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Zinc Biofortification in Groundnut [*Arachis hypogaea.*L]

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ABSTRACT

A field experiment was conducted at Agricultural College Farm, Bapatla during *kharif* 2016 to study the effect of zinc in combination with organic manures on yield and zinc content in different plant parts at different growth stages of groundnut. The experimental soil was slightly acidic in reaction, low in organic carbon, available N, available P_2O_5, medium in available K_2O, sufficient in available sulphur and all micro nutrients except zinc. The experiment was laid out in randomized block design (RBD) with seven treatments replicated thrice. The treatments consisted of T_1- RDF (30 kg N-40 kg P_2O_5-50 kg K_2O ha^{-1}); T_2- T_1+ 50 kg $ZnSO_4$ ha^{-1} (soil application);T_3- T_1+ 0.2% $ZnSO_4$ foliar spray at 30and 40 days after sowing; T_4 - T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Vermicompost @ 5 t ha^{-1}; T_5- T_1 + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1}; T_6- T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Farmyard manure @ 5 t ha^{-1}; T_7- T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Press mud @ 5 t ha^{-1}. Application of zinc along with organic manures increased groundnut yield. Among all the treatments, the combined application of RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1} (T_7) recorded significantly higher pod yield and kernel yield over all other treatments. The highest zinc content was recorded under T_7 and it was on par with all other treatments supplied with zinc alone and zinc in combination with organic manures. The lowest zinc content was recorded in the treatment T_1 at all stages like peg formation, pod development and harvest. At harvest stage significantly highest zinc uptake in kernel was recorded in the treatment T_7 followed by T_5, T_4, T_6, T_2 and T_3. While the lowest zinc uptake was recorded in the treatment T_1.

Key words: *Groundnut, organic manures, yield and zinc content, zinc sulphate.*

Groundnut (*Arachis hypogaea* L.) is an important oil seeds, as well as food crop. Among the oilseed crops, Groundnut is "king of oilseeds" belongs to the family leguminosae and is commonly called as poor man's almond or peanut In India groundnut is being grown over an area of 4.76 M ha with a total production of 7.40 M t with productivity of 1552 kg ha^{-1}. Andhra Pradesh is one of the leading states with 0.87 M ha area under groundnut with the production of 0.49 M t and a productivity of 564 kg ha^{-1} (Indiastat 2014-15 http://www.indiastat.com). Zn deficiency is a well-documented problem in food crops, causing decreased crop yields and nutritional quality. Generally, the regions in the world with Zn deficient soils are also characterized by widespread Zn deficiency in humans. Zinc is an essential nutrient for plant and human health and about two billion people worldwide are at the risk of Zn deficiency. In India, zinc is now considered as the fourth most important yield limiting nutrient after nitrogen, phosphorus and potassium respectively. Among oilseeds, groundnut in particular suffers from Zn deficiency. Bio-fortification of staple food crops with micronutrient fertilization is one of the cost-effective and sustainable approach to address this problem. Thus biofortification is the process of increasing bio available concentration of essential elements in edible portion of crop plant through agronomic approach.

MATERIAL AND METHODS

Organic manures were applied one week before sowing as per the treatments. Chemical characteristics of the organic manures were given in table 1. Recommended dose of nitrogen, phosphorus and potassium (30 kg N-40 kg P_2O_5-50 kg K_2O ha^{-1}) were applied to all the plots in the

form of urea, single super phosphate and muriate of potash respectively full dose as basal application to the experimental plots before sowing of crop. Zinc as $ZnSO_4$ @ 50 kg ha^{-1} and 37.5 kg ha^{-1} was applied to the respective plots as per the treatments as basal application before sowing i.e., 48 hours after application of P fertilizer. Foliar application of $ZnSO_4$ @ 0.2% twice at 30 and 40 DAS was applied as per the treatments. During pegging stage, gypsum @ 500 kg ha^{-1} was applied near pegging zone. Available zinc in the soils was determined in DTPA extract, using atomic absorption spectrophotometer (Lindsay and Norvell, 1978). Haulm yield was calculated by taking plants from the net plot area threshed and dried and their weight was recorded as per plot basis and later converted to kg per ha. Pods from the net plot area were cleaned and pod weight was recorded on the basis of pod yield kg per plot. Later the pod yield per net plot was computed on hectare basis and expressed in kg per ha. As soon as crop growth period was over, plant samples were collected, washed with water followed by 0.1 N HCl and distilled water and kept for air drying. Air dried plant samples were oven dried at 60^0C for over night and powdered in willey mill. Zinc in the di acid extract was determined using atomic absorption spectrophotometer as per the specifications mentioned by Lindsay and Norvell (1978). The uptake of zinc at harvest was worked out by using the following formula. Zinc uptake was expressed in g ha^{-1}.

