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Nutritional Yield and Economic Responses of Sunflower (*Helianthus annuus* L.) to Zinc Sources and Levels in Alfisols

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Abstract The field experiment was carried out during *kharif* 2014 in Alfisols with sunflower (*Helianthus annuus* L.) as a test crop in Alfisols. The experiment was laid out in randomized block design with three sources ($ZnSO_4.H_2O$, $ZnSO_4.7H_2O$ and Zn-EDTA) and levels (10, 15 and 20 kg ha^{-1}) of zinc. The results indicated that application of 20 kg $ZnSO_4.H_2O$ ha^{-1} with 90:60:30 kg NPK ha^{-1} recorded higher grain yield (1680 kg ha^{-1}), net return (Rs 29,064) and benefit cost ratio (1.85) over the control. Soil available nitrogen, phosphorus, potassium, sulfur and zinc (chemical properties) from initial to harvest in all treatments buildup revealed that there was an increased nutrient status due to application of various sources and levels of zinc. There was a buildup of DTPA-Zn in the post harvest soil due to application of zinc sulfate, irrespective of levels. Based on the results on investigation it can be concluded that among the sources, $ZnSO_4.H_2O$ found to be a better source due to its solubility in soil solution compared to the other sources.

Keywords Sunflower, Zinc application, Alfisol, Available soil nutrients, Economics.

Introduction

The scenario of oilseeds in India has undergone significant change since inception of Technology Mission on Oilseeds (TMO) which created conditions that could harness best of production, processing and storage technologies [1]. They occupy about 13.5% of the gross cropped area. India also has a prominent position in the global oilseeds scenario covering 19% of total area and nine percent of production.

Sunflower is cultivated on a commercial scale from 1980 onwards. Presently, it is estimated to be grown on an area of 1.81 M ha with a production of 1.16 M t. and productivity of 641 kg ha^{-1}. Andhra Pradesh is one of the major states in the country growing sunflower on an area of 4.2 lakh hectare producing 3.3 lakh tones seed. The productivity is 786 kg ha^{-1} [2].

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Table 1. Cropping history of the experimental site.

Sl. No.	Year	Season	Crop
1	2012–2013	*Kharif*	Castor
		Rabi	Sesame
		Summer	Fallow
2	2013–2014	*Kharif*	Sunflower (Experimental)

Oil seeds play an important role in Indian agriculture as food and an industrial commodity. India is the largest producer of oilseeds in the world in terms of output and in terms of area. Among the oilseed crops, sunflower (*Helianthus annuus* L.), is an all-season crop. In India, it is cultivated over an area of about 2.4 million hectares with a production of 1.44 million tonnes [3]. It is a crop with short duration and photo-insensitivity, suits well to rainy season [4]. Critically analyzed the major constraints for low productivity of sunflower in India [5].

In soils of various districts of the Indian states, deficiency of Zn is most widespread in Alfisols. Nearly 50% of the soil samples analyzed were found to be deficient in Zn. The extent of deficiency of Zn was by 49.4% in Andhra Pradesh, 86% in Maharashtra, 72.8% in Karnataka, 60.5% in Haryana, 58.4% in Tamil Nadu, 57% in Meghalaya, 54% in Bihar and Orissa, and 46.1% in Punjab [6]. Incidentally these are the states which contribute more than 82% of the total oilseed production from the 80% of total oilseed cultivated area [5]. In the coming years, there will be intensive cultivation of oilseeds and other crops to meet the growing food demands of people and industry. This will lead to exacerbated deficiency of Zn. Such an alarming signal of Zn deficiency has made its application vital with macronutrients. Hence, an attempt was made in the present investigation to find out an optimum dose and source of zinc for the sunflower hybrid DRSH-1 by studying yield attributes and seed yield [7].

Among the micronutrients, zinc plays a vital role in growth and development of plant. Zinc is required for nitrogen metabolism, photosynthesis and also participates in many other metabolic activities of plant life. Zinc controls the auxin content and regulators reproduction process in plants. Zinc deficiency severely affects growth and yield of oilseed crop. Zn deficiency is common in semi-arid soils where sunflower cultivation is in practice by the farmers [5, 8]. Low solubility of Zn in soils rather than low total amount of Zn is the major reason for the widespread occurrence of Zn deficiency problem in crop plants.

