

Original Research Article

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Effect of Soil and Foliar Application of Zinc on Growth and Yield of Greengram (*Vigna radiate* L.)

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ABSTRACT

A field experiment was conducted to study the Response of greengram to soil and foliar application of zinc in southern dry zone of Karnataka during early kharif 2018 at Junjanahally, Hassan. Experiments consist of nine treatments replicated thrice with RCBD. Results revealed that significantly higher growth and yield parameters such as plant height(71.93 cm) number of branches per plant(4.37), number of effective nodules per plant(28.07) dry matter production per plant (27.07g), pod length (13.60 cm) number of pods per plant(24.40), number of seeds per pod (13.40), pod weight per plant (29.73g), seed yield (1022.99kg/ha) and haulm yield (2544.93kg/ha) were recorded with T9 (soil application of zinc sulphate @ 10 kg/ha + foliar spray of zinc EDTA at 1.0 percent along with NPK and FYM). The available nitrogen, phosphorus and potassium content of soil were non significant however higher nitrogen and potassium recorded (239.80& 177.10 kg/ha) in the treatment T1(NPK+FYM) and lower nitrogen and potassium recorded (232.70 &171.40 kg/ha)in T9 (T3 + FSZn EDTA @1.0%). Higher phosphorus recorded in T9 (44.70 kg/ha). As regard to DTPA extractable micronutrients in soil , low iron (7.69 mg/kg),copper (0.369ppm),manganese (8.16 ppm) and Boron (0.35 mg/kg) content in soil was recorded in T9 (T3+ FS of Zn EDTA).Application of zinc increased carbonate bound zinc (3.14mg/kg), , organic bound zinc (1.73 mg/kg) and Fe and Al oxide bound zinc (2.84 mg/kg) was recorded in T3 (T1+ SA of ZnSO₄ @10 kg/ha) over with NPK+ FYM. The higher total zinc was observed in the treatment T9 (130.42 mg/kg) which received T3+ FS of Zn EDTA@1.0 percent followed by treatment T7(135.32 mg/kg) and lowest Zn content was recorded (130.42 mg/kg) in the treatment T1(NPK+FYM).

Keywords

Zinc sulphate, Zn
EDTA, Foliar spray

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Introduction

Pulses play a pivotal role in nutritional security. considering this Food and Agriculture Organization (FAO) has marked year 2016 as international year of pulses to show-cause the importance of pulses in human and animal nutrition. Pulses are

importance sources of protein, vitamin and minerals. Important pulses which grown in India are greengram, chickpea pigeon pea horse gram, cowpea and rice bean. It is asserted that in India pulse are cultivated on an area of 29.36 mha with a production and productivity of 24.51 mt and 835 kg per hectare (Anon., 2018). Low productivity of of

these pulses ascribed to the conditions under which these are grown. In general pulses grown in rainfed area in marginal soils under residual moisture conditions and most importantly without or merger fertilizer input.

Green gram known as Mung or Golden gram is native to Indian continent. Apart from India it is also grown in China, Thailand, Indonesia, Burma, Bangladesh, Laos and Cambodia and also in hot and dry regions of southern Europe and southern united states. The favourable conditions for its better growth and development are warm humid climate with an optimum temperature range of 25⁰ to 35⁰ C with moderate rains of 80-100 cm. Normally it is sown during April to June as high temperature and low humidity keeps insects and diseases infestations at below threshold level(Anon,2017a). In India it is grown on an area of 43.05 lakh hectare with annual production of 20.70 lakh tonne and productivity of 481 kgper hectare (Anno., 2017b). Greengram contains 25 percent protein, 1.3 percent fat and 57 percent carbohydrate. Green gram is also rich source of calcium (68 mg/100gseed), phosphorus (300g/100g seed) and Iron (7 mg/ 100 gseed). It is one of the main source of protein and certain essential amino acids like tryptophan and lysine in vegetarian diets. It also a rich source of energy and provides 334 kilocalories of energy (Srivastava and Ali, 2004). Wide spread deficiency of micronutrient has become major constraint for achieving higher genetic potential yield of greengram along with quality of crop. Among the micronutrients the deficiency of Zinc and boron has become wide spread in recent years all over the country. In India next to Nitrogen, phosphorus, potassium and sulphur 5th important yield limiting nutrient is zinc which accounts for 48 percent of Indian soils. Hence, an investigation entitled “Response of greengram (*Vigna radiata* L.) to soil and foliar application of zinc in Southern Dry Zone of Karnataka” was carried out

