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IMPACT OF DIFFERENT SOURCES AND LEVELS OF ZINC ON POMEGRANATE CROP PRODUCTION

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ABSTRACT

Field experiment was conducted to assess the effect of different zinc sources *Viz.*, zinc metalosate, Zn-EDTA, and zinc sulphate applied at varying levels (concentrations) on the growth, yield, and physical attributes of pomegranate. The study was carried out during 2015–16 and 2016–17 in a four-year-old pomegranate orchard (var. Bhagwa) at a farmer's field in Marganahalli village, Chickaballapura district, Karnataka. The experiment was laid out in a randomized block design (RBD) with twenty treatments and three replications. The findings indicated that, among the different sources and levels of zinc, foliar application of zinc at 0.150% through zinc metalosate (T_{13}) significantly increased plant height (217.70 cm), number of fruits per plant (88.71), number of fruits per shoot (5.25), total fruit weight per shoot (1752.76 g), yield per plant (27.38 kg plant^{-1}), yield per hectare (25.05 t ha^{-1}), fruit length (12.14 cm), fruit breadth (13.84 cm), and fruit weight (329.19 g) compared to other treatments. These results were statistically comparable with treatment T_{18} , which received zinc at 0.150% through Zn-EDTA.

***Key words*:** Zinc metalosate, Zn-EDTA, $ZnSO_4$, Foliar spray, Pomegranate, Growth, Yield parameters and physical parameters of pomegranate.

Introduction

Pomegranate (*Punica granatum* L.) is one of the oldest fruit crop which dates back to antiquity and it predominantly grown in arid and semi-arid regions of the world. It is well known for its nutritional value, drought tolerance, and high market demand. Being, highly remunerative crop, it helps in replacing subsistence farming and alleviate poverty. It has high nutritional value better than grapes, mango, orange and papaya. It is richest source of riboflavin and polyphenols like ellagic acid and punicalgins which acts as antioxidants. Fruit also contains good amount of CHO (14.50 %), protein (1.60 %), calcium (10 mg/100g), phosphorus (70 mg/ 100 g), iron (0.3 mg/100 g) and vitamin C (65 mg/100 g) besides its calorofic value of 65 kcal/100 g. Therefore, pomegranate fruit is referred as 'Elixir of life' (Patil and Manjunath, 2014).

India is one of the largest producers of pomegranate in the world and contributes about 50 per cent towards the world's production. In India, during 2023-24, area under pomegranate cultivation was 2.24 lakh ha, production was 28.4 lakh tonnes and productivity was 12.69 tonnes/ha (NRCP Annual Report 2024). Among states, Maharashtra is the leading pomegranate producer followed by Karnataka with an area 28.09 (000 ha), production 3.3 lakh tonnes and productivity 11–12 t ha^{-1} during 2023-24. Other pomegranate growing states in India are Gujarat, Telangana and Tamil Nadu. In Karnataka, pomegranate is commercially cultivated in Koppal, Bagalkote, Vijayapura, Chitradurga and Tumkur districts.

Fruit crop production is governed by several factors like climate, soil, irrigation, varieties, pests, diseases, and nutritional status of soil as well as plant. Deficiency of various nutrients causes drastic reduction in growth, yield, and quality of fruits. Among the nutrients, micronutrients though required in small quantities their importance in growth, yield and quality of fruit crops is quite essential (Raja, 2009).

Deficiency of zinc is characterized by interveinal chlorosis, short internodes, little leaf, rosetting and poor flowering and fruit setting. Zinc deficiency in the soil and plant can be correcting by adding different zinc sources like zinc sulphate, Zn-EDTA, zinc metalosate and FYM to soil and foliage.

Foliar sprays are widely used as their application rates are much lower than the rates required for soil application. Uniform application is easily obtained, 6 to 20 times more effective and helps in rapid uptake and plant response (Anees *et al*., 2011). Hence, the nutrient deficiencies can be corrected during the growing season. It is also beneficial in correcting nutritional and physiological disorders in fruit trees thereby helps in improving fruit setting, quality and productivity of fruit crops.

