers of days (78.36) were taken by plants treated with three sprays (at 20, 40 and 60 DAT). Whereas, the plants which received only one spray (at 20 DAT) took maximum number of days (82.68) for first harvesting.

Total chlorophyll content (mg g^{-1})

The maximum total chlorophyll content (1.246) at 70 DAT was observed in treatment Zn_4 *i.e.* 200 ppm zinc sulphate which was found to be significantly higher over Zn_0, Zn_1 and Zn_2 but statistically at par with Zn_3. The mean increase in total chlorophyll content at 70 DAT under Zn_3 was found to be 9.43, 4.28, and 2.05 per cent higher than Zn_0, Zn_1 and Zn_2, respectively. The data further indicated that three sprays (at 20, 40 and 60 DAT) of zinc sulphate at different concentrations gave significantly higher total chlorophyll content at 70 DAT (1.225) as compared to single spray (1.184) at (20 DAT).

Yield and yield attributes

Fruit diameter (cm)

Fruit diameter was significantly influenced by different levels of zinc sulphate. Maximum fruit diameter was observed in Zn_4 (5.34 cm) followed by Zn_3 (5.18 cm), Zn_2 (4.87 cm), Zn_1 (4.43 cm) and Zn_0 (3.79 cm) but Zn_4 ($ZnSo_4$ 200 ppm) was statistically at par with Zn_3 ($ZnSo_4$ 150 ppm). The result for number of sprays showed that maximum fruit diameter (5.39 cm) was observed in three sprays (at 20, 40 and 60 DAT). Whereas minimum fruit diameter (4.58 cm) was recorded in single spray (at 20 DAT).

Fruit length (cm)

Maximum fruit length was observed in Zn_4 (5.68 cm) followed by Zn_3 (5.54 cm), Zn_2 (5.17 cm), Zn_1 (4.68 cm) and Zn_0 (4.00 cm) but Zn_4 ($ZnSo_4$ 200 ppm) was found statistically at par with Zn_3 (($ZnSo_4$ 150 ppm). For number of sprays maximum fruit length (4.95 cm) was observed in three spray (at 20, 40 and 60 DAT). Whereas, minimum fruit length (4.44 cm) was recorded in single spray (at 20 DAT).

Fruit weight (g)

Maximum fruit weight was observed in Zn_4 (56.28 g) followed by Zn_3 (55.11 g), Zn_2 (51.66 g), Zn_1 (45.60 g) and Zn_0 (38.20 g) but Zn_4 ($ZnSo_4$ 200 ppm) was statistically at par with Zn_3 ($ZnSo_4$ 150 ppm). For number of sprays maximum fruit weight (53.57 g) was observed in three sprays (at 20, 40 and 60 DAT). Whereas, minimum fruit weight (44.47 g) was recorded in single spray (at 20 DAT).

Number of fruits per plant

The maximum number of fruits (45.82) was observed in Zn_4 *i.e*. 200 ppm zinc sulphate which was found to be significantly higher over Zn_0 (28.91), Zn_1 (35.30) and Zn_2 (40.81) but statistically at par with Zn_3 (45.06). The data in same table further indicated that three sprays (at 20, 40 and 60 DAT) of zinc sulphate at different concentrations produced significantly higher number of fruits per plant (44.65) as compared to single spray (32.61) (at 20 DAT) and double spray (40.28).

Fruit yield per plant

The Maximum yield (2.25 kg) was observed in Zn_4 i.e. 200 ppm zinc sulphate which was found to be significantly higher over Zn_0 (1.30 kg), Zn_1 (1.69 kg) and Zn_2 (1.99 kg) but statistically at par with Zn_3 (2.21 kg). The perusal of data showed that number of spray significantly influenced the tomato yield per plant. The maximum tomato yield per plant (2.06 kg) was recorded with the three sprays (at 20, 40 and 60 DAT), while minimum (1.68 kg) was recorded under single spray (at 20 DAT).