Materials and Methods

A field experiment was conducted during early *Kharif* 2018 to study the “Response of greengram (*Vigna radiata* L.) to soil and foliar application of zinc in Southern Dry Zone of Karnataka” at farmers field, Junjanahalli, Hassan, Karnataka. The soil was sandy loam in texture with 78.10, 4.90 and 17.00 per cent sand, silt and clay, respectively. The soil was slightly alkaline in pH (8.0) reaction and normal in soluble salts (0.24 dS m⁻¹). The soil was low in organic carbon (4.8 g kg⁻¹) content and medium in available nitrogen (298 kg ha⁻¹), available P₂O₅ (38.5 kg ha⁻¹), available K₂O (189 kg ha⁻¹) and low in sulphur (9.1mg kg⁻¹). Exchangeable calcium and magnesium content of soil was 3.6 and 1.7 cmol kg⁻¹, respectively. The soil selected was deficient in zinc with zinc content of 0.52 mg kg⁻¹ and the DTPA extractable micronutrient content *viz.*, iron, copper, manganese and hot water soluble boron were 8.65, 0.42, 8.93 and 0.38 mg kg⁻¹, respectively. Experiment was laid out during early *Kharif* 2018 in Randomized Complete Block Design. There are nine treatments replicated thrice. The size of each plot was 5.1 m x 2 m (gross). Treatments were distributed randomly in the plots within the blocks (Table 1).

The treatment details of the research are as follows:

T1: NPK + FYM T2: T₁+ SA of ZnSO₄. 7H₂O @ 5 kg ha⁻¹ T3: T₁+ SA of ZnSO₄. 7H₂O @ 10 kg ha⁻¹
T4: T₁+ FS of Zn EDTA @ 0.50 % T5: T₁+ FS of Zn EDTA @ 1.00 %
T6: T₂+ FS of Zn EDTA @ 0.50 % T7: T₃+ FS of Zn EDTA @ 0.50 %
T8: T₂+ FS of Zn EDTA @ 1.00 % T9: T₃+ FS of Zn EDTA @ 1.00 %
NPK: 12.5:25:25 N: P₂O₅:K₂O kg ha⁻¹ FYM: Farm yard manure. SA: Soil application. FS: Foliar spray at 35 DAS.

Zn EDTA

Zinc Ethylene diamine tetra acetic acid. Greengram variety BGS-9 was grown as a test crop.

Fertilizer application

The calculated quantity of urea, diammonium phosphate (DAP) and murate of potash (MOP) i.e. 5.89: 54.34: 41.66 kg ha⁻¹, respectively was used to supply N, P, K respectively as per the treatments. The fertilizers were applied at the time of sowing as basal.

All the fertilizers were applied in line opened 4 cm away from the seed row and mixed well with soil. Soil application of zinc was took at the time of sowing and foliar spray of zinc EDTA at 35 DAS. Greengram seeds were inoculated with rhizobium inoculum before sowing and sown with spacing of 30 cm X 10 cm.

Biometric observations on growth parameters like plant height, number of leaves per plant, leaf area, dry matter production, Number of nodules and effective nodules. Yield attributing parameters like number of pods per plant, number of seeds per plant, pod length, pod weight and test weight were recorded. Soil and plant samples were analysed for major (NPK) and micronutrient (Cu Zn Fe Mn) using standard procedure prescribed by Jackson (1973) and Lindsay and Norwel (1978).

Estimation of total zinc in soils is described by Sridhar and Jackson (1974). The concentration of zinc in the above solutions was determined by atomic absorption spectrophotometer under suitable measuring conditions (Page *et al.*, 1982). Estimation of Fractions of zinc in soils defined as given below (Ma and Uren, 1995).

Results and Discussion

Results of experiment revealed that the growth parameters like plant height (70.27 cm) and drymatter production (27.07g) was higher in treatments receiving soil application of zinc sulphate @ 10 kg per hectare and foliar application of 1% Zn EDTA along with NPK+ FYM which was on par with T3(NPK+FYM+SA of Zn and FS of ZnEDTA0.5%). Lower plant height (60.73cm) and dry matter production was recorded in T1(NPK+FYM applied).

The higher plant height and dry matter production was attributed to sufficient supply of zinc through foliar spray and soil application which influenced on growth and development of plant. Similar results were also recorded by Akay (2011).