Zinc sulfate is the most commonly used source around the world and is available in both the crystalline monohydrate and heptahydrate form. Synthetic chelates, which are special types of complexed micronutrients generally formed by combining a chelating agent such as Ethylene Diamine Tetra-acetic Acid (EDTA) with a metal ion and the stability of the metal-chelate complex determines the availability of the metal to plants. Natural organic complexes include those, which are manufactured by reacting zinc salts with citrates or with organic by-products from paper pulp manufacture such as lignosulfonates, phenols and polyflavonoids. They are generally less expensive than synthetic chelates such as Zn-EDTA, but are generally much less effective [9].

Sulfur is also increasingly being recognized as the fourth major plant matrient next to nitrogen, phosphorus and potassium [10]. It helps in the synthesis of cystein, methionine, chlorophyll, vitamins (B), biotin and thiamine), metabolism of carbohydrates, increasing oil and protein contents as well as is associated with growth and metabolism, especially affecting the protolytic enzymes [11].

Zinc is an essential micronutrient for higher plants especially oil crops where it is required for the activity of various types of enzymes (dehydrogenases, RNA and DNA polymerases), carbohydrate metabolism and protein synthesis. Zinc also plays an important role in the production of biomass [12]. Furthermore, zinc may be required for chlorophyll production, pollen function and fertilization [13]. Zinc deficiency also affects carbohydrate metabolism, damages pollen structure and decreases the yield.

Materials and Methods

The experiment was carried out at Indian Institute of

Table 2. Effect of different sources and levels of zinc on soil available N, P, K, S (kg ha^{-1}) and Zn (mg kg^{-1}) at 60 DAS and 90 DAS.

	Treatments	60 DAS					90 DAS				
		N	P	K	S	Zn	N	P	K	S	Zn
T_1	Control (RDF-90-60-30)	184.3	21.8	207.7	23.6	1.1	158.7	12.5	184.5	17.8	0.18
T_2	RDF + $ZnSO_4.7H_2O$ @ 10 kg ha^{-1}	214.8	28.9	241.9	34.0	2.6	193.7	21.0	203.4	27.0	0.81
T_3	RDF + $ZnSO_4.7H_2O$ @ 15 kg ha^{-1}	211.7	28.7	221.1	32.7	2.5	177.4	20.8	202.1	26.5	0.72
T_4	RDF + $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}	206.1	27.9	212.8	30.8	2.3	174.5	19.9	199.3	25.3	0.68
T_5	RDF + $ZnSO_4$. H_2O @ 10 kg ha^{-1}	236.4	25.5	254.1	31.8	2.9	200.3	24.1	221.6	34.3	1.21
T_6	RDF + $ZnSO_4$. H_2O @ 15 kg ha^{-1}	228.8	24.6	244.9	31.7	2.6	196.7	23.5	217.4	31.3	0.99
T_7	RDF + $ZnSO_4$. H_2O @ 20 kg ha^{-1}	219.1	22.8	243.1	30.2	2.4	190.0	22.5	211.9	28.9	0.86
T_8	RDF + Zn-EDTA @ 10 kg ha^{-1}	203.5	27.8	291.8	29.2	2.3	174.7	18.9	194.7	25.0	0.67
T_9	RDF + Zn-EDTA @ 15 kg ha^{-1}	200.2	24.8	274.4	29.1	2.1	166.7	17.5	190.5	24.1	0.50
T_{10}	RDF + Zn-EDTA @ 20 kg ha^{-1}	192.9	23.6	266.9	24.7	1.9	164.6	16.8	188.8	21.6	0.47
	SEm ±	9.853	0.8	10.94	1.43	0.47	7.028	0.7	11.66	2.13	0.04
	CD (p=0.05%)	NS	2.4	NS	4.28	1.41	NS	NS	NS	6.37	0.32

Oilseed Research, Rajendranagar, Hyderabad during *kharif* 2014. The experimental field was sandy loam in texture, slightly alkaline in reaction (8.3) and non saline (0.082 dS m^{-1}). The organic carbon (0.26%), available nitrogen (150.6 kg ha^{-1}) and available phosphorus (9.56 kg ha^{-1}) were low and available potassium (193.9 kg ha^{-1}), available sulfur (25.22 kg ha^{-1}) were medium while DTPA extractable Zn (0.48 mg kg^{-1}) was deficient. In general the experimental field used for present study has poor fertility status. The experiment was laid out in randomized block design with ten treatments each replicated thrice. The treatments consist of T_1 (control (90-60-30), T_2 [RDF + $ZnSO_4.7H_2O$ (21% Zn) @ 10 kg ha^{-1}], T_3 (RDF + $ZnSO_4.7H_2O$ @ 15 kg ha^{-1}), T_4 (RDF + $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}), T_5 [RDF + $ZnSO_4.H_2O$ (33% Zn) @ 10 kg ha^{-1}], T_6 (RDF + $ZnSO_4.H_2O$ @ 15 kg ha^{-1}), T_7 (RDF + $ZnSO_4.H_2O$ @ 20 kg ha^{-1}), T_8 [RDF + Zn-EDTA (12% Zn) @ 10 kg ha^{-1}), T_9 [RDF + Zn-EDTA @ 15 kg ha^{-1}) and T_{10} [RDF + Zn-EDTA @ 20 kg ha^{-1}). The sunflower hybrid DRSH-1 was sown in rows 60 cm apart with 30 cm plant to plant distance. The crop was kept free of weeds by manual weeding (Table 1).