Fruit yield kg ha^{-1}

The maximum yield (66721kg ha^{-1}) was observed in Zn_4 *i.e.* 200 ppm zinc sulphate which was found to be significantly higher over Zn_0 (38538 kg ha^{-1}), Zn_1 (50205 kg ha^{-1}), and Zn_2 (58993 kg ha^{-1}), but statistically at par with Zn_3 (65509 kg ha^{-1}). The perusal of data showed that number of spray significantly influenced the tomato yield kg ha^{-1}. The maximum tomato yield (61180 kg ha^{-1}) was recorded with the three spray (at 20, 40 and 60 DAT) While, minimum (49770 kg ha^{-1}) was recorded under single spray (at 20 DAT).

Discussion

Effect of foliar application of zinc sulphate on vegetative growth attributes

The zinc sulphate (200 ppm) concentration proved better for all growth characters as compared to control and its lower concentration. Minimum growth characters were produced under 0 ppm concentration of zinc sulphate.

Sammauria and Yadav (2008) [16] also reported that increasing levels of Zn increased the number of branches per plant in fenugreek. Davood and Mubarak (2010) [7] while working with knol-khol found the similar increase in number of leaves per plant and leaf area with foliar application of Zn. Chandra *et al.* (2014) [6] also reported the similar trend in tomato variety *Azad* T6. They observed that significant influence on plant growth flowering, fruit yield with application of boric acid and zinc sulphate. Devi *et al*. (2013) [8] also observed the similar finding in chilli (*Capsicum annuum* var. *accuminatum* L.) cultivar Pant C-3 using foliar application of micro-nutrients. Zinc sulphate @ 0.75% was found highest for the character *viz*. plant height (75.20 cm), stem diameter (1.2 cm), fruit length (9.5 cm). Mishra *et al.* (2012) [11] also found that number of branches increased significantly in tomato cv. Utkal Urbasi (BT-12) by foliar application of micronutrients. The increase in plant height, number of branches per plant, number of flower per plant and decrease in days to first flowering with foliar application of zinc sulphate may be ascribed due to sufficient availability of zinc to plant which might have enhanced catalytic or stimulatory effect on most of the physiological and metabolic processes of plant. Important role in regulating the auxin concentrations in plants, independently of its effect on growth. Zinc also enhances the absorption of essential elements via increasing the cation exchange capacity of roots. Zinc sulphate treatment was found to increase the photosynthetic activity and the rate of respiration which results in improved the growth (Martin *et al*., 1966). Agarwal *et al.* (2008) [1] confirmed the similar finding that foliar spray of micronutrients (Zn, B, Fe and Cu) gives superior plant height, number of branches and leaves per plant and stem girth in tomato.

Effect of foliar application of zinc sulphate on yield attributes

The reason for increased number of fruits might be due to increased absorption of zinc sulphate similar results were observed by (Raghav and Sharma (2003) [13]. Further, there might be efficient absorption of zinc sulphate by tomato leaves because of close synchronization of foliar spray with flowering and fruiting in tomatoes. This absorbed zinc by plant has increased photosynthesis due to its direct role in chlorophyll formation leading to greater number of fruits. The increase in fruit weight might be assigned to frequent spray of zinc sulphate, since it has promoted the growth of all vegetative parts and consequently more food material for fruit development. Davood and Mubarak (2010) [7] also studied the similar influence. The present results corroborated with the finding of Bhatt *et al.* (2004) [4] where they observed that yield was significantly influenced by the foliar application of mixture of micronutrients (Fe, Zn, Cu, Mn, B and Mo) and increase in yield was to the extent of 33 per cent over control. Varghese, A. and Duraisami (2005) [19] also reported 35.5 per cent more yield than in cauliflower by application of 1.0 kg borax ha^{-1} and 2.5 kg $ZnSO_4$ ha^{-1}. Kumar and Sen (2005) [9] also reported that application of zinc up to 30 kg/ha as $ZnSO_4$ significantly improved the number of fruits per plant (13.34), fruit length (16.82 cm), fruit weight (16.58 g), yield per plant (218.55g) as well as yield/ha (147.20 q/ha) in okra var. Prabhani Kranti. Highest number of fruit per plant (44.65) was observed when three spray of zinc sulphate was used as compared to one spray (32.61) (at 20 DAT). Mishra and Nandi (2007) [10] observed that the spray of micronutrients increased the yield of tomato.

