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SOIL SCIENCE

Effect of Zinc and Iron Ferti-Fortification on Growth, Pod Yield and Zinc Uptake of Groundnut (*Arachis hypogaea* L.) Genotypes

Sai Surya Gowthami, V.[1*] and Ananda, N.[2]

[1]Department of Agronomy, Agriculture College, Bapatla, A.P., India
[2]AICRP on Weed Management, Main Agricultural Research Station, University of Agricultural Sciences, Raichur, India

*Corresponding author: gowthami.101290@gmail.com

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ABSTRACT

A field experiment was conducted during *rabi* season of 2014-15 at Agronomy field unit, College of Agriculture, University of Agricultural Sciences (UAS), Raichur to study the effect of zinc and iron ferti-fortification on growth, pod yield and zinc uptake of groundnut genotypes. The soil of the experimental site was deep black, clay in texture with pH 8.4, deficient in DTPA extractable zinc and iron. Three groundnut genotypes in main plots and seven micronutrient treatments comprising of one control and three each of zinc and iron as soil, foliar and both were assigned in the sub-plot in a split-plot design replicated thrice. Results revealed that the groundnut genotype ICGV-00351 recorded significantly higher plant height and leaf area at harvest (40.05 cm and 5.40 dm^2 $plant^{-1}$, respectively), pod yield (2656 kg ha^{-1}) and Zn uptake by kernels, haulm and total (59.29, 130.46 and 189.75 g ha^{-1}, respectively) when compared to other genotypes. Among the micronutrients soil (25 kg ha^{-1}) and foliar (0.5 %) application of $ZnSO_4$ recorded significantly higher plant height and leaf area at harvest (42.09 cm and 6.30 dm^2 $plant^{-1}$, respectively), pod yield (2656 kg ha^{-1}) and Zn uptake by kernels, haulm and total (67.42, 153.61 and 221.03 g ha^{-1}, respectively) when compared to other treatments.

Highlights

- ICGV-00351 gave best response to zinc and iron application through soil (25 kg ha^{-1}) and foliar (0.5 %) application of $ZnSO_4$ at 30 and 45 DAS as compared to TMV-2 and it were comparable with K-9.
- Soil (25 kg ha^{-1}) and foliar (0.5 %) application of $ZnSO_4$ at 30 and 45 DAS was found to be more effective in increasing pod yield and zinc uptake in the ground nut.

Keywords: Groundnut genotypes, Leaf area, Pod yield, Zinc uptake, Zinc and Iron fortification.

About half of the world's human population suffers from micronutrient malnutrition (a term used to refer any condition in which the body does not receive enough nutrients for proper functioning), including Selenium (Se), Zinc (Zn), Iron (Fe) and Iodine (I), which are mainly associated with low dietary intake of micronutrients in diets with less diversity of food (Mayer *et al.* 2008). Micronutrient malnutrition can lower intelligence quotient, cause stunting and blindness in children, lower resistance to disease in both children and adults and increase risks for both mothers and infants during child birth.

Zinc (Zn) and iron (Fe) deficiency is a well-documented problem in food crops, causing decreased crop yield and nutritional quality. Generally, the regions in the world with Zn and Fe deficient soils are also characterized by widespread Zn and Fe deficiency in humans (Rakshit *et al.* 2015). According to World Health Organization (WHO) report on the risk factors responsible for

the development of illnesses and diseases, Zn and Fe deficiencies rank 11th and 12th among the 20 most important factors in the world and 5th and 6th among the 10 most important factors in the developing countries (Anon., 2002).

Among the oilseed crops, Groundnut (*Arachis hypogaea* L.), the king of oilseeds, is the world's fourth most important source of edible oil and third most important source of vegetable protein.

Zinc plays significant role in various enzymatic and physiological activities of the plant. Zinc catalyses the process of oxidation in plant cells and is vital for transformation of carbohydrates, regulates the consumption of sugar, increases source of energy for the production of chlorophyll, aids in the formation of auxins which produce more plant cells and more dry matter, that in turn will be stored in seed as a sink and promotes absorption of water. In plants, the deficiency of zinc arises mainly due to alkaline soil pH, calcareousness, low organic matter, exposed sub soil, Zn free fertilizers and flooding induced electrochemical changes.

Zinc deficiency is responsible for many severe health complications, including impairments of physical growth, immune system and learning ability, combined with increased risk of infections, DNA damage and cancer development.

However, in India due to low productivity, the per capita availability of groundnut is less. High Zn density groundnuts may be a solution to ensure adequate level of Zn intake (Singh and Lal, 2007) which necessitates increasing Zn concentrations of seed through fortification and selection of high Zn density genotypes. Thus, an effort was made to increase the seed Zn content in a number of groundnut cultivars through soil and foliar application of Zn.