Significantly higher pod length(13.60 cm), number of pods plant⁻¹ (24.40), number of seeds pod⁻¹(13.40), pod weight per plant⁻¹(29.73 g) and test weight (5.58g) were obtained in treatment T₉ with soil application of zinc sulphate at 10 kg ha⁻¹+ foliar spray of zinc EDTA at 1.00 % along with NPK and FYM. Lower pod length (11.53cm), number of pods per plant, pod weight and test weight recorded in T1 (NPK + FYM).

The positive effect of zinc on growth character might be due to its direct influence on synthesis of tryptophan, a precursor for production of growth hormone i.e. auxin. Auxin has key role in cell elongation process which in turn helps in plant growth and development (Krishna, 1995) (Table 2 and 3).

Seed yield (kg ha⁻¹)

Significantly higher seed yield was obtained with the application of T₉ (T₃+ FS of Zn EDTA @ 1.00 %) (1022.19 kg ha⁻¹) which was significantly superior over the treatments

T₁ (805.51 kg ha⁻¹), T₂ (938.14 kg ha⁻¹), T₄ (879.51 kg ha⁻¹), T₅ (905.84 kg ha⁻¹) and T₆ (943.89 kg ha⁻¹) and it was on par with T₇ (982.65 kg ha⁻¹), T₈ (968.50 kg ha⁻¹), and T₃ (973.00 kg ha⁻¹).

Haulm yield (kg ha⁻¹)

The effect of soil and foliar application of zinc on haulm yield is presented in Table 4. Significantly higher haulm yield was obtained with the application of T₉ (T₃+ FS of Zn EDTA @ 1.00 %) (2544.93 kg ha⁻¹) which was on par with T₃ (2453.43 kg ha⁻¹), T₆ (2417.00 kg ha⁻¹), T₇ (2458.57 kg ha⁻¹) and T₈ (2442.39 kg ha⁻¹) and was significantly superior over the treatments T₁ (2217.80 kg ha⁻¹), T₂ (2402.26 kg ha⁻¹), T₄ (2387.88 kg ha⁻¹) and T₅ (2390.27 kg ha⁻¹).

The adequate availability of zinc in soil results in growth parameters, photosynthesis efficiency, assimilation and production (Ali, 2004) and in turn to achieve higher yield and yield attributes in basal or combined application treatments i.e. T₉ (T₃+ FS of Zn EDTA @ 1.00 %), T₇ (T₃+ FS of Zn EDTA @ 0.50 %), T₈ (T₂+ FS of Zn EDTA @ 1.00 %), T₆ (T₂+ FS of Zn EDTA @ 0.50 %), T₃ (T₁+ SA of ZnSO₄ 7H₂O @ 10 kg ha⁻¹) and T₂ (T₁+ SA of ZnSO₄ 7H₂O @ 5 kg ha⁻¹). The findings are also in agreement with the verdicts of Yashona *et al.*, (2018).

The available Nitrogen, phosphorous and potassium content of the soil after harvest was non-significant. However the lower Nitrogen and potassium content were found in treatment T₉ (T₃ + FS of Zn EDTA @ 1.00 %) which were 232.70 kg ha⁻¹ and 171.40 kg ha⁻¹ respectively and higher N and K₂O content were found in treatment T₁ (NPK+FYM) which were 239.80 kg ha⁻¹ and 177.10 kg ha⁻¹. Higher P₂O₅ content was found in treatment T₉ (44.70 kg ha⁻¹) and lowest was recorded in treatment T₁ (41.60 kg ha⁻¹) (Table 5).

The data on DTPA extractable Fe, Mn, Zn, Cu and hot water soluble B status (g ha⁻¹) of soil at harvest of crop as influenced by soil and foliar application of zinc are presented as below.

Iron

The iron content did not vary significantly among the treatments. However, higher iron content was observed in the treatment T₁ (7.90 mg kg⁻¹) which received NPK along with FYM, followed by T₄ (7.87 mg kg⁻¹). The lowest was in T₉ (T₃+ FS of Zn EDTA @ 1.00 %) (7.69 mg kg⁻¹).

Manganese

The manganese content did not vary significantly among the treatments. However, higher manganese content was observed in the treatment T₁ (8.27 mg kg⁻¹) which received NPK along with FYM, followed by T₅ and T₇ (8.25 mg kg⁻¹). The lowest was in T₉ (T₃+ FS of Zn EDTA @ 1.00 %)(8.16 mg kg⁻¹).