Zinc metalosate is an amino acid chelated zinc fertilizer contains 6.8 per cent of zinc, liquid in nature, 100 per cent water soluble, neutral in charge and brown in colour. Several research workers have been reported that, foliar spray of zinc by using zinc sulphate has improved significantly yield and quality of fruits (Kumar and Verma, 2004 and Dinesh *et al*., 2007). However, information on effects of other sources of zinc like Zn-EDTA and zinc metalosate on productivity and quality of pomegranate is lacking. Hence, this research work was carried out to elucidate the beneficial effects of different sources of zinc *viz*., zinc metalosate, Zn-EDTA and $ZnSO_4$ on growth, yield, and physical parameters of pomegranate fruit.

Material and Methods

The field experiment was conducted in the Eastern Dry Zone (Zone 5) of Karnataka at Marganahalli village, Chikkaballapur district (13°522 293 N latitude and 77°832 673 E longitude, at an elevation of 835 m above mean sea level) Karnataka, India during the years 2015–16 and 2016–17.

A four-year-old pomegranate orchard (variety Bhagwa) was selected for the study. The experiment was laid out in a Randomized Block Design (RBD) with twenty treatments and three replications. The treatments includes: T_1: NPK, T_2: NPK+ soil application of Zn as $ZnSO_4$, T_3: NPK + FYM, T_4: NPK + Foliar spray of 0.010 % Zn as $ZnSO_4$, T_5: NPK + Foliar spray of 0.025 % Zn as $ZnSO_4$, T_6: NPK + Foliar spray of 0.050 % Zn as $ZnSO_4$, T_7: NPK + Foliar spray of 0.100 % Zn as $ZnSO_4$, T_8: NPK + Foliar spray of 0.150 % Zn as $ZnSO_4$, T_9: NPK + Foliar spray of 0.010% Zn as zinc metalosate, T_{10}: NPK + Foliar spray of 0.025 % Zn as zinc metalosate, T_{11}: NPK + Foliar spray of 0.050% Zn as zinc metalosate, T_{12}: NPK + Foliar spray of 0.10% Zn as zinc metalosate, T_{13}: NPK + Foliar spray of 0.150% Zn as zinc metalosate, T_{14}: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA, T_{15}: NPK + Foliar spray of 0.025% Zn as Zn-EDTA, T_{16}: NPK + Foliar spray of 0.050% Zn as Zn-EDTA, T_{17}: NPK + Foliar spray of 0.10% Zn as Zn-EDTA, T_{18}: NPK + Foliar spray of 0.150% Zn as Zn-EDTA, T_{19}: T_3 + Soil application of Zn as $ZnSO_4$ and T_{20}: T_3+ Foliar spray of 0.01% Zn as $ZnSO_4$. The recommended dose of fertilizers (200:100:100 kg N:P_2O_5: K_2O kg/ha) and FYM (12.5 t ha^{-1}) were applied as per standard package of practices. Foliar sprays were applied at a volume of 500 L ha^{-1} during critical growth stages, namely vegetative stage, fruit half-lemon stage, and fruit half-grown stage.

Zinc metalosate is a liquid, amino acid–chelated zinc fertilizer containing 6.8% zinc, which is 100% water soluble and neutral in charge. Zinc sulphate and Zn-EDTA are also water-soluble fertilizers containing 21% and 12% zinc, respectively.

Prior to treatment imposition, soil, water, and FYM samples were collected and analysed for their physico-chemical properties using standard procedures (Table 1, 2 and 3).

At the time of harvest, observations were recorded on growth parameters (plant height (cm)), yield parameters (number of fruits per shoot, total fruit weight per shoot (g), number of fruits per plant, yield per plant (kg) and yield per hectare (t ha^{-1})), and physical parameters of fruits (length, breadth, and weight). The recorded data were subjected to statistical analysis using Fisher's method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984). The significance of treatments was tested at the 5% probability level using 'F' and 't' tests. Whenever the 'F' test was found significant, the 't' test was employed to determine the critical difference (CD) for comparison among treatments. The results were interpreted and discussed based on the pooled data of two years (2015–16 and 2016–17).

Results and Discussion

Effect of different sources and levels of zinc on growth and yield parameters of pomegranate

Plant height (cm):

Application of zinc through different sources and at varying concentrations significantly improved the growth and yield of pomegranate. Among the treatments, foliar application of zinc at 0.150% through zinc metalosate

Table 1: Initial physico - chemical properties of the experimental site.

