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Effect of zinc on uptake of macronutrients by soybean (*Glycine max*. L.) in swell shrink soil

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Abstract
A pot culture experiment was conducted during kharif season of 2013 - 14 at Nagarjun Medicinal Plant Garden, Dr. P.D.K.V - Akola, to assess the effect of zinc on uptake of macronutrients on soybean in swell shrink soil. The experiment was laid out completely randomised design (CRD) with five treatments and two replications. The treatments comprised of varied level of soil application of zinc at 0.0, 1.5, 3.0, 4.5 and 6.0 kg ha^{-1} in different soil samples. The results of pot culture study revealed that application of zinc @ 4.5 kg ha^{-1} had significantly influenced and improve the dry matter yield and uptake of nitrogen, phosphorus and potassium by soybean.

Keywords: pot culture, zinc, swell shrink soil, dry matter, uptake

Introduction
Soybean (*Glycine max*. (L.) Merill) belongs to family papillionaceae, a subfamily of leguminosae. Being a leguminous crop, it helps in fixing atmospheric nitrogen in soil and improves soil fertility. Therefore, soybean is called as "*Gold of soil*". In India, at present area under soybean crop is 106.94 lakh ha with the production of 126.77 lakh MT. The productivity of soybean in India is low as compared to other countries. The main reasons in the productivity decline are untimely sowing inadequate and imbalanced nutrient application and moisture stress at critical stages. Among these factors mineral nutrition plays an important role. The plants require essential nutrients *viz.*, primary, secondary and micro nutrients. Micronutrients have assumed a greater importance in a modern agriculture. Among the micronutrients, zinc deserves special attention. Zinc deficiency is likely to become more wide spread and intense. The Zn deficiencies are mainly attributed to unfavourable soil conditions, rather than total Zn reserves. With this background, a pot culture experiment was conducted to assess the effect of zinc on uptake of macronutrients on soybean in swell shrink soil with the test variety JS-335.

Material and methods
Experimental soil
The soils were selected have wide variation in the available zinc content. The soil sample used for conducting the study was air dried, broken with wooden mallet and sieved through 2 mm sieve for pot culture experiment. Particle size distribution was determined by Bouyoucos hydrometer method as suggested by Gee and Bauder (1986) [4]. The pH and EC of soil sample were determined by using 1:2.5 soil water extract (Jackson, 1973) [9] and calcium carbonate content was determined by rapid titration with acid.
The organic carbon was estimated by chromic acid wet digestion (Walkley and Black, 1934) [24], available N by alkaline permanganate method (Subbiah and Asija, 1956) [22], available P by using 0.5 M $NaHCO_3$ (Olsen *et al*, 1954) [14], available K by neutral normal NH_4OAC method (Stanford and English, 1949) [21] followed by flame photometry and available micronutrients by DTPA extraction and AAS method (Lindsay and Norvell, 1978) [13]. These soil samples were categorized as low, medium and high in zinc content. The data pertaining to zinc content in plants, N, P, K were statistically analyzed as per Panse and Sukhatme (1967) [15] using method of analysis of variance and means were tested at 5% level of significance separately for soils under low, medium and high zinc content and the data were interpreted.

Pot culture experiment
The pot culture experiment was conducted during kharif (rainy) season of 2013 -14 at Nagarjun Medicinal Plant Garden, Dr. Panjabrao Deshmukh Krishi Vidyapeeth. Akola is situated in subtropical zones at the latitude of 22^0 42' North and longitude of 77^0 02' East, at the altitude of 307.42 m above mean sea level (MSL). The fifteen different soil samples from Central Research Station and farmer's field of nearly same group (Swell – shrink soils) were collected based on texture, $CaCO_3$ and DTPA-Zn and grouped as low (7), medium (5) and high (3).

There are 5 treatments in the pot culture experiment. The experiment was laid out in completely randomised design (CRD) with two replications and a net mud pots having capacity of 7 kg were used.

The treatments were as follows:

Treatments	Details
T_1	Control
T_2	Zn @ 1.5 kg ha^{-1}
T_3	Zn @ 3.0 kg ha^{-1}
T_4	Zn @ 4.5 kg ha^{-1}
T_5	Zn @ 6.0 kg ha^{-1}

The experimental soil samples of about 5 kg were thoroughly filled in pots irrespective of low (07), medium (05) and high (03) zinc content. A uniform dose of 30:75:30 kg N (as Urea), P_2O_5 (as Dihydrogen orthophosphate) and K_2O ha^{-1} (Potassium Chloride), as per RDF of soybean and Zn (as Zinc oxide) were applied to pots as fertilizer solution as per the treatment schedule. Seeds (5 seeds per pot) of soybean of variety JS-335 were sown at equal distance at 2.0 cm depth and watering was done with deionized water immediately after sowing. The earthen pots were kept as per treatments in shade net under control condition. Irrigation was given as and when required, weeding was done and plant protection measures were taken up against pest and diseases.