$$\text{Zinc Uptake (g ha}^{-1}\text{)} = \frac{\text{Nutrient concentration (\%) x Drymatter yield (g ha}^{-1}\text{)}}{100}$$

RESULTS AND DISCUSSION

YIELD:

The data pertaining to pod, haulm and kernel yields is presented in table 2. The data revealed significant influence of zinc and zinc along with organics in increasing the pod, haulm and kernel yields of groundnut.

Among all the treatments, the combined application of RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1} (T_7) recorded significantly higher pod yield (2613 kg ha^{-1}) over all other treatments. Application of RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1} (T_5) recorded 2320 kg ha^{-1}, RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Vermicompost @ 5 t ha^{-1} (T_4 - 2292 kg ha^{-1}) and RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Farmyard manure @ 5 t ha^{-1} (T_6 – 2180 kg ha^{-1}) which were on par with each other. While the lowest pod yield was observed in T_1 (RDF) which recorded 1757 kg ha^{-1}.

Among all the treatments, the combined application of RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1} (T_7) recorded significantly higher haulm yield (3026 kg ha^{-1}) over all other treatments. Application of RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1} (T_5) recorded 2649 kg ha^{-1}, RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Vermicompost @ 5 t ha^{-1} (T_4 - 2604 kg ha^{-1}), RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Farmyard manure @ 5 t ha^{-1} (T_6 –2483 kg ha^{-1}) and RDF + 50 kg $ZnSO_4$ ha^{-1} (T_2 –2341 kg ha^{-1}) which were on par with each other. While the lowest haulm yield was observed in T_1 (RDF) which recorded 2035 kg ha^{-1}.

Among the different treatments significantly highest kernel yield (1887 kg ha^{-1}) was recorded in the treatment T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) over all other treatments. Application of RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1} (T_5) 1617 kg ha^{-1}, RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Vermicompost @ 5 t ha^{-1} (T_4 - 1575 kg ha^{-1}), RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Farmyard manure @ 5 t ha^{-1} (T_6 – 1491 kg ha^{-1}) which were on par with each other. While the lowest kernel yield was observed in T_1 (RDF) which recorded 1122 kg ha^{-1}.

This might be due to the application of zinc and organics which helped in the slow and steady rate of nutrient release into soil solution to match the required absorption pattern of groundnut thereby increased the yield. Further the rapid release of N, P and K from inorganic fertilizers and steady supply of these nutrients from organic manures might have met the nutrient requirement of crop at all the critical stages of crop growth. In addition, the beneficial influence of zinc through activation of various enzymes and basic metabolic rate in plants facilitated the synthesis of nucleic acids and hormones, which in turn enhanced the pod yield due to greater availability of nutrients and production of photosynthates. These results are in agreement with those of Elayaraja (2014).

The increase in the yield due to application of zinc is that it acts as catalyst in many physiological and metabolic processes and metal activator of enzymes and that might have increased growth and development of plants, zinc also exerted a beneficial effect on chlorophyll content in the leaves and so it indirectly increased the production of photosynthates which ultimately gave higher pod and haulm yields.

Similar results were also reported by Kulandaivel *et al.* (2004).

Available Zinc:

Available zinc was significantly influenced by different treatments at peg formation, pod development and harvest stage of the crop. Data on the effect of RDF + zinc and combined application of RDF + zinc and organic manures on soil DTPA extractable zinc content at peg formation, pod development and harvest stage of crop are presented in the table 3.