Sr.	Parameters	Values	Method	Reference
1	Sand (%)	66.90	International pipette method	Piper (1966)
2	Silt (%)	15.70		
3	Clay (%)	17.30		
4	Texture class	Sandy loam		
5	pH (1:2.5)	6.28	Potentiometry	Jackson (1973)
6	EC (dS m^{-1})	0.30	Conductometry	Jackson (1973)
7	SOC (%)	0.52	Wet oxidation	Walkley and Black (1934)
8	Available N (kg ha^{-1})	292	Macrokjeldahl distillation	Subbiah and Asija (1956)
9	Available P_2O_5 (kg ha^{-1})	26	Spectrophotometry	Jackson (1973)
10	Available K_2O_5 (kg ha^{-1})	169	Flame photometry	Jackson (1973)
11	Exchangeable Ca (C mol (p^+) kg^{-1})	4.35	Versenate titrimetry	Jackson (1973)
12	Exchangeable Mg (C mol (p^+) kg^{-1})	1.98	Versenate titrimetry	Jackson (1973)
13	Available S (mg kg^{-1})	11.51	Turbidometry	Jackson (1973)
14	Available Zn (mg kg^{-1})	0.49	Atomic Absorption Spectrophotometry	Lindsay and Norwell, (1978)
15	Available Fe (mg kg^{-1})	40.06		
16	Available Mn (mg kg^{-1})	27.51		
17	Available Cu (mg kg^{-1})	0.35		
18	Available B (mg kg^{-1})	0.46	Azomethane –H method	Jones and Case (1990) [16]

(T_{13}) resulted in the highest plant height (217.70 cm), which was statistically on par with treatment T_{18} (216.44 cm) where 0.150% zinc was applied as Zn-EDTA. The lowest plant height (204.66 cm) was observed in treatment T_1, which received only the recommended dose of NPK fertilizers (Table 4).

Number of fruits per plant:

Application of zinc at different concentrations and from various sources significantly influenced the yield parameters of pomegranate. Among the treatments, foliar application of zinc at 0.150% through zinc metalosate (T_{13}) resulted in the highest number of fruits per plant (88.71), and it was statistically at par with treatment T_{18} (87.87), where 0.150% zinc was applied as Zn-EDTA. The lowest number of fruits per plant (77.17) was recorded in treatment T_1 which received only the recommended dose of NPK fertilizers (Table 4).

Number of fruits harvested per shoot:

Foliar application of zinc at 0.150% through sources such as zinc metalosate (T_{13}: 5.25) and Zn-EDTA (T_{18} : 5.15) significantly increased the number of fruits per shoot compared to other treatments. The lowest number of fruits per shoot (3.75) was observed in treatment T_1 (Table 4).

Total weight of fruits per shoot:

Spraying zinc at lower concentrations *i.e.*, 0.010% (T_9: 930.79 g; T_{14}: 923.42 g) and 0.025% (T_{10}: 1080.21 g; T_{15}: 1059.39 g) through zinc metalosate and Zn-EDTA,

Table 2: Quality parameters of irrigation water used in the field experiment.

Parameters	Content
pH	6.40
EC (dS/m)	0.60
Ca^{2+}(meq/l)	8.00
Mg^{2+}(meq/l)	1.60
$CO_3^{=}$ (meq/l)	Nil
HCO_3^{-}(meq/l)	2.00
Cl^{-}(meq/l)	4.00
Na^{+}(meq/l)	1.40
Zn (mg/l)	ND
Cu (mg/l)	ND
Mn (mg/l)	ND
Fe(mg/l)	0.23
SAR	0.64
RSC	-

Table 3: Nutrient content of farm yard manure used in the field experiment.

Parameters	Composition
pH	7.64
EC (dS/m)	0.11
O.C (%)	28.00
N (%)	1.06
P (%)	0.41
K (%)	0.57
S (%)	0.32
Ca (%)	0.20
Mg (%)	0.12
Fe (mg/kg)	4536
Mn (mg/kg)	246
Zn (mg/kg)	109
Cu (mg/kg)	34

Table 4: Effect of different sources and levels of zinc on growth and yield parameters of pomegranate.