The soybean plants were harvested at 45 days after sowing. The plants were uprooted carefully without disturbing the root. The plant sample along with the roots were washed first in deionized water and then in distilled water to remove the soil from the roots. The roots were removed by cutting and air dried in oven by putting them in paper bags at 64 ºC temperature till they showed constant weight. After completion of drying the dry matter weight of sample was recorded.

Total nitrogen, phosphorus and potassium from plant samples was estimated by using Micro-Kjeldahl's (Piper, 1966) [16], Vandomolybdate yellow colour method using spectrophotometer from Diacid extract by Piper (1966) [16] and flame photometrically from Diacid extract by Piper (1966) [16] respectively. Uptake can calculated by taking nutrient concentrations in plant samples and dry matter.

Result and discussion
Initial characteristics of the experimental soil
The soil samples from fifteen different locations were analyzed and all the composition and parameters varied from location to location (Table.1). Mechanical composition of experimental soils indicated that sand content ranged from 4.16 to 44.44 per cent, silt from 12.56 to 60.56 per cent and clay from 30.00 to 55.68 per cent with textural class from clay loam to clay. The pH of the soils ranged from 7.20 to 8.82, electrical conductivity ranged from 0.13 to 0.29 dS m^{-1} and organic carbon content of the soils varied from 2.34 to 6.81 g kg^{-1}. The available nitrogen, phosphorus and potassium varied from 134.4 to 358.4 kg ha^{-1}, 12.7 to 25.1 kg ha^{-1} and 337.3 to 731.4 kg ha^{-1} respectively. The micro nutrient contents were as follows: Fe - 5.02 - 11.4 mg kg^{-1}, Cu - 1.97 to 4.36 mg kg^{-1}, Mn - 11.90 to 22.15mg kg^{-1} and the seven soils were in low in zinc (< 0.60 mg kg^{-1}), five in medium (0.60 - 1.80 mg kg^{-1}) and three in high zinc (> 1.80 mg kg^{-1}). Thus, the soils selected for pot culture experiment were neutral to slightly alkaline in reaction, low to moderate in organic carbon, low in available nitrogen, low to moderately high in available phosphorus, high to very high in available potassium and low to high in DTPA-zinc, low to medium in Fe, medium to high in Mn and Cu.

Table 1: Physical and chemical properties of soils

S. No.	pH (1:2.5)	EC (dSm^{-1})	Organic carbon (g kg^{-1})	$CaCO_3$ (%)	Available nutrient (kg ha^{-1})			Available micronutrients (mg kg^{-1})				Particle size analysis (%)			Textural class
					N	P	K	Zn	Fe	Mn	Cu	Sand	Silt	Clay	
1	7.69	0.21	5.51	2.75	246.4	15.20	647.7	0.43	7.72	16.60	2.19	17.16	33.56	49.28	Clay
2	7.20	0.24	3.20	3.25	358.4	16.21	681.1	0.23	7.01	17.60	1.98	12.92	50.08	37.00	clay loam
3	7.36	0.29	2.34	4.25	224.0	14.50	337.3	0.39	10.6	20.15	2.16	34.40	28.60	37.00	Clay loam
4	7.86	0.23	2.81	5.25	156.8	18.50	343.5	0.40	9.77	18.11	1.97	39.68	30.32	30.00	Clay loam
5	8.82	0.20	3.32	4.25	246.4	16.70	513.3	0.51	11.4	15.90	2.06	44.44	12.56	43.00	Clay
6	7.81	0.18	3.21	5.75	291.2	20.90	525.6	0.57	6.27	21.13	3.19	7.72	49.28	43.00	Clay loam
7	7.77	0.14	2.43	2.50	268.8	19.50	554.5	0.46	5.02	20.03	2.48	9.44	60.56	30.00	clay loam
8	7.80	0.18	3.50	7.50	246.4	23.00	627.4	0.71	5.94	21.84	2.97	16.76	37.16	46.08	Clay
9	8.14	0.15	3.62	7.54	224.0	16.00	425.2	1.18	9.38	22.15	3.78	31.32	32.60	38.08	Clay loam
10	8.19	0.16	4.34	3.75	313.6	18.90	370.3	0.73	8.92	19.22	4.0	23.48	30.44	46.08	Clay
11	8.32	0.13	5.16	8.25	134.4	25.10	731.4	0.78	10.4	12.20	3.67	9.64	34.88	55.68	Clay
12	8.10	0.16	4.01	2.50	201.6	22.90	337.6	1.06	9.43	14.10	4.36	4.16	46.56	49.28	Clay loam
13	8.02	0.16	6.57	8.75	336.0	20.50	728.0	1.86	5.53	11.90	3.23	18.00	32.00	50.00	Clay
14	7.94	0.17	6.81	4.25	268.8	23.90	726.9	2.05	8.70	18.01	3.13	8.40	42.32	49.28	Silty clay
15	7.98	0.19	6.18	8.13	224.0	12.70	705.6	1.84	6.08	13.8	4.21	7.92	39.60	52.48	Clay