Among the different treatments at peg formation stage the maximum soil DTPA extractable zinc content (1.54 mg kg^{-1}) was recorded in the treatment T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) which was on par with all other treatments supplied with zinc along with organic manures i.e., T_5 (1.46 mg kg^{-1}), T_4 (1.39 mg kg^{-1}) and T_6 (1.31 mg kg^{-1}). The lowest soil DTPA extractable zinc content (0.54 mg kg^{-1}) was recorded in the treatment T_1 (RDF).

Among the different treatments the maximum soil DTPA extractable zinc content (1.90 mg kg^{-1}) was recorded in the treatment T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) at pod development stage. This treatment however was on par with all other treatments supplied with zinc along with organic manures i.e., T_5 (1.83 mg kg^{-1}), T_4 (1.71 mg kg^{-1}) and T_6 (1.69 mg kg^{-1}). The lowest soil DTPA extractable zinc content (0.61 mg kg^{-1}) was recorded in the treatment T_1 (RDF).

The highest available zinc status at harvest stage (1.72 mg kg^{-1}) was recorded with the combined application of (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1} (T_7). This treatment however was on par with all other treatments supplied with zinc along with organic manures i.e., T_5 (1.64 mg kg^{-1}), T_4 (1.59 mg kg^{-1}) and T_6 (1.57 mg kg^{-1}). This was followed by T_2 (1.21 mg kg^{-1}) and T_3 (0.92 mg kg^{-1}). The treatment supplied with RDF (T_1) registered the lowest DTPA-Zn availability of 0.57 mg kg^{-1} at harvest stage.

The increased zinc availability might be attributed to the direct addition of these nutrients either by zinc fertilizer or organic manures. Further the chelation of micronutrients with applied organics might have mobilized and increased the availability of Zn in soil. These findings are in accordance with Raniperumal *et al.* (1991) and Singaravel *et al.* (2004).

Zinc Content

The data pertaining to zinc content in plants are presented in table 4. The data revealed a significant effect of zinc and combined application of zinc with organic manures on zinc content of groundnut.

The highest zinc content was recorded under T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) and it was on par with all other treatments supplied with zinc alone and zinc in combination with organic manures. The lowest zinc content was recorded in the treatment T_1 (RDF) at all stages like peg formation, pod development and harvest.

At harvest stage, among the different treatments the highest zinc content (46.79, 11.70 and 31.56 ppm in haulm, shell and kernel, respectively) was recorded in the treatment T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) and it was on par with all other treatments supplied with zinc alone and zinc in combination with organic manures except T_1. While the lowest zinc content (36.53, 10.08 and 27.62 ppm in haulm, shell and kernel, respectively) was recorded in the treatment T_1 (RDF).

Zinc application fortified the kernel and haulm of groundnut. Application of zinc as well as zinc in combination with organic manures improved zinc content in kernel, shell and haulm at harvest. (Rana *et al.,* 2016).

Effect of zinc application on the zinc content in kernel was significant. This improvement in zinc content in kernel might be attributed to more availability of zinc in the soil, which improved the uptake of zinc and thereby improvement in zinc content. The results corroborate the findings of Chitdeshwari and Poongthai (2003) and Arunachalam *et al.* (2012). They reported that basal application of zinc enhanced the soil available zinc content and also increased the zinc content in kernel.

Zinc Uptake

The data pertaining to uptake of zinc by groundnut is presented in table 5. The results indicated significant differences among the treatments on zinc uptake at peg formation, pod development and at harvest stages and have shown an increasing trend. The zinc accumulated by haulm, shell and kernel was significantly increased due to the application of zinc fertilizer and zinc in combination with organic manures.