Zinc

The data in Table 6 indicated that DTPA extractable Zn content in soil differed significantly due to treatments. Higher zinc content in soil was recorded in T₉ (0.90 mg kg⁻¹) which received T₃+ FS of Zn EDTA @ 1.00 per cent which was on par with T₇ and T₃ which were 0.88 mg kg⁻¹ and 0.87 mg kg⁻¹ respectively and was significantly higher than Treatment T₁ i.e, NPK + FYM (0.46 mg kg⁻¹) and rest of the treatments (T₂, T₄, T₅, T₆ and T₈).

The data on DTPA extractable Fe, Mn, Zn, Cu and hot water soluble B status (g ha⁻¹) of soil at harvest of crop as influenced by soil and foliar application of zinc are presented in the Table 6 and Table 8.

Iron

The iron content did not vary significantly among the treatments. However, higher iron content was observed in the treatment T₁ (7.90 mg kg⁻¹) which received NPK along with FYM, followed by T₄ (7.87 mg kg⁻¹). The lowest was in T₉ (T₃+ FS of Zn EDTA @ 1.00 %) (7.69 mg kg⁻¹).

Manganese

The manganese content did not vary significantly among the treatments. However, higher manganese content was observed in the treatment T₁ (8.27 mg kg⁻¹) which received NPK along with FYM, followed by T₅ and T₇ (8.25 mg kg⁻¹). The lowest was in T₉ (T₃+ FS of Zn EDTA @ 1.00 %)(8.16 mg kg⁻¹).

Zinc

The DTPA extractable Zn content in soil differed significantly due to treatments. Higher zinc content in soil was recorded in T₉ (0.90 mg kg⁻¹) which received T₃ + FS of Zn

EDTA @ 1.00 per cent which was on par with T₇ and T₃ which were 0.88 mg kg⁻¹ and 0.87 mg kg⁻¹ respectively and was significantly higher than Treatment T₁ i.e, NPK + FYM (0.46 mg kg⁻¹) and rest of the treatments (T₂, T₄, T₅, T₆ and T₈).

Significantly higher zinc content in soil was recorded in T₉ (T₃+ FS of Zn EDTA @ 1.00 %). The results are in line with the verdicts of Sharma *et al.*, (2016). The increase in zinc content might be due to the considerable exchange of Zinc on the clay complexes with other cations on its addition. The results are in accordance with the findings of Kulandaivel *et al.*, (2004).

Copper

The treatments had non-significant effect on copper status in soil. However, higher copper content was recorded in T₁ (NPK + FYM) with 0.392 mg kg⁻¹ followed by treatment T₄ (0.389 mg kg⁻¹) and lowest copper content was observed in treatment T₉ (T₃ + FS of Zn EDTA @ 1.00 %) which was 0.369 mg kg⁻¹ (Table 7).

Table.1 Fractions of soil at the experimental site

Sl. No	Fraction	Value (mg kg ⁻¹)
1.	Water soluble zinc	0.37
2.	Sorbed zinc	2.10
3.	Easily reducible manganese bound zinc	3.71
4.	Carbonate bound zinc	2.73
5.	Organic bound zinc	1.04
6.	Fe & Al oxides bound zinc	2.44
7.	Residual zinc	122.19
8.	Total zinc	134.58

Table.2 Effect of soil and foliar application of zinc on growth parameters of greengram

Treatments	Growth Parameters		
	Plant height (cm)	Drymatter production (g)	Number of branches/plant
T₁: NPK + FYM	60.73	20.15	3.47
T₂: T₁+ SA of ZnSO₄7H₂O @ 5 kg ha⁻¹	65.63	23.08	3.73
T₃: T₁+ SA of ZnSO₄7H₂O @ 10 kg ha⁻¹	68.93	26.02	4.20
T₄: T₁+ FS of Zn EDTA @ 0.50 %	63.17	21.61	3.53
T₅: T₁+ FS of Zn EDTA @ 1.00 %	64.40	22.00	3.60
T₆: T₂+ FS of Zn EDTA @ 0.50 %	66.43	24.10	3.83
T₇: T₃+ FS of Zn EDTA @ 0.50 %	70.27	26.44	4.30
T₈: T₂+ FS of Zn EDTA @ 1.00 %	66.67	25.23	3.90
T₉: T₃+ FSof Zn EDTA @ 1.00 %	71.93	27.07	4.37
S.Em±	1.52	0.98	0.13
CD (P=0.05)	4.55	2.93	0.40

Table.3 Effect of soil and foliar application of zinc on yield and yield parameters of greengram