Effect of zinc application on dry matter yield of soybean
The average dry matter yield of soybean was recorded highest in the soils (2.79 g $plant^{-1}$) containing high zinc and medium (2.79 g $plant^{-1}$) and followed by low (2.67 g $plant^{-1}$) zinc containing soil (Table 2).

The increasing level of zinc application significantly increased the dry matter yield of soybean up to 4.5kg Zn ha^{-1} in all the soils. The application of zinc @ 4.5kg Zn ha^{-1} (T_4) showed significant increase in dry matter yield of soybean (2.67 g $plant^{-1}$) in low containing soils over control (1.43 g plant^{-1}). The application of zinc @ 6.0 kg Zn ha^{-1} (T_5) (2.44 g plant^{-1}) decreased the dry matter yield of soybean. However, the treatments comprising application of zinc 6.0 kg Zn ha^{-1} (T_5) showed reduction in the dry matter yield. This could be attributed to the adverse effect of excess zinc in crop productivity.

In the medium zinc containing soils application of zinc @ 1.5 to 4.5 kg Zn ha^{-1} (T_4) also recorded significantly superior dry matter over control (T_1). The application of zinc @ 6.0kg Zn ha^{-1} (T_5) found at par in respect of dry matter yield with 4.5 kg Zn ha^{-1}. Similarly in the high status soils, the application of zinc @ 4.5 kg Zn ha^{-1} (T_4) showed significant increase in dry matter yield of soybean.

The result obtained in the present investigation are in accordance with the results reported by Jha and Chandel (1987) [10] who reported that the 49.2 per cent increase in dry matter yield of soybean over control due to 4 mg kg^{-1} zinc application. Similarly Ghildayal *et al.* (1978) [5] reported that application of zinc @ 2.50, 5.00 mg Zn kg^{-1} soil significantly increased the dry matter production of pea.

The result indicated that the application of higher levels of zinc (6.0 kg Zn ha^{-1}) did not show significant effect on the dry matter yield of soybean grown in soils with low, medium and high zinc content. Increase in 49.2 per cent dry matter production with application of 4 mg kg^{-1} zinc in soybean crop was reported by Jha and Chandel (1987) [10]. Similarly Ghildayal *et al.* (1978) [5] reported that application of zinc @ 2.50, 5.00 mg kg^{-1} Zn in soil significantly increased the dry matter production of pea (Kadam *et al.*, 2002) [11]. It could be also be noticed that the magnitude of dry matter yield increase was higher from low to medium zinc containing soils (21.9 %) as compared to medium to high zinc containing soils (20 %)

Table 2: Effect of zinc application on dry matter yield of soybean

Treatments	Dry matter yield (g plant^{-1})			
	Soil zinc status			
	Low	Medium	High	Mean
T_1 : Zn @ 0.0 kg ha^{-1}	1.43	2.07	2.31	1.94
T_2 : Zn @ 1.5 kg ha^{-1}	1.65	2.30	2.43	2.13
T_3 : Zn @ 3.0 kg ha^{-1}	2.07	2.59	2.50	2.39
T_4 : Zn @ 4.5 kg ha^{-1}	2.67	2.79	2.79	2.75
T_5 : Zn @ 6.0 kg ha^{-1}	2.44	2.74	2.69	2.82
Mean	2.05	2.50	2.55	
SE (m) ±	0.06	0.05	0.03	
CD at 5 %	0.17	0.16	0.09	

Effect of soil zinc on the concentration of nitrogen in soybean

The nitrogen content in soybean plant ranged from 2.13 to 2.22 per cent under low zinc containing soils, 2.16 to 2.26 per cent in medium zinc containing soils while in high zinc containing soils it varied from 2.19 to 2.26 per cent (Table.3).