The soil samples were collected from experimental site from 0–30 cm depth at 60 and after harvest of sunflower crop and sample was dried under shade, gently powdered to pass through a 2 mm sieve and soil samples were subjected to chemical analysis as per the standard procedures.

The price of the inputs and the produce prevailed during the experimental period was considered for working out the cost of cultivation and gross income. Gross returns obtained from the income realized from the sale of seed and stalk of sunflower based on current market rate. Net returns were obtained by subtracting total cost of production from the gross returns. Net returns (Rs ha^{-1})=Gross returns (Rs ha^{-1}) – Cost of cultivation (Rs ha^{-1})

B:C ratio was obtained from the ratio between gross returns and cost of cultivation.

$$\text{B:C ratio} = \frac{\text{Gross returns (Rs ha}^{-1}\text{)}}{\text{Cost of cultivation (Rs ha}^{-1}\text{)}}$$

Results and Discussion

Effect on available nutrients in soil

Data on physico-chemical properties of soil at 60 DAS and 90 DAS is presented in Table 2. Soil physico-chemical properties like soil reaction; electrical conductivity at 60 DAS and at 90 DAS (at harvest) did not show any significant change with reference to zinc treatments.

Table 3. Effect of sources and levels of zinc on yield (kg ha^{-1}) of sunflower.

	Treatments	Seed yield
T_1	Control (RDF-90-60-30)	1122
T_2	RDF + $ZnSO_4.7H_2O$ @ 10 kg ha^{-1})	1319
T_3	RDF + $ZnSO_4.7H_2O$ @ 15 kg ha^{-1})	1365
T_4	RDF + $ZnSO_4.7H_2O$ @ 20 kg ha^{-1})	1377
T_5	RDF + $ZnSO_4.H_2O$ @ 10 kg ha^{-1})	1395
T_6	RDF + $ZnSO_4$. H_2O @ 15 kg ha^{-1})	1453
T_7	RDF + $ZnSO_4$. H_2O @ 20 kg ha^{-1})	1680
T_8	RDF + Zn-EDTA @ 10 kg ha^{-1})	1168
T_9	RDF + Zn-EDTA @ 15 kg ha^{-1})	1236
T_{10}	RDF + Zn-EDTA @ 20 kg ha^{-1})	1283
	SEm ±	71.9
	CD (*p*=0.05)	215.2

Table 4. Treatment wise cost of cultivation (Rs ha^{-1}), gross returns (Rs ha^{-1}), net returns (Rs ha^{-1}) and B:C ratio of sunflower hybrid (DRSH-1) as influenced by different sources and levels of zinc.

Treat-ments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
T_1	26151	44751.2	18600	1.71
T_2	32520	52168.8	19649	1.6
T_3	35704	54029.1	18325	1.51
T_4	38889	54425.8	15537	1.4
T_5	30183	55086.3	24903	1.83
T_6	32199	56962.5	24764	1.77
T_7	34215	63279.2	29064	1.85
T_8	28951	46554.3	17603	1.61
T_9	30351	49109.8	18759	1.62
T_{10}	31751	51481.4	19730	1.62

Post-harvest soil status of available N, P and K were not significantly influenced by different sources and levels of zinc. However, there was a marginal buildup of available zinc in the post harvest soil sample. The results showed that there was no significant difference in available N, P, K and S in soil at 60 DAS and 90 DAS. The available nitrogen in the soil after crop harvest was not much affected by various treatments. At 60 DAS and post harvest among the zinc treatments highest available N content (236.4, 200.3 kg ha^{-1}) was observed in the treatment T_5 (RDF + $ZnSO_4.H_2O$ @ 10 kg ha^{-1}) and the lowest (184.3, 158.7 kg ha^{-1}) was observed in the treatment T_1 (Control) respectively. The data on available phosphorus was affected by application of different doses and levels of zinc (Table 2). It was noticed that available P_2O_5 of soil was significantly influenced by different levels of zinc. The highest available phosphorus was recorded at 60 DAS under treatment T_2 (28.9 kg ha^{-1}) and lowest in control (21.8 kg ha^{-1}). Similarly at 90 DAS significant influence on available P. The highest available P was recorded under T_5 (24.1 kg ha^{-1}) and the lowest was recorded at control (12.5 kg ha^{-1}) at 90 DAS. The decrease in available phosphorus with higher dose of zinc might be due to antagonistic effect between P and Zn.