Treatments	Pod length (cm)	No. of pods plant ⁻¹	No. of seeds pod ⁻¹	Pod weight(g)	Test weight (g)
T₁: NPK + FYM	11.53	19.27	11.80	23.33	4.89
T₂: T₁+ SA of ZnSO₄7H₂O @ 5 kg ha⁻¹	12.80	22.13	12.80	25.68	5.19
T₃: T₁+ SA of ZnSO₄7H₂O @ 10 kg ha⁻¹	13.17	23.40	13.13	27.89	5.63
T₄: T₁+ FS of Zn EDTA @ 0.50 %	12.43	19.73	12.13	24.92	5.12
T₅: T₁+ FS of Zn EDTA @ 1.00 %	12.60	20.67	12.60	25.07	5.16
T₆: T₂+ FS of Zn EDTA @ 0.50 %	13.00	22.93	12.87	25.94	5.33
T₇: T₃+ FS of Zn EDTA @ 0.50 %	13.30	24.07	13.33	28.85	5.58
T₈: T₂+ FS of Zn EDTA @ 1.00 %	13.13	23.07	12.93	26.89	5.39
T₉: T₃+ FSof Zn EDTA @ 1.00 %	13.60	24.40	13.40	29.73	5.58
S.Em±	0.30	0.62	0.27	0.76	0.15
CD (P=0.05)	0.91	1.86	0.80	2.27	NS

Table.4 Effect of soil and foliar application of zinc on seed, haulm yield and harvest Index of greengram

Treatments	Seed Yield (kg/ha)	Haulm yield (kg/ha)	Harvest Index (%)
T₁: NPK + FYM	805.51	2217.80	0.267
T₂: T₁+ SA of ZnSO₄7H₂O @ 5 kg ha⁻¹	938.14	2402.26	0.281
T₃: T₁+ SA of ZnSO₄7H₂O @ 10 kg ha⁻¹	973.00	2453.43	0.284
T₄: T₁+ FS of Zn EDTA @ 0.50 %	879.51	2387.88	0.269
T₅: T₁+ FS of Zn EDTA @ 1.00 %	905.84	2390.27	0.275
T₆: T₂+ FS of Zn EDTA @ 0.50 %	943.89	2417.00	0.281
T₇: T₃+ FS of Zn EDTA @ 0.50 %	982.65	2458.57	0.285
T₈: T₂+ FS of Zn EDTA @ 1.00 %	968.50	2442.39	0.284
T₉: T₃+ FS of Zn EDTA @ 1.00 %	1022.19	2544.93	0.287
S.Em±	24.62	43.06	0.006
CD (P=0.05)	73.81	129.09	NS

Table.5 Available N, P₂O₅ and K₂O content of soil after harvest of greengram as influenced by soil and foliar application of zinc

Treatment	N (kg ha ⁻¹)	P ₂ O ₅ (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)
T₁: NPK + FYM	239.80	41.60	177.10
T₂: T₁+ SA of ZnSO₄7H₂O @ 5 kg ha⁻¹	236.62	42.10	174.23
T₃: T₁+ SA of ZnSO₄7H₂O @ 10 kg ha⁻¹	234.60	43.80	171.60
T₄: T₁+ FS of Zn EDTA @ 0.50 %	239.64	42.96	176.14
T₅: T₁+ FS of Zn EDTA @ 1.00 %	237.50	43.80	175.55
T₆: T₂+ FS of Zn EDTA @ 0.50 %	237.20	44.30	173.30
T₇: T₃+ FS of Zn EDTA @ 0.50 %	234.80	42.80	172.80
T₈: T₂+ FS of Zn EDTA @ 1.00 %	238.90	43.90	174.90
T₉: T₃+ FS of Zn EDTA @ 1.00 %	232.70	44.70	171.40
S.Em±	6.27	1.61	5.21
CD (P=0.05)	NS	NS	NS

SA: Soil application

FS: Foliar spray at 35 DAS

Table.6 DTPA extractable iron, manganese and zinc content of soil after harvest of greengram as influenced by soil and foliar application of zinc