Summary and Conclusion

$ZnSo_4$ @ 200 ppm zinc sulphate recorded maximum plant height (121.84 cm) at 70 DAT and (156.92 cm) at 90 DAT, increased number of branches per plant (9.38) at 70 DAT and (14.62) at 90 DAT, plants flowered earlier (33.37 DAT) than others and control plants, highest number of flowers per plant (86.83) was recorded, minimum of days (76.26) taken for first harvesting as compared to (86.49) control and maximum total chlorophyll (1.246) content at 70 DAT was observed. Three spray shown to have significant effect on all the growth attributes compared to one. A maximum of (5.34 cm) average fruit diameter, maximum fruit length (5.68 cm) as compared to control (4.00 cm) (minimum), maximum fruit weight of (56.28 gm) and number of fruit per plant (45.82), maximum yield of fruits per plant (2.25 kg) and highest recorded yield kg ha-1(66721) were observed in Zn_4 *i.e.* 200 ppm zinc sulphate. Three spray shown to have significant effect on all the yields attributes compared to one spray.

It may be concluded that the application of zinc sulphate as foliar spray is beneficial in improving vegetative growth and fruit yield of tomato cv. Arka Rakshak in Bikaner under polyhouse condition. The most effective treatment in increasing the growth and yield of tomato under present experiment was foliar spray of zinc sulphate 200 ppm.

Table 1: Effect of foliar spray of zinc sulphate on plant height and number of branches (at 70 and 90 DAT) of tomato

Treatments	Plant height (cm)		Branches plant^{-1}	
	70 DAT	90 DAT	70 DAT	90 DAT
Zinc sulphate levels (ppm)				
Zn_0 0 ppm	93.62	119.56	5.68	8.95
Zn_1 50 ppm	102.78	131.68	6.87	10.88
Zn_2 100 ppm	111.64	143.18	8.04	12.63
Zn_3 150 ppm	119.51	153.89	9.16	14.26
Zn_4 200 ppm	121.84	156.92	9.38	14.62
S.Em+	2.315	3.29	0.370	0.307
CD (P=0.05)	6.686	9.49	1.067	0.886
Number of spray at (DAT)				
S_1 20	101.33	131.01	6.81	11.07
S_2 20,40	110.23	141.56	7.85	12.31
S_3 20, 40, 60	118.08	150.56	8.81	13.41
S.Em+	1.793	2.546	0.286	0.238
CD (P=0.05)	5.179	7.353	0.827	0.686

Table 2: Effect of foliar spray of zinc sulphate on days to first flowering, flowers plant^{-1} (at 70 DAT) and days to first harvest of tomato

Treatments	Days to first flowering	Flowers plant^{-1} (at 70 DAT)	Days to first harvest
Zinc sulphate levels (ppm)			
Zn_0 0 ppm	39.01	65.88	86.49
Zn_1 50 ppm	36.68	73.62	82.71
Zn_2 100 ppm	34.76	80.39	79.66
Zn_3 150 ppm	33.54	85.60	76.97
Zn_4 200 ppm	33.37	86.83	76.26
S.Em+	0.902	1.631	1.794
CD (P=0.05)	2.606	4.712	5.181
Number of spray at (DAT)			
S_1 20	35.79	65.88	82.68
S_2 20,40	35.62	73.62	80.21
S_3 20, 40, 60	35.01	80.39	78.36
S.Em+	NS	85.60	1.390
CD (P=0.05)	NS	86.83	4.013

Table 3: Effect of foliar spray of zinc sulphate on total chlorophyll content (at 70 and 90 DAT) of tomato

Treatments	Total chlorophyll content (mg g^{-1})	
	70 DAT	90 DAT
Zinc sulphate levels (ppm)		
Zn_0 0 ppm	1.134	0.889
Zn_1 50 ppm	1.190	0.892
Zn_2 100 ppm	1.216	0.894
Zn_3 150 ppm	1.241	0.896
Zn_4 200 ppm	1.246	0.897
S.Em+	0.006	NS
CD (P=0.05)	0.017	NS
Number of spray at (DAT)		
S_1 20	1.184	0.890
S_2 20,40	1.207	0.894
S_3 20, 40, 60	1.225	0.896
S.Em+	0.004	NS
CD (P=0.05)	0.013	NS