Table 1: Chemical Characteristics of Organic Manures

S. No.	Characteristics	FYM	Vermicompost	Poultry manure	Press mud
1	Total nitrogen (%)	0.56	1.10	1.21	1.33
2	Total phosphorus (%)	0.35	0.81	0.90	1.42
3	Total potassium (%)	0.42	0.50	1.08	1.31
4	Total sulphur (%)	0.02	0.16	0.23	0.49
5	Total calcium (%)	0.08	1.26	2.50	3.26
6	Zn (mg kg^{-1})	93.61	110.40	212.70	39.70
7	Fe (mg kg^{-1})	2041.90	2216.30	2413.40	2569.90
8	Mn (mg kg^{-1})	226.00	270.00	368.00	52.00
9	Cu (mg kg^{-1})	36.00	41.00	46.00	81.00

Table 2: Effect of zinc in combination with organic manures on yield and yield parameters of groundnut

Treatments	Haulm yield (kg ha^{-1})	POD yield (kg ha^{-1})	Kernal yield (kg ha^{-1})
T_1: RDF (30 kg N-40 kg P_2O_5-50 kg K_2O ha^{-1})	2035	1757	1122
T_2: T_1+ 50 kg $ZnSO_4$ ha^{-1} (soil application)	2341	1955	1353
T_3: T_1+ 0.2% $ZnSO_4$ foliar spray at 30 and 40 days after sowing	2216	1915	1296
T_4: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Vermicompost @ 5 t ha^{-1}	2604	2292	1575
T_5: T_1 + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1}	2649	2320	1617
T_6: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Farmyard manure @ 5 t ha^{-1}	2483	2180	1491
T_7: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Press mud @ 5 t ha^{-1}	3026	2613	1887
SEm±	106.50	81.40	64.85
CD @ 0.05	328.00	251.00	200.00
CV (%)	7.20	7.28	7.24

Table 3: Effect of zinc in combination with organic manures on soil available Zn (mg kg^{-1}) at different growth stages of groundnut

Treatments	Peg formation	POD development	Harvest
T_1: RDF (30 kg N-40 kg P_2O_5-50 kg K_2O ha^{-1})	0.54	0.61	0.57
T_2: T_1+ 50 kg $ZnSO_4$ ha^{-1} (soil application)	1.11	1.27	1.21
T_3: T_1+ 0.2% $ZnSO_4$ foliar spray at 30 and 40 days after sowing	0.65	1.03	0.92
T_4: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Vermicompost @ 5 t ha^{-1}	1.39	1.71	1.59
T_5: T_1 + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1}	1.46	1.83	1.64
T_6: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Farmyard manure @ 5 t ha^{-1}	1.31	1.69	1.57
T_7: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Press mud @ 5 t ha^{-1}	1.54	1.90	1.72
SEm±	0.07	0.13	0.10
CD (0.05)	0.23	0.40	0.30
CV (%)	11.51	10.02	9.13
Initial		0.51	

Table 4: Effect of zinc in combination with organic manures on Zn content (ppm) in different plant parts at different growth stages of groundnut

Treatments	Peg formation	POD development	Harvest Haulm	Harvest Shell	Harvest Kernel
T_1 : RDF (30 kg N-40 kg P_2O_5-50 kg K_2O ha^{-1})	28.14	37.40	36.53	10.08	27.62
T_2 : T_1+ 50 kg $ZnSO_4$ ha^{-1} (soil application)	31.12	43.30	46.21	11.23	31.10
T_3: T_1+ 0.2% $ZnSO_4$ foliar spray at 30 and 40 days after sowing	28.89	43.64	46.67	11.63	31.48
T_4: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Vermicompost @ 5 t ha^{-1}	32.17	43.79	46.60	11.42	31.37
T_5: T_1 + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1}	32.71	44.20	46.67	11.60	31.44
T_6: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Farmyard manure @ 5 t ha^{-1}	31.76	43.53	46.47	11.33	31.25
T_7: T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Press mud @ 5 t ha^{-1}	32.88	44.54	46.79	11.70	31.56
SEm±	0.92	1.46	1.89	0.32	0.56
CD (0.05)	2.84	4.52	5.83	1.00	1.72
CV (%)	8.14	7.89	9.13	8.51	9.14

Table 5: Effect of zinc in combination with organic manures on Zn uptake (g ha^{-1}) in different plant parts at different growth stages of groundnut