Treat-ments	Plant height (cm)			Number of fruits plant^{-1}			Number of fruits harvested shoot^{-1}			Total weight of fruits shoot^{-1} (g)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	183.45	225.87	**204.66**	75.81	78.53	**77.17**	3.70	3.80	**3.75**	838.05	879.21	**858.63**
2	183.94	227.13	**205.54**	76.10	78.80	**77.45**	3.90	4.00	**3.95**	915.76	958.44	**937.10**
3	185.21	230.76	**207.99**	78.03	81.25	**79.64**	4.10	4.30	**4.20**	1024.59	1115.39	**1069.99**
4	183.61	226.09	**204.85**	75.86	78.59	**77.23**	3.80	3.90	**3.85**	866.81	909.05	**887.93**
5	184.12	227.38	**205.75**	76.63	79.31	**77.97**	4.00	4.10	**4.05**	941.40	986.54	**963.97**
6	185.31	230.15	**207.73**	77.81	80.63	**79.22**	4.30	4.40	**4.35**	1069.93	1121.34	**1095.63**
7	186.63	233.80	**210.22**	79.92	82.90	**81.41**	4.60	4.80	**4.70**	1232.34	1308.25	**1270.30**
8	188.08	237.89	**212.99**	82.85	85.35	**84.10**	4.80	5.10	**4.95**	1391.21	1515.36	**1453.29**
9	183.93	227.05	**205.49**	75.94	78.76	**77.35**	3.90	4.00	**3.95**	909.09	952.48	**930.79**
10	185.27	230.71	**207.99**	78.11	80.97	**79.54**	4.20	4.30	**4.25**	1053.91	1106.52	**1080.21**
11	186.74	234.80	**210.77**	80.66	83.70	**82.18**	4.50	4.80	**4.65**	1226.07	1327.13	**1276.60**
12	188.33	239.75	**214.04**	83.93	86.75	**85.34**	4.80	5.10	**4.95**	1424.98	1569.71	**1497.34**
13	190.00	245.39	**217.70**	87.26	90.16	**88.71**	5.00	5.50	**5.25**	1625.25	1840.26	**1752.76**
14	183.88	226.85	**205.37**	75.89	78.71	**77.30**	3.90	4.00	**3.95**	901.84	945.00	**923.42**
15	185.09	230.25	**207.67**	77.93	80.85	**79.39**	4.10	4.30	**4.20**	1021.02	1097.75	**1059.39**
16	186.42	234.09	**210.26**	80.13	83.33	**81.73**	4.40	4.70	**4.55**	1182.15	1294.24	**1238.20**
17	187.85	238.44	**213.15**	83.12	86.26	**84.69**	4.70	5.00	**4.85**	1372.64	1507.05	**1439.84**
18	189.37	243.50	**216.44**	86.33	89.41	**87.87**	5.00	5.30	**5.15**	1585.51	1759.45	**1677.48**
19	185.23	230.90	**208.07**	78.06	81.46	**79.76**	4.00	4.40	**4.20**	1009.33	1126.62	**1067.98**
20	185.31	231.11	**208.21**	78.25	81.79	**80.02**	4.20	4.50	**4.35**	1050.46	1171.11	**1110.78**
SEm ±	**3.92**	**4.82**	**4.25**	**1.56**	**1.79**	**1.65**	**0.30**	**0.42**	**0.33**	**40.31**	**44.81**	**40.04**
CD @ 5%	**NS**	**NS**	**12.15**	**4.46**	**5.13**	**4.72**	**NS**	**NS**	**0.95**	**115.40**	**128.28**	**114.64**