The data revealed that the application of zinc to soybean grown on low, medium and high zinc containing soils showed non-significant effect on nitrogen concentration in soybean. The increase level of zinc application slightly increased the nitrogen concentration in soybean in all the type soils over the control. The zinc application @ 4.5 kg Zn ha^{-1} recorded highest zinc concentration as compared to zinc @ 6.0, 3.0, 1.5 kg ha^{-1}.

The results indicated that the applications of higher levels of zinc application to soybean grown in varying zinc containing soils were not found beneficial for increasing nitrogen concentration in soybean. Thus, application of zinc has been reported both synergistic as well as antagonistic effects on nitrogen concentration in plants. Increase (Kene and Deshpande, 1980) [12] as well as decrease (Dev and Shukla, 1980) [3] in the concentration of nitrogen due to the application of zinc has been reported. These contradictory results suggest that the effect of zinc application on the concentration of nitrogen will depend upon its supply from soil in relation to demand by the shoot.

Effect of soil application of zinc on the concentration of phosphorus in soybean

The phosphorus content in soybean plant varied from 0.21 to 0.26 per cent under low zinc containing soils, 0.24 to 0.29 per cent in medium zinc containing soils which in high zinc containing soils it varied from 0.27 to 0.34 per cent (Table.3).

The different levels of zinc application in low, medium and high zinc content soils were found significant in respect of phosphorus concentration in soybean. The average P concentration in soybean crop was highest in high zinc status soils (0.30 %) followed by medium (0.27 %) and low (0.23 %) zinc status soils.

The application of zinc @ 4.5 kg Zn ha^{-1} to soybean grown on low zinc content soils recorded significantly higher phosphorus concentration (0.26 %) which was found superior over the treatments comprising levels of zinc *viz*., 1.5 and 3.0 and 6.0 kg Zn ha^{-1}. However, it was found at par with the zinc application @ 3.0 and 6.0 kg Zn ha^{-1}. Similarly soils in medium zinc content also noticed significant increase in P concentration (0.29 %) which increased up to 4.5 kg Zn ha^{-1} and at par with 1.5, 3.0, and 6.0 kg Zn ha^{-1}. In case of soils having high zinc content, application @ 4.5 kg Zn ha^{-1} (T_4) showed significantly higher P concentration (0.34 %). It was however at par with 1.5, 3.0 and 6.0 kg Zn ha^{-1}.The concentration of phosphorus in soybean by zinc application was decreased at higher level of zinc @ 6.0 kg ha^{-1}.

The result indicated that the application of higher zinc content in soils with increased level of zinc application were adversely influenced the phosphorus concentration in soybean. The findings of present investigation are in accordance with De and Chatterjee (1976) [2] who reported the antagonistic effect between phosphorus and zinc in groundnut at higher doses of Zn. Samui *et al*. (1981) [19] reported that synergistic effect at lower dose of application of $ZnSO_4$ to mustard while antagonistic effect between these nutrients at higher dose of application of Zn.

It was observed that the phosphorus concentration in soybean was found at par in different level of zinc application. This might be due to adverse effect of zinc phosphorus interaction on phosphorus concentration in soybean at higher level of zinc by Kadam *et al.* (2002) [11].

Effect of soil zinc application on concentration of potassium in soybean

The concentration of potassium in soybean as influenced by different levels of zinc in low, medium and high zinc content soils is reported in Table 3. The potassium content in soybean plant ranged from 1.84 to 1.96 per cent under low zinc containing soils, 1.87 to 1.99 per cent in medium zinc containing soils which in high zinc containing soils it varied from 1.92 to 2.03 per cent (Table.3).

The potassium content in soybean plant ranged from 1.84 to 1.96 per cent under low zinc containing soils, 1.87 to 1.99 per cent in medium zinc containing soils which in high zinc containing soils it varied from 1.92 to 2.03 per cent.

The result indicated that the differences in the potassium concentration in soybean due to different levels of zinc were found significant. All the levels of zinc application significantly increased the potassium concentration in soybean over control. The low zinc content soils recorded the highest potassium concentration (1.96 %) at 4.5 kg Zn ha^{-1} (T_4) which was at par with 6.0kg Zn ha^{-1} (T_5) (1.92 %) and followed by 3.0 T_3 (3.0) and T_2 (1.5). The medium zinc status also recorded the highest potassium concentration at 4.5 kg Zn ha^{-1} (T_4) soil application (1.99 %). However, in high zinc status soils recorded highest concentration of potassium in treatment 4.5 kg Zn ha^{-1} (2.03 %) soil which was at par with 6.0 kg Zn ha^{-1} soil (T_5) (2.01 %) in soybean plant.