Treatment	Fe(mg kg ⁻¹)	Mn(mg kg ⁻¹)	Zn(mg kg ⁻¹)
T₁: NPK + FYM	7.90	8.27	0.46
T₂: T₁+ SA of ZnSO₄7H₂O @ 5 kg ha⁻¹	7.79	8.21	0.79
T₃: T₁+ SA of ZnSO₄7H₂O @ 10 kg ha⁻¹	7.76	8.19	0.87
T₄: T₁+ FS of Zn EDTA @ 0.50 %	7.87	8.24	0.48
T₅: T₁+ FS of Zn EDTA @ 1.00 %	7.81	8.25	0.50
T₆: T₂+ FS of Zn EDTA @ 0.50 %	7.79	8.22	0.81
T₇: T₃+ FS of Zn EDTA @ 0.50 %	7.72	8.25	0.88
T₈: T₂ + FS of Zn EDTA @ 1.00 %	7.70	8.21	0.82
T₉: T₃+ FS of Zn EDTA @ 1.00 %	7.69	8.16	0.90
S.Em±	0.23	0.25	0.02
CD (P=0.05)	NS	NS	0.07

NOTE:

SA: Soil application

FS: Foliar spray at 35 DAS

Table.7 DTPA extractable copper and hot water soluble boron content of soil

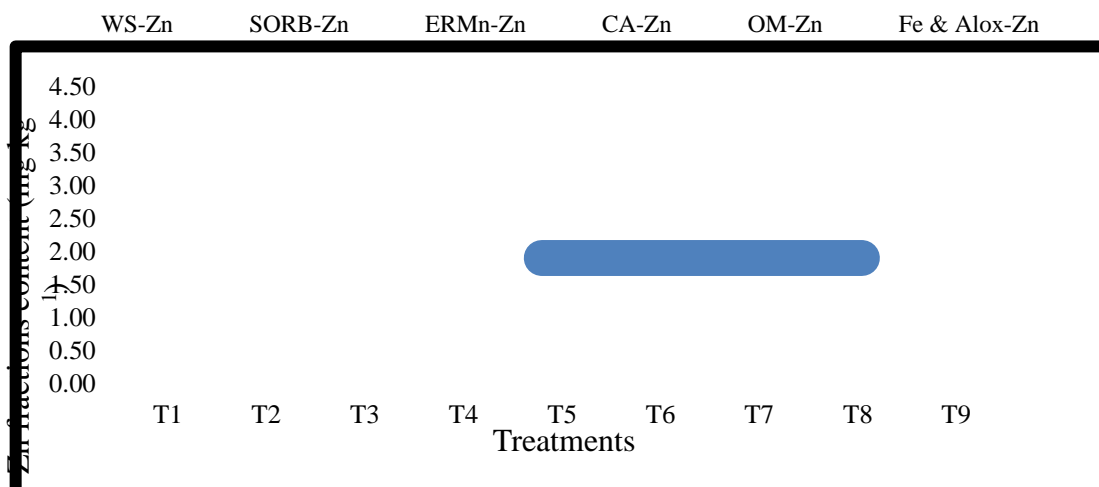
Treatment	Cu (mg kg ⁻¹)	B (mg kg ⁻¹)
T₁: NPK + FYM	0.392	0.35
T₂: T₁+ SA of ZnSO₄ 7H₂O @ 5 kg ha⁻¹	0.386	0.34
T₃: T₁+ SA of ZnSO₄7H₂O @ 10 kg ha⁻¹	0.381	0.32
T₄: T₁+ FS of Zn EDTA @ 0.50 %	0.389	0.33
T₅: T₁+ FS of Zn EDTA @ 1.00 %	0.381	0.33
T₆: T₂+ FS of Zn EDTA @ 0.50 %	0.383	0.33
T₇: T₃+ FS of Zn EDTA @ 0.50 %	0.378	0.32
T₈: T₂ + FS of Zn EDTA @ 1.00 %	0.373	0.33
T₉: T₃+ FS of Zn EDTA @ 1.00 %	0.369	0.31
S.Em±	0.012	0.01
CD (P=0.05)	NS	NS

Table.8 Distribution of zinc fractions (mg kg⁻¹) in soil at harvest of greengram as influenced by soil and foliar application of zinc