T_1: NPK; T_2: NPK+ Soil application of Zn as $ZnSO_4$; T_3: NPK + FYM; T_4: NPK + Foliar spray of 0.010 % Zn as $ZnSO_4$; T_5: NPK + Foliar spray of 0.025 % Zn as $ZnSO_4$; T_6: NPK + Foliar spray of 0.050 % Zn as $ZnSO_4$; T_7: NPK + Foliar spray of 0.100 % Zn as $ZnSO_4$; T_8: NPK + Foliar spray of 0.150 % Zn as $ZnSO_4$; T_9: NPK + Foliar spray of 0.010% Zn as zinc metalosate; T_{10}: NPK + Foliar spray of 0.025 % Zn as zinc metalosate; T_{11}: NPK + Foliar spray of 0.050 % Zn as zinc metalosate; T_{12}: NPK + Foliar spray of 0.10 % Zn as zinc metalosate; T_{13}: NPK + Foliar spray of 0.150% Zn as zinc metalosate; T_{14}: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA; T_{15}: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA; T_{16}: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA; T_{17}: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA; T_{18}: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA ; T_{19}: T_3+ Soil application of Zn as $ZnSO_4$; T_{20}: T_3+ Foliar application of 0.01 % Zn as $ZnSO_4$

as well as 0.010% (T_4: 887.93 g), 0.025% (T_5: 963.97 g), and 0.050% (T_6: 1095.63 g) through zinc sulphate did not significantly increase total fruit weight per shoot compared to the control (T_3: 1069.99 g). Among all treatments, the highest total fruit weight per shoot was recorded in T_{13} (1752.76 g), where zinc was applied at 0.150% as zinc metalosate, which was statistically on par with T_{18} (1677.48 g) receiving 0.150% zinc through Zn-EDTA. Treatments T_{12} (1497.34 g) and T_{11} (1276.60 g) were also comparable with T_{17} (1439.84 g) and T_{16} (1238.20 g), where zinc was applied at 0.10% and 0.050% through zinc metalosate and Zn-EDTA, respectively. These were further found to be at par with treatments receiving zinc sulphate at 0.150% (T_8: 1453.29 g) and 0.10% (T_7: 1270.30 g). The lowest total fruit weight per shoot (858.63 g) was observed in T_1, which received only the recommended dose of NPK fertilizers (Table 4).

Yield (kg plant^{-1}):

Among the different sources and levels of zinc, both zinc metalosate and Zn-EDTA significantly enhanced yield per plant at 0.050%, 0.10%, and 0.150% concentrations compared to zinc sulphate ($ZnSO_4$) applied at 0.10% and 0.150%, as well as the control treatment (T_3: NPK + FYM). The highest yield per plant was recorded in treatment T_{13} (27.38 kg plant^{-1}), where zinc was applied at 0.150% as zinc metalosate. This was statistically at par with treatment T_{18} (26.79 kg plant^{-1}), which received zinc at 0.150% through Zn-EDTA. Yields obtained in treatments T_{12} (24.64 kg plant^{-1}), T_{17} (24.26 kg plant^{-1}), and T_8 (24.01 kg plant^{-1}) were comparable with each other. The lowest yield per plant (17.53 kg plant^{-1}) was observed in treatment T_1, which received only the recommended dose of NPK fertilizers (Table 5).

Table 5: Effect of different sources and levels of zinc on yield of pomegranate.

Treatments	Yield (kg plant $^{-1}$)			Yield (t ha^{-1})		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	17.15	17.90	**17.53**	15.69	16.38	**16.04**
2	17.34	18.61	**17.98**	15.87	17.03	**16.45**
3	19.27	20.70	**19.98**	17.63	18.94	**18.29**
4	17.22	18.05	**17.63**	15.76	16.52	**16.14**
5	17.75	18.81	**18.28**	16.25	17.21	**16.73**
6	19.12	20.39	**19.75**	17.49	18.65	**18.07**
7	21.00	22.53	**21.77**	19.22	20.52	**19.87**
8	23.06	24.95	**24.01**	21.10	22.75	**21.93**
9	17.31	18.57	**17.94**	15.84	16.99	**16.42**
10	19.22	20.60	**19.91**	17.59	18.85	**18.22**
11	21.37	22.87	**22.12**	19.51	20.83	**20.17**
12	23.68	25.59	**24.64**	21.67	23.32	**22.50**
13	26.21	28.55	**27.38**	23.98	26.12	**25.05**
14	17.28	18.50	**17.89**	15.81	16.93	**16.37**
15	19.15	20.43	**19.79**	17.52	18.69	**18.11**
16	21.22	22.60	**21.91**	19.43	20.59	**20.01**
17	23.35	25.17	**24.26**	21.37	22.94	**22.16**
18	25.68	27.89	**26.79**	23.50	25.52	**24.51**
19	19.33	20.81	**20.07**	17.69	19.04	**18.37**
20	19.42	21.06	**20.24**	17.77	19.27	**18.52**
SEm ±	**0.44**	**0.49**	**0.47**	**0.37**	**0.45**	**0.41**
CD @ 5 %	**1.26**	**1.41**	**1.33**	**1.07**	**1.30**	**1.18**