The application of 4.5 kg Zn ha^{-1} in low and medium zinc status soil were useful for increasing the potassium concentration in soybean. Similarly trend was noticed in high zinc content soils. These observations are in close conformity with Gupta and Rajhans (1983) [7] reported the synergistic relationship between zinc and potassium in wheat crop.

Table 3: Effect of zinc application on macronutrients concentration in soybean

Treatments	Nitrogen concentration (%)			Mean	Phosphorus concentration (%)			Mean	Potassium concentration (%)			Mean
	Soil zinc status				Soil zinc status				Soil zinc status			
	Low	Medium	High		Low	Medium	High		Low	Medium	High	
T_1 : Zn @ 0.0 kg ha^{-1}	2.13	2.16	2.19	2.16	0.21	0.24	0.27	0.24	1.84	1.87	1.92	1.88
T_2 : Zn @ 1.5 kg ha^{-1}	2.15	2.20	2.23	2.19	0.22	0.26	0.29	0.26	1.87	1.90	1.95	1.90
T_3 : Zn @ 3.0 kg ha^{-1}	2.18	2.23	2.26	2.23	0.24	0.28	0.32	0.28	1.91	1.94	1.97	1.94
T_4 : Zn @ 4.5 kg ha^{-1}	2.22	2.26	2.29	2.26	0.26	0.29	0.34	0.30	1.96	1.99	2.03	1.99
T_5 : Zn @ 6.0 kg ha^{-1}	2.19	2.24	2.26	2.23	0.25	0.27	0.30	0.27	1.92	1.95	2.01	1.96
Mean	2.18	2.22	2.25		0.23	0.27	0.30		1.90	1.93	1.97	
SE (m)±	0.13	0.10	0.15		0.0054	0.0109	0.0201		0.01	0.01	0.05	
CD at 5 %	NS	NS	NS		0.016	0.0325	0.059		0.04	0.04	0.16	

Effect of zinc application on uptake of nitrogen by soybean

The application of 4.5 kg Zn ha^{-1} in soil zinc application registered the highest nitrogen uptake in high zinc content soils (64.00 mg plant^{-1}) which was followed with the Zn @ 6.0, 3.0, 1.5 kg ha^{-1} (60.88, 56.58, 54.09 mg plant^{-1} respectively). In medium and low zinc content soils same treatment recorded highest uptake of nitrogen (Table.4).

The result have clearly indicated that the soils having low to medium zinc status increased the nitrogen uptake by soybean due to 4.5 kg Zn ha^{-1} soil application of zinc. For high zinc status soils also 4.5 kg Zn ha^{-1} soil zinc application was just sufficient to increase the nitrogen uptake by soybean.

The result in present investigation are in accordance with Varavipour *et al.* (1999) [23], they reported significant rise in nitrogen uptake by soybean grain due to zinc application. The observations recorded by Sahu *et al.* (1996) [18] in rice were also of similar nature.

The increased uptake of nitrogen might because of the increased dry matter yield due to zinc application. However, the maximum dry matter yield increase was noticed at 4.5 kg Zn ha^{-1} soil zinc application in low, medium and high zinc content soil zinc application.

The higher dose of zinc were ineffective in the production of dry matter yield and therefore, increase in nitrogen uptake by soybean was observed up to 4.5 kg Zn ha^{-1} soil in low, medium and high zinc content soil.

Effect of zinc application on uptake of phosphorus by soybean

The phosphorus uptake by soybean grown on soils with varying zinc content significantly influenced due to different level of zinc application (Table.4). The mean uptake of phosphorus by soybean grown on soil with high zinc status was higher (7.77 mg plant^{-1}) followed by medium (6.77 mg plant^{-1}) and low (4.88 mg plant^{-1}) zinc status soil. The zinc application @ 4.5 kg Zn ha^{-1}soil recorded significantly higher phosphorus uptake by soybean grown on low (6.96 mg plant^{-1}) zinc status soil. Whereas, zinc application @ 3.0 and 6.0 kg ha^{-1} were found on par in respect of uptake of phosphorus by soybean grown on soils with high zinc content.