Table 4: Effect of foliar spray of zinc sulphate on diameter (cm), length (cm) and weight (g) of tomato

Treatments	Diameter (cm)	Length (cm)	Weight (g)
Zinc sulphate levels (ppm)			
Zn_0 0 ppm	3.79	4.00	38.20
Zn_1 50 ppm	4.43	4.68	45.60
Zn_2 100 ppm	4.87	5.17	51.66
Zn_3 150 ppm	5.18	5.54	55.11
Zn_4 200 ppm	5.34	5.68	56.28
S.Em+	0.102	0.119	1.177
CD (P=0.05)	0.296	0.344	3.400
Number of sprays at (DAT)			
S_1 20	4.44	4.58	44.47
S_2 20,40	4.77	5.06	50.07
S_3 20, 40, 60	4.95	5.39	53.57
S.Em+	0.08	0.09	0.91
CD (P=0.05)	0.23	0.27	2.63

Table 5: Effect of foliar spray of zinc sulphate on fruits plant^{-1}, yield kg plant^{-1} and yield kg ha^{-1} of tomato

Treatments	Fruits plant^{-1}	Yield kg plant^{-1}	Yield kg ha^{-1}
Zinc sulphate levels (ppm)			
Zn_0 0 ppm	28.91	1.30	38538
Zn_1 50 ppm	35.30	1.69	50205
Zn_2 100 ppm	40.81	1.99	58993
Zn_3 150 ppm	45.06	2.21	65509
Zn_4 200 ppm	45.82	2.25	66721
S.Em+	1.222	0.059	1743
CD (P=0.05)	3.529	0.169	5035
Number of sprays at (DAT)			
S_1 20	32.61	1.68	49770
S_2 20,40	40.28	1.92	57031
S_3 20, 40, 60	44.65	2.06	61180
S.Em+	0.95	0.05	1350
CD (P=0.05)	2.73	0.13	3900

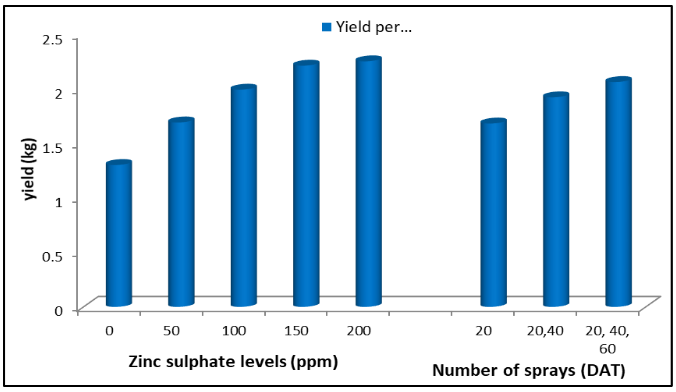

Fig 1: Effect of zinc sulphate on yield plant^{-1} of tomato

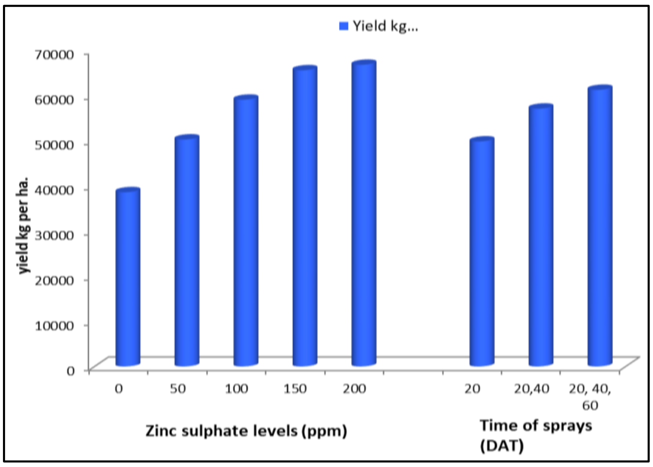

Fig 2: Effect of zinc sulphate on yield (kg ha^{-1}) of tomato

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