T_1: NPK; T_2: NPK+ Soil application of Zn as $ZnSO_4$; T_3: NPK + FYM; T_4: NPK + Foliar spray of 0.010 % Zn as $ZnSO_4$; T_5: NPK + Foliar spray of 0.025 % Zn as $ZnSO_4$; T_6: NPK + Foliar spray of 0.050 % Zn as $ZnSO_4$; T_7: NPK + Foliar spray of 0.100 % Zn as $ZnSO_4$; T_8: NPK + Foliar spray of 0.150 % Zn as $ZnSO_4$; T_9: NPK + Foliar spray of 0.010% Zn as zinc metalosate; T_{10}: NPK + Foliar spray of 0.025 % Zn as zinc metalosate; T_{11}: NPK + Foliar spray of 0.050 % Zn as zinc metalosate; T_{12}: NPK + Foliar spray of 0.10 % Zn as zinc metalosate; T_{13}: NPK + Foliar spray of 0.150% Zn as zinc metalosate; T_{14}: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA; T_{15}: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA; T_{16}: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA; T_{17}: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA; T_{18}: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA ; T_{19}: T_3+ Soil application of Zn as $ZnSO_4$; T_{20}: T_3+ Foliar application of 0.01 % Zn as $ZnSO_4$

Yield (t ha^{-1}):

Foliar application of zinc at 0.150% through zinc metalosate (T_{13}) significantly increased pomegranate yield to 25.05 t ha^{-1} compared to other treatments; however, it was statistically at par with T_{18} (24.51 t ha^{-1}), where zinc was applied at the same concentration as Zn-EDTA.Treatments T_{12}, T_{17}, and T_8 recorded yields of 22.50, 22.16, and 21.93 t ha^{-1}, respectively, and were found to be comparable with each other. Soil application of zinc sulphate along with farmyard manure (T_{19}) resulted in a significantly higher yield (18.37 t ha^{-1}) than T_2 (16.45 t ha^{-1}), where zinc sulphate was applied without farmyard manure. The lowest yield (16.04 t ha^{-1}) was observed in treatment T_1, which received only the recommended dose of NPK fertilizers (Table 5).

The significant increase in the plant height, number of fruits per shoot, number of fruits/plants, total weight of fruit/shoot, yield/plant (kg/plant) and yield/hectare (t/ha) in T_{13} and T_{18} treatments might be due to application of zinc through chelated sources. Zinc metalosate, a liquid amino acid chelated zinc fertilizer, has small particle size and neutral charge, enabling easy penetration through leaf pores. Similarly, Zn-EDTA, being a chelated form, neutralizes the positive charge of zinc, facilitating its movement through the leaf cuticle. As a result, both sources effectively enhanced zinc availability and uptake by the plant. Zinc plays a vital role in plant metabolism, being involved in respiration, chlorophyll formation, and the synthesis of proteins and DNA. Its presence in chloroplasts improves the efficiency of physiological and biochemical processes, thereby promoting vegetative growth. The increase in plant height due to foliar zinc application may be attributed to enhanced photosynthesis and metabolic activities, which stimulate the production of metabolites responsible for cell division and elongation (Parmar *et al.*, 2014). Similar improvements in plant growth with zinc application have also been reported by

Table 6: Effect of different sources and levels of zinc on physical parameters of pomegranate fruit.