Soil DTPA extractable zinc varied from 1.1 to 2.9 mg kg^{-1} at 60 DAS of sunflower crop. The highest soil available zinc (2.9 mg kg^{-1}) was recorded by T_5 (RDF + $ZnSO_4.H_2O$ @ 10 kg ha^{-1}) and the lowest (1.1 mg kg^{-1}) was recorded by the treatment T_1 (control). There was an increase in available zinc content in the soil by 163% in T_5 over the control (T_1). At post-harvest it varied from 1.21 to 0.18 mg kg^{-1}. The significantly highest soil extractable zinc (1.21 mg kg^{-1}) was recorded by T_5 (RDF + $ZnSO_4.H_2O$ @ 10 kg ha^{-1}), followed by T_6 (RDF + $ZnSO_4.H_2O$ @ 15 kg ha^{-1}) with (0.99 mg kg^{-1} and the lowest (0.18 mg kg^{-1}) was recorded by T_1 (control).

Singh et al. [14] reported that constant and positive effect of zinc application on its content and uptake by mustard during study period may be due to increase in concentration of zinc in soil solution with its application. The results achieved in this study are similar to the Singh and Mann [15] reported that application of Zn significantly increased the available DTPA-Zn during both the years. Available Zn status at harvest was 0.36 to 0.38 mg kg^{-1} in the control plots and 0.77 to 0.87 mg kg^{-1} under 7.5 kg Zn ha^{-1} soil applications. Zinc had significant variation in relation to Zn and S uptake by soybean. Application of zinc on its uptake in grains did not have obvious effect. However, on an average, zinc uptake by plants increased at different level of zinc in comparison to control [16].

However, among the sources, $ZnSO_4.H_2O$ found to be a better source due to its solubility in soil solu-

Table 5. Effect of different sources and levels of zinc on physico-chemical properties of soil.

	Treatments	60 DAS pH	60 DAS EC (dS m^{-1})	60 DAS OC (%)	90 DAS pH	90 DAS EC (dS m^{-1})	90 DAS OC (%)
T_1	Control (RDF-90-60-30)	8.2	0.08	0.28	8.2	0.07	0.24
T_2	RDF + $ZnSO_4.7H_2O$ @ 10 kg ha^{-1}	8.3	0.07	0.32	8.4	0.07	0.28
T_3	RDF + $ZnSO_4.7H_2O$ @ 15 kg ha^{-1}	8.3	0.07	0.34	8.3	0.08	0.28
T_4	RDF + $ZnSO_4.7H_2O$ @ 20 kg ha^{-1}	8.2	0.08	0.38	8.1	0.09	0.31
T_5	RDF + $ZnSO_4$. H_2O @ 10 kg ha^{-1}	8.4	0.07	0.34	8.3	0.06	0.28
T_6	RDF + $ZnSO_4$. H_2O @ 15 kg ha^{-1}	8.3	0.08	0.34	8.2	0.08	0.29
T_7	RDF + $ZnSO_4$. H_2O @ 20 kg ha^{-1}	8.3	0.08	0.36	8.0	0.09	0.34
T_8	RDF + Zn-EDTA @ 10 kg ha^{-1}	8.4	0.07	0.34	8.4	0.07	0.26
T_9	RDF + Zn-EDTA @ 15 kg ha^{-1}	8.3	0.07	0.34	8.3	0.09	0.27
T_{10}	RDF + Zn-EDTA @ 20 kg ha^{-1}	8.2	0.08	0.37	8.1	0.09	0.31
	SEm ±	0.09	0.006	0.022	0.11	0.009	0.025
	CD (p=0.05)	NS	NS	NS	NS	NS	NS

tion compared to the other sources. Chelated-Zn source might have complexed with the soil organic matter thereby the availability to the crop might have been limited.