Treatment	WS-Zn	SORB-Zn	ERMn-Zn	CA-Zn	OM-Zn	Fe & Alox-Zn	RES-Zn	Total-Zn
T ₁	0.32 (0.25)	1.87 (1.43)	3.45 (2.65)	2.31 (1.77)	0.96 (0.74)	2.27 (1.74)	119.24 (91.43)	130.42
T ₂	0.40 (0.30)	3.79 (2.82)	4.08 (3.03)	2.89 (2.15)	1.61 (1.20)	2.68 (1.99)	119.15 (88.52)	134.60
T ₃	0.45 (0.33)	3.86 (2.86)	4.14 (3.06)	3.14 (2.32)	1.73 (1.28)	2.84 (2.10)	119.03 (88.05)	135.19
T ₄	0.33 (0.25)	1.79 (1.37)	3.43 (2.62)	2.33 (1.78)	0.93 (0.71)	2.32 (1.77)	119.79 (91.50)	130.92
T ₅	0.33 (0.25)	1.84 (1.41)	3.47 (2.66)	2.34 (1.79)	0.91 (0.70)	2.33 (1.79)	119.22 (91.40)	130.44
T ₆	0.39 (0.29)	3.77 (2.80)	4.10 (3.05)	2.83 (2.10)	1.64 (1.22)	2.72 (2.02)	119.18 (88.52)	134.63
T ₇	0.46 (0.34)	3.87 (2.86)	4.20 (3.10)	3.06 (2.26)	1.76 (1.30)	2.87 (2.12)	119.10 (88.01)	135.32
T ₈	0.40 (0.30)	3.76 (2.79)	4.09 (3.04)	2.88 (2.14)	1.62 (1.20)	2.71 (2.01)	119.13 (88.51)	134.59
T ₉	0.45 (0.33)	3.89 (2.87)	4.18 (3.09)	3.10 (2.29)	1.78 (1.31)	2.89 (2.13)	119.08 (87.97)	135.37
S.Em±	0.01	0.10	0.12	0.08	0.04	0.08	3.64	3.99
CD (P=0.05)	0.04	0.29	0.35	0.25	0.13	0.23	NS	NS

Figures in parenthesis indicate percentage of total Zn

Fig.1 Distribution of zinc fractions (WS-Zn, SORB-Zn, CA-Zn, OM-Zn, Fe & Alox-Zn) (mg kg⁻¹) in soil at harvest of greengram as influenced by soil and foliar application of zinc



Boron

Boron content in the soil did not varied significantly due to treatments. However higher B content of 0.35 mg kg⁻¹ was observed in T₁(NPK + FYM) and the minimum boron content was recorded in T₉ (0.31 mg kg⁻¹) which received T₃+ FS of Zn EDTA @ 1.00 %. Total zinc content in soil not differed significantly due to treatment. However, higher total zinc was observed in treatment T₉ (135.37 mg kg⁻¹) which received T₃+ FS of Zn EDTA @ 1.00 per cent followed by treatment T₇ (135.32 mg kg⁻¹) and lowest total zinc was observed in the treatment T₁ (NPK+ FYM) which was 130.42 mg kg⁻¹.

Distribution of zinc fractions in soil at harvest of greengram

Sorbed water soluble zinc

Significantly higher water soluble fraction was observed in treatment T₇ (T₃ + FS of Zn EDTA @ 0.5 %) (0.46 mg kg⁻¹) followed by T₉ (0.45 mg kg⁻¹) and T₃ (0.45 mg kg⁻¹) and were significantly higher than rest of the treatments T₁ NPK +FYM (0.32 mgkg⁻¹), T₂

(0.40 mgkg⁻¹), T₄ (0.33mgkg⁻¹), T₅ (0.33mg kg⁻¹), T₆(0.39 mg kg⁻¹) and T₈(0.40 mg kg⁻¹).

zinc

Sorbed zinc fraction varied significantly due to treatments and higher sorbed zinc content was recorded in treatment T₉ (T₃ + FS of Zn EDTA @ 1.00 %) which was 3.89 mg kg⁻¹ which was significantly higher than treatments T₁.i.e.NPK + FYM (1.87 mg kg⁻¹), T₄ (1.79 mg kg⁻¹) and T₅ (1.84 mg kg⁻¹) and on par with rest of the treatments (T₂, T₃, T₆, T₇, T₈).

Easily reducible manganese bound zinc

The reducible manganese bound zinc content in soil differed significantly due to treatment. Significantly higher easily reducible manganese bound fraction was observed in treatment T₇(4.2 mg kg⁻¹) which received T₃+ FS of Zn EDTA @ 0.50 per cent followed by T₉ (4.18 mg kg⁻¹) and were on par with treatment T₂(4.08 mg kg⁻¹), T₃(4.14 mg kg⁻¹),T₆ (4.10 mg kg⁻¹) and T₈ (4.09 mg kg⁻¹) and significantly higher than treatment T₁.i.e NPK + FYM (3.45 mg kg⁻¹), T₄ (3.43 mg kg⁻¹) and T₅ (3.47 mg kg⁻¹).