Treat-ments	Length of fruit (cm)			Breadth of fruit (cm)			Weight of fruit (g)		
	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean	Season I	Season II	Pooled mean
1	8.95	9.04	**9.00**	9.30	9.47	**9.39**	226.50	231.37	**228.93**
2	9.04	9.21	**9.13**	9.37	9.63	**9.50**	234.81	239.61	**237.21**
3	9.35	9.65	**9.50**	10.06	10.45	**10.26**	249.90	254.73	**252.32**
4	8.96	9.10	**9.03**	9.32	9.51	**9.42**	228.13	233.09	**230.61**
5	9.09	9.27	**9.18**	9.42	9.67	**9.55**	235.35	240.62	**237.99**
6	9.27	9.53	**9.40**	10.00	10.29	**10.15**	248.82	254.85	**251.84**
7	9.57	9.90	**9.74**	10.79	11.33	**11.06**	267.90	274.66	**271.28**
8	10.24	10.51	**10.38**	11.70	12.45	**12.08**	289.85	297.13	**293.49**
9	8.99	9.17	**9.08**	9.35	9.60	**9.48**	233.10	238.12	**235.61**
10	9.30	9.61	**9.45**	10.09	10.45	**10.27**	250.93	257.33	**254.13**
11	9.81	10.19	**10.00**	10.95	11.55	**11.25**	272.46	278.61	**275.54**
12	10.65	10.95	**10.80**	12.10	12.82	**12.46**	296.87	304.06	**300.47**
13	11.93	12.34	**12.14**	13.41	14.26	**13.84**	325.05	333.32	**329.19**
14	8.98	9.19	**9.09**	9.34	9.55	**9.45**	231.24	236.25	**233.75**
15	9.20	9.57	**9.39**	10.05	10.36	**10.21**	249.03	255.29	**252.16**
16	9.63	10.03	**9.83**	10.85	11.42	**11.14**	268.66	275.37	**272.02**
17	10.35	10.71	**10.53**	11.87	12.63	**12.25**	292.05	299.21	**295.63**
18	11.50	11.92	**11.71**	13.10	13.91	**13.51**	317.12	325.18	**321.15**
19	9.40	9.57	**9.49**	10.08	10.52	**10.30**	250.11	256.05	**253.08**
20	9.45	9.65	**9.55**	10.18	10.65	**10.42**	252.35	258.69	**255.52**
SEm ±	**0.64**	**0.75**	**0.65**	**0.18**	**0.20**	**0.19**	**4.66**	**4.89**	**4.34**
CD @ 5 %	**NS**	**NS**	**1.85**	**0.52**	**0.57**	**0.53**	**13.34**	**14.02**	**12.42**

T_1: NPK; T_2: NPK+ Soil application of Zn as $ZnSO_4$; T_3: NPK + FYM; T_4: NPK + Foliar spray of 0.010 % Zn as $ZnSO_4$; T_5: NPK + Foliar spray of 0.025 % Zn as $ZnSO_4$; T_6: NPK + Foliar spray of 0.050 % Zn as $ZnSO_4$; T_7: NPK + Foliar spray of 0.100 % Zn as $ZnSO_4$; T_8: NPK + Foliar spray of 0.150 % Zn as $ZnSO_4$; T_9: NPK + Foliar spray of 0.010% Zn as zinc metalosate; T_{10}: NPK + Foliar spray of 0.025 % Zn as zinc metalosate; T_{11}: NPK + Foliar spray of 0.050 % Zn as zinc metalosate; T_{12}: NPK + Foliar spray of 0.10 % Zn as zinc metalosate; T_{13}: NPK + Foliar spray of 0.150% Zn as zinc metalosate; T_{14}: NPK + Foliar spray of 0.010 % Zn as Zn-EDTA; T_{15}: NPK + Foliar spray of 0.025 % Zn as Zn-EDTA; T_{16}: NPK + Foliar spray of 0.050 % Zn as Zn-EDTA; T_{17}: NPK + Foliar spray of 0.10 % Zn as Zn-EDTA; T_{18}: NPK + Foliar spray of 0.150 % Zn as Zn-EDTA ; T_{19}: T_3+ Soil application of Zn as $ZnSO_4$; T_{20}: T_3+ Foliar application of 0.01 % Zn as $ZnSO_4$

Razzaq *et al.*, (2013) in Kinnow mandarin, Banik and Sen (1997) in mango, and Arshad and Ali (2016) in guava. Zinc being involved in balancing of auxin in plant and also regulates the fruits drop or retention in plants by delaying the formation of abscission layer during early stages of fruit development. Zinc helps in hormonal metabolism, cell division, cell expansion, higher synthesis of metabolites, regulating the semi permeability of cell wall for enhanced mobilization of food and minerals from other parts of the plant towards developing fruits, resulting increase in fruit weight and yield. Similar results were observed in pomegranate by Khorsandi *et al.*, (2009), Mohamad *et al.*, (2011), Hasani *et al.*, (2012), Mirazapour and Khoshgoftarmanesh (2013), Obaid and Hadethi (2013) and Hamouda *et al.*, (2016).