Treatments	Peg formation	POD development	Harvest Haulm	Harvest Shell	Harvest Kernel
T_1 : RDF (30 kg N-40 kg P_2O_5-50 kg K_2O ha^{-1})	33.99	67.99	65.28	5.08	29.19
T_2 : T_1+ 50 kg $ZnSO_4$ ha^{-1} (soil application)	43.37	84.70	91.04	5.88	36.95
T_3 : T_1+ 0.2% $ZnSO_4$ foliar spray at 30 and 40 days after sowing	36.39	79.34	90.15	5.99	36.06
T_4 : T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Vermicompost @ 5 t ha^{-1}	49.34	92.84	97.03	6.43	39.50
T_5 : T_1 + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1}	50.43	97.86	98.33	6.68	40.65
T_6 : T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Farmyard manure @ 5 t ha^{-1}	45.15	87.59	94.51	6.37	38.60
T_7 : T_1 + 37.5 kg $ZnSO_4$ ha^{-1}+ Press mud @ 5 t ha^{-1}	57.03	112.07	113.22	6.83	47.62
SEm±	1.99	4.58	4.66	0.32	1.84
CD (0.05)	6.14	14.14	14.37	1.01	5.67
CV (%)	7.65	8.89	8.70	9.20	8.31

At peg formation stage significantly highest zinc uptake (57.03 g ha^{-1}) was recorded in the treatment T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) followed by 50.43, 49.34 and 45.15 g ha^{-1} in treatment T_5 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1}), T_4 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Vermicompost @ 5 t ha^{-1} and T_6 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Farmyard manure @ 5 t ha^{-1}), respectively and these treatments were on par with each other. The lowest zinc uptake (33.99 g ha^{-1}) was recorded in the treatment T_1 (RDF).

At pod development stage significantly highest zinc uptake (112.07 g ha^{-1}) was recorded in the treatment T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) followed by 97.86, 92.84, 87.59 and 84.70 g ha^{-1} in treatment T_5 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Poultry manure @ 5 t ha^{-1}), T_4 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Vermicompost @ 5 t ha^{-1}), T_6 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Farmyard manure @ 5 t ha^{-1}) and T_2 (RDF + 50 kg $ZnSO_4$ ha^{-1}) respectively and these treatments were on par with each other. The lowest zinc uptake (67.99 g ha^{-1}) was recorded in the treatment T_1 (RDF).

At harvest stage significantly highest uptake (113.22, 6.83 and 47.62 g ha^{-1} in haulm, shell and kernel, respectively) was recorded in the treatment T_7 (RDF + 37.5 kg $ZnSO_4$ ha^{-1} + Press mud @ 5 t ha^{-1}) followed by T_5 (98.33 g ha^{-1}), T_4 (97.03 g ha^{-1}), T_6 (94.51 g ha^{-1}), T_2 (91.04 g ha^{-1}) and T_3 (90.15 g ha^{-1}) in haulm. In shell, treatment T_7 was on par with all other treatments except T_1 and in kernel, T_7 was followed by T_5 (40.65 g ha^{-1}), T_4 (39.50 g ha^{-1}), T_6 (38.60 g ha^{-1}), T_2 (36.95 g ha^{-1}) and T_3 (36.06 g ha^{-1}). While the lowest zinc uptake (65.28, 5.08 and 29.19 g ha^{-1} in haulm, shell and kernel, respectively) was recorded in the treatment T_1 (RDF).

The uptake of zinc by groundnut haulm, shell and kernel were affected significantly due to zinc alone and zinc in combination with organic manures application.

Zinc application enhanced the uptake of zinc and this increase was due to higher concentration of zinc in plants parts. The uptake of zinc in haulm, shell and kernel of groundnut increased significantly due to application of organic manures. The significant increase in the uptake of zinc by haulm, shell and kernel under organic manure application might be due to significant increase in yield and zinc concentration in haulm, shell and kernel. An increase in uptake of zinc due to FYM was also reported by Sharma *et al.* (2002).

Conclusion

Based on the above results and discussion, it can be concluded that application of RDF + $ZnSO_4$ @ 37.5 kg ha^{-1} along with organic manures *viz.,* pressmud, poultry manure, vermicompost and farmyard manure were beneficial and effectively increased yields in groundnut. Application of $ZnSO_4$ (soil, foliar and along with organic manures *viz.,* pressmud, poultry manure, vermicompost and farmyard manure) significantly increased available zinc, zinc content and uptake of zinc over control.

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