These results indicated that soybean crop did not respond to the zinc application for phosphorus uptake grown on high zinc content soils. However, Zn @ 4.5 kg ha^{-1} soil application increased the uptake of phosphorus by soybean crop grown on low zinc content soils than control. The decreased uptake of phosphorus by soybean due to increased doses of zinc as noticed in the present study indicated antagonistic effects between these two nutrient elements at higher zinc level. Antagonistic effect between these two nutrient elements was also reported earlier by De and Chatterjee (1976) [2] and Kadam *et al.* (2002) [11] reported that antagonistic effect between Zn and P in soybean crop.

As zinc has the ability to control the rate of phosphorus absorption by roots possibly through some functional association in cell membrane (Safaya, 1976) [17] it might have caused the decreased uptake of phosphorus at higher zinc levels.

The results obtained in the present investigation are in accordance with Sankhyan and Sharma (1997) [20], they reported that the zinc application increased the phosphorus uptake only at lower levels of its application in maize.

Effect of zinc application on uptake of potassium by soybean

The mean uptake of potassium was found to be highest in the high zinc containing soils (50.32 mg plant^{-1}) followed by medium (48.36 mg plant^{-1}) and low zinc status soils (39.15 mg plant^{-1}) (Table.4). The increasing levels of zinc application were found to increase the uptake of potassium by soybean up to 4.5 kg Zn ha^{-1} (T_4) in low, medium and high zinc status soils, which was significant over control (T_1), 1.5 kg Zn ha^{-1} (T_3) and 6.0 kg Zn ha^{-1} (T_5). The result indicated that the application of potassium with 4.5 kg Zn ha^{-1} (T_4) significantly increased the potassium uptake in soybean.

The soil application of Zn @ 4.5 kg ha^{-1} to the soils of low and medium zinc status was found beneficial for potassium uptake by soybean. Whereas, different levels of zinc in high zinc status soils were effective in for potassium uptake by soybean. This may probably due to synergism between these two nutrient elements in low Zn status soils (Gupta and Rajhans, 1983) [7].

In general, the level of zinc to soybean grown on soils of high Zn content did not influence the potassium uptake by soybean crop. Whereas, zinc application @ 4.5 kg ha^{-1} to soybean influenced the potassium uptake by soybean grown on low and medium zinc containing soils.

Table 4: Effect of zinc application on uptake of macronutrients by soybean

Treatments	Nitrogen uptake (mg $plant^{-1}$) Soil zinc status			Mean	Phosphorus uptake (mg $plant^{-1}$) Soil zinc status			Mean	Potassium uptake (mg $plant^{-1}$) Soil zinc status			Mean
	Low	Medium	High		Low	Medium	High		Low	Medium	High	
T_1 : Zn @ 0.0 kg ha^{-1}	30.49	44.73	50.63	41.95	3.01	5.00	6.23	4.75	26.39	38.85	44.37	36.54
T_2 : Zn @ 1.5 kg ha^{-1}	35.54	50.68	54.09	46.77	3.56	6.04	6.97	5.53	30.80	43.70	47.28	40.60
T_3 : Zn @ 3.0 kg ha^{-1}	45.17	57.80	56.58	53.18	4.87	7.18	8.05	6.70	39.48	50.14	49.28	46.30
T_4 : Zn @ 4.5 kg ha^{-1}	59.23	63.09	64.00	62.11	6.96	8.15	9.39	8.16	52.26	55.66	56.58	54.83
T_5 : Zn @ 6.0 kg ha^{-1}	53.53	61.30	60.88	58.57	6.00	7.48	8.19	7.22	46.80	53.43	54.10	51.44
Mean	44.79	55.52	57.24		4.88	6.77	7.77		39.15	48.36	50.32	
SE (m)±	0.32	0.44	0.34		0.11	0.16	0.29		0.17	0.27	0.39	
CD at 5 %	0.96	1.32	1.1		0.33	0.47	0.87		0.51	0.79	1.17	

Conclusion

From the study, it was concluded that among varied levels of zinc (Zn @ 0.0, 1.5, 3.0, 4.5, 6.0 kg ha^{-1}), The dry matter yield was significantly higher at 4.5 kg Zn ha^{-1} zinc level on low (2.05 g $plant^{-1}$), medium (2.50 g $plant^{-1}$) and high (2.55 g $plant^{-1}$) zinc containing soils in comparison with lower levels of zinc. The application of zinc up to 4.5 kg Zn ha^{-1} was beneficial in increasing the dry matter, macronutrient concentrations in plant and uptake of nitrogen, phosphorus and potassium were found significantly.

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