Carbonate bound zinc

Carbonate bound fraction varied significantly due to treatments and higher Carbonate bound zinc content was recorded in treatment T₃(T₁+ SA of ZnSO₄. 7H₂O @ 10 kg ha⁻¹) which was 3.14mg kg⁻¹ which was significantly higher than treatments T₁, i.e. NPK + FYM (2.31 mg kg⁻¹), T₄ (2.33 mg kg⁻¹), T₅ (2.34 mg kg⁻¹) and T₆ (2.83 mg kg⁻¹), and on par with rest of the treatments T₂ (2.89 mg kg⁻¹), T₇ (3.06 mg kg⁻¹), T₉ (3.10 mg kg⁻¹) and T₈ (2.88mg kg⁻¹).

Organic bound zinc

The organic bound zinc content in soil differed significantly due to treatment. Significantly higher Organic bound fraction was observed in treatment T₉ (T₃+ FS of Zn EDTA @ 1.00 %)(1.78 mg kg⁻¹) and was on par with treatment T₇ (1.76 mg kg⁻¹), T₃ (1.73 mg kg⁻¹) and significantly higher than T₆ (1.64 mg kg⁻¹) and T₈ (1.62 mg kg⁻¹), T₂ (1.61 mg kg⁻¹), T₁, i.e. NPK + FYM (0.96 mg kg⁻¹), T₄ (0.93 mg kg⁻¹) and T₅ (0.91 mg kg⁻¹).

Fe & Al oxides bound zinc

Fe & Al oxides bound fraction varied significantly due to treatments and higher Fe & Al oxides bound zinc content was recorded in treatment T₉ (T₃ + FS of Zn EDTA @ 1.00 %) which was 2.89 mg kg⁻¹ which was significantly higher than treatments T₁, i.e. NPK + FYM (2.27 mg kg⁻¹), T₄ (2.32 mg kg⁻¹) and T₅ (2.33 mg kg⁻¹) and on par with rest of the treatments T₇ (2.87 mg kg⁻¹), T₃ (2.84 mg kg⁻¹), T₆ (2.72 mg kg⁻¹), T₂ (2.68mg kg⁻¹) and T₈ (2.71 mg kg⁻¹).

Residual zinc

The residual zinc content in soil not differed significantly due to treatment. However, higher residual zinc was observed in treatment T₄ (119.79 mg kg⁻¹) which received T₁+ FS of Zn EDTA @ 0.5 per cent and lowest residual zinc

was observed in the treatment T₃(T₁+ SA of ZnSO₄. 7H₂O @ 10 kg ha⁻¹) which was 119.03 mg kg⁻¹.

Total zinc

Higher total zinc was observed in treatment T₉ (135.37 mg kg⁻¹) which received T₃+ FS of Zn EDTA @ 1.00 per cent followed by treatment T₇ (135.32 mg kg⁻¹) and lowest total zinc was observed in the treatment T₁ (NPK+ FYM) which was 130.42 mg kg⁻¹. The changes in Zn fractions were dependent on number of mechanisms involving: surface complexation of the residual zinc form by organic ligands released from roots, the inhibition of iron (Fe) and aluminum (Al) crystallization providing reactive surfaces and effective sinks for zinc, thus enhancing further dissolution of residual zinc and by the adsorption of organic ligands to the oxide surfaces. Ligand adsorption usually conveys negative charge on to the oxide surfaces and thus increases zinc adsorption by oxides (Barrow 1987).

Application of zinc increased all the zinc fractions in soil except residual fraction and total zinc which showed non-significant difference. Zinc application increased the sorbed fraction to the greater extent, whereas with respect to other fractions mere increase in the content over NPK + FYM was observed. An increase in the concentration of zinc in all the fractions except residual zinc (RES) due to the applied zinc sulphate, which has high solubility and mobility in soil got distributed into soluble and sparingly soluble fractions of zinc such as water soluble (WS), sorbed (SORB), easily reducible manganese bound zinc (ERMn) calcium bound (CA) and organic bound zinc (OM), iron and aluminum oxides bound zinc (Fe & Al-ox). This indicates that applied zinc in the form of zinc sulphate in sandy loam soil mainly concentrated in easily and sparingly soluble fractions but not in the residual fraction and thereby an increase in its availability in soil was observed due to their contribution to the available pool (Patil and Kedlaya, (1988).

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