Effect on yield

The results revealed that there was significant increase in seed yield of sunflower with increasing levels of zinc (Table 3). Among various sources, RDF+$ZnSO_4.H_2O$ @ 20 kg ha^{-1} recorded significantly highest seed yield as compared to control. Seed yield was lowest at control (1122.0 kg ha^{-1}) and highest at T_7 (1680.0) which received $ZnSO_4.H_2O$ @ 20 kg ha^{-1} along with recommended dose of N, P, K in sunflower. On an average, the percent increase in seed yield was 49% in the treatment T_7 over the control T_1. Seed yield is the function of several growth parameters (plant height, leaf area index and dry matter accumulation) yield attributing characters viz., head diameter, number of filled seeds, test weight and yield $plant^{-1}$. Among different levels and sources (namely $ZnSO_4.H_2O$, $ZnSO_4.7H_2O$ and Zn-EDTA), the $ZnSO_4.H_2O$ @ 20 kg ha^{-1} has shown (Table 3) better influence on seed yield.

Greater head diameter, higher number of filled seeds $head^{-1}$ and test weight due to adequate supply of recommended dose of fertilizers along with zinc application had positively reflected in higher seed yield. Head diameter is the most important attributing character, which improves the seed yield by providing maximum number of florets for higher seed set. The cumulative effect of all these growth and yield components were reflected on seed yield Mirzapour and Khoshgoftar [17] found that the increase in seed yield of sunflower with the application of 10 and 20 kg ha^{-1} zinc. Zinc deficiency known to reduce net photosynthesis, intermodal length of stem, increasing chlorosis and necrotic spots in the leaves and severely reduce seed yield [18].

Riley et al. [19] revealed that Zn-treated plants exhibited a significant increase in yield components compared to control. It is evident that this element plays important role in plants. The increase in yield induced by Zn treatments will markedly affect plant growth and development. The increased in yield attributes and yield of sunflower due to zinc may be attributed basically to the reason that Zn shows beneficial effect on chlorophyll content and so it indirectly affect the photosynthesis and reproduction.

A significant increase in seed and stover yield of mustard up to 5.0 kg Zn ha^{-1} application was reported the increase in yield might be due to role of zinc in biosynthesis of indole acetic acid and especially due to its role in initiation of primordia for reproductive parts and partitioning of photosynthates towards them, which resulted in better flowering and fruiting.

The findings of present investigation are supported by [20, 21]. In the present study, higher seed yield recorded in $ZnSO_4$. H_2O could be due to the better utilization of bioavailable Zn from this source compared to the other source.

Effect on economics

The present study revealed that among the different treatments maximum gross (Rs 63279 ha^{-1}) returns were obtained with the treatment T_7 (RDF + $ZnSO_4$. H_2O @ 20 kg ha^{-1}). While the lowest gross returns (Rs 44751 ha^{-1}) were recorded from the treatment (T_1).

The efficiency of a treatment is finally decided in terms of the economics (benefit cost ratio) of that treatment (Table 4). Among the different treatments, T_7 (RDF + $ZnSO_4$. H_2O @ 20 kg ha^{-1}) recorded higher net returns (Rs 29064 ha^{-1}) over rest of the treatments. While T_1 recorded lowest net returns (Rs 18600 ha^{-1}). Similar trend was reflected in terms of B:C ratio (T_7) recorded higher B:C ratio (1.85) over rest of the treatments, while T_1 recorded lowest B:C ratio (1.71). Among the different zinc sources, $ZnSO_4$. H_2O in widely used by the farmer and also easily available at cheaper rate compared to the other sources (Zn-EDTA and $ZnSO_4.7H_2O$).

Higher seed yield under treatment (T_7) consisting RDF + $ZnSO_4.H_2O$ @ 20 kg ha^{-1} had resulted in higher net returns and B:C ratio over rest of the treatments. While lower net returns and B:C ratio manifested with T_1 was due to lower seed yield and in comparison to rest of the treatments (Table 5).

Conclusion

Highest seed yield (1680 kg ha^{-1}), net returns (Rs 29.064) and benefit cost ratio (1.85) was noticed in $ZnSO_4.H_2O$ @ 20 kg ha^{-1}. Thus it can be concluded that in Alfisols having poor fertility status particularly low in available Zn, highest sunflower seed yield and quality, inturn gross returns, net returns and benefit cost ratio can be obtained by applying recommended dose of NPK with combination of $ZnSO_4.H_2O$ @ 20 kg ha^{-1}. However, among the sources, $ZnSO_4$. H_2O found to be a better source due to its solubility in soil solution compared to the other sources. Chelated-Zn source might have complexed with the soil organic matter thereby the availability to the crop might have been limited.

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