Effect of different sources and levels of zinc on physical parameters of pomegranate fruit (Table 6)

Length of fruit (cm):

Fruit length varied from 9.0 to 12.14 cm under different sources and levels of zinc. Zinc sulphate did not have a significant effect on increasing fruit length, whereas zinc metalosate and Zn-EDTA at higher concentrations (0.150%) significantly enhanced fruit length. The highest values were recorded in T_{13} (12.14 cm) and T_{18} (11.71 cm), compared to the control (T_3: 9.50 cm). The lowest fruit length (9.0 cm) was observed in T_1, which did not receive any zinc application.

Breadth of fruit (cm):

Fruit breadth in the control treatment (T_3) was 10.26 cm, which increased significantly to 13.84 cm in treatment T_{13} due to foliar application of zinc at 0.150% as zinc metalosate along with the recommended dose of NPK. However, the fruit breadth in T_{13} was statistically at par with T_{18} (13.51 cm). The increase in fruit breadth observed in T_{12} (zinc @ 0.10% as zinc metalosate) was comparable with T_{17} (12.25 cm) and T_8 (12.08 cm), where zinc was applied at 0.10% and 0.150% as Zn-EDTA and $ZnSO_4$, respectively. The lowest fruit breadth (9.39 cm) was recorded in T_1, which received only the recommended dose of NPK fertilizers.

Weight of fruit (g):

Application of zinc at 0.150% significantly increased fruit weight compared to other zinc levels, while lower concentrations (0.010% and 0.025%) were not effective over the control (T_3). The highest fruit weight (329.19 g) was recorded in T_{13}, where zinc was applied at 0.150% as zinc metalosate, and this was statistically at par with T_{18} (321.15 g), which received zinc at the same concentration through Zn-EDTA.Fruit weight recorded in T_{12} (300.47 g) and T_{11} (275.54 g) was comparable with T_{17} (295.63 g), T_8 (293.49 g), T_{16} (272.02 g), and T_7 (271.28 g). Soil application of zinc sulphate along with FYM (T_{19}) resulted in a significantly higher fruit weight (253.08 g) compared to zinc sulphate alone (T_2: 237.21 g). The lowest fruit weight (228.93 g) was observed in T_1, which received only the recommended dose of NPK fertilizers.

Improvement in physical parameters such as fruit length, breadth, and weight in pomegranate can be attributed to the role of zinc in promoting cell division, cell enlargement, and increasing the volume of intercellular spaces in mesocarp cells. Zinc application may also enhance auxin levels in fruits, which facilitates better development of fruit components, as fruit growth is directly associated with auxin content. Additionally, zinc regulates cell wall permeability, enabling greater movement of water into the fruits, thereby contributing to increased fruit length and breadth (Wali *et al*., 2005). The increase in fruit weight may be due to the strengthening of the middle lamella and cell wall, which improves the translocation of solutes to the fruits. This results in greater fruit size, both in terms of length and diameter, ultimately leading to higher individual fruit weight. A positive and significant correlation was observed among fruit length, breadth, and weight. These findings are in agreement with earlier reports by Razzaq *et al*., (2013), Girirajjat and Kacha (2014), Kaur *et al*., (2015), Singh *et al*., (2015) and Pawar (2016).

Conclusion

Foliar application of zinc at 0.150% through zinc metalosate and Zn-EDTA along with recommended dose of NPK and FYM significantly enhanced growth, yield, and physical parameters of pomegranate. It resulted in increased plant height, number of fruits per shoot, total fruit weight per shoot, number of fruits per plant, yield per plant (kg $plant^{-1}$), yield per hectare (t ha^{-1}), as well as improved fruit length, breadth, and weight compared to other zinc sources and levels.

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