Among micronutrients, Fe was the first nutrient element discovered as essential for plant life. In the plant system, Fe plays an important role in a series of metabolic activities involving respiratory enzymes and various photosynthetic reactions. Iron also plays an important role in legumes for nodulation and nitrogen fixation. It is not only essential element required by legume host plants but also the rhizobium. Failure of the infecting rhizobia to obtain adequate amounts of Fe from the plant results in arrested nodule development and failure of the host plant to fix nitrogen in adequate amounts. Fe application also found to improve the protein content in groundnut kernels. Gris (1844) corrected the chlorosis in grapevine by foliar application of ferrous sulphate thus, establishing the essentiality of Fe for growth and development of higher plants. Iron has been considered to be associated with chlorophyll formation because any of its deficiency in the plant system results in foliar chlorosis.

The extent of Fe deficiency in India is next to that of zinc and seems to be one fourth as extensive as that of zinc. Iron deficiency is responsible for many severe health complications, including anemia, reduced cognitive ability, childbirth complications, reduced physical capacity and productivity.

There are several approaches to increase the concentration of micronutrients in foods, including food stuff nutrient fortification, supplementation programmes, conventional breeding and genetic engineering to diagnose and manage the problem of micronutrient malnutrition. However, these approaches appear to be expensive and are not easily accessible by those living in the developing countries. Alternatively, bio-fortification of staple food crops with micronutrients through the use of agricultural tools (e.g., breeding and fertilization) is a cost-effective and sustainable approach to address this problem. However, plant breeding, the most powerful agricultural approach, may not effectively work in regions where soils have very low plant-available pools of micronutrients due to very adverse soil chemical and physical conditions (Cakmak, 2008). Besides, finding sufficient and promising genotypic variation and maintaining the stability of targeted micronutrient traits across diverse types of environments may also be difficult. Under such circumstances, agronomic bio-fortification, including the use of micronutrient fertilizers, is an important complementary solution (White and Broadley, 2009). Hence, the present investigation was carried out to assess the performance of groundnut genotypes with respect to plant height, leaf area, pod yield and zinc uptake as influenced by ferti-fortification.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* season of 2014-15 at Agronomy field unit, College

of Agriculture, Univerity of Agricultural Sciences (UAS), Raichur. The soil of the experimental site was deep black soil, clay in texture (sand 23.5 %, silt 27.5 % and clay 49.2 %) with a bulk density of 1.30 Mg m^{-3} having pH 8.4. The soil was low in available N (231 kg ha^{-1}), medium in available P_2O_5 (27.3 kg ha^{-1}) high in available K_2O (345 kg ha^{-1}) and deficient in zinc and iron with DTPA extractable value of 0.45 and 3.72 ppm, respectively. An amount of 48.7 mm rainfall was received during crop growth period (November 2014 to March 2015).

The experiment was conducted in split plot design having three replications with three groundnut genotypes (ICGV-00351, K-9 and TMV-2) in the main plots and seven micronutrient treatments *viz.*, control (no micronutrient- only recommended dose of fertilizer + FYM @ 10 tones ha^{-1}), soil application of $ZnSO_4$ @ 25 kg ha^{-1}, foliar application of $ZnSO_4$ @ 0.5% at 30 and 45 DAS, soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5% at 30 and 45 DAS, soil application of $FeSO_4$ @ 25 kg ha^{-1}, foliar application of $FeSO_4$ @ 0.5% at 30 and 45 DAS, soil application of $FeSO_4$ @ 25 kg ha^{-1} + foliar application of $FeSO_4$ @ 0.5% at 30 and 45 DAS in the sub-plots.

I. TMV-2

TMV-2 is a Spanish bunch type with light green color foliage, small to medium size pod without beak. It is most suited for summer season and has a shelling turnover of 76% and oil content of 49.7%. The crop duration is about 100-105 days. This is the most popular and widely grown variety in Andhra Pradesh. But, it is highly susceptible to iron chlorosis. Its yield potential is 1600-2000 kg ha^{-1}. It is drought-tolerant variety.

II. K-9

K-9 is also known as MK-374. This variety was released from ANGRAU, Kadiri in 2009. It matures in 115-125 days. Plant height is 18 – 23 cm. It has two seeded bold pods. Seeds are of medium size and of brownish rose colour. Its seeds contain 43.75% oil and shelling percentage is 76 %. It has a yield potential of 2800 to 3500 kg ha^{-1}. It is tolerant to thrips, jassids, nematodes, late leaf spot, rust, dry root rot and collar rot.

III. ICGV-00351

ICGV-00351 is a spanish bunch type of variety developed by ICRISAT, Patancheru, Telangana. It is also known as CO^{-}_{2}. It matures in 105 to 110 days. Its yield potential is 3800-4000 kg ha^{-1}.

The recommended dose of fertilizer nitrogen, phosphorus and potassium were applied at the rate of 25:75:25 kg N, P_2O_5 and K_2O ha^{-1} in the form of 12:36:12, a complex fertilizer. The entire quantity of fertilizer was applied at the time of sowing in the furrows opened with 5 cm spacing away from the seed line and later the furrows were covered with soil. Zinc as $ZnSO_4$ @ 25 kg and iron as $FeSO_4$ @ 25 kg ha^{-1} were applied to the respective plots as per the treatments at the time of sowing. Foliar application of $ZnSO_4$ @ 0.5% and $FeSO_4$ @ 0.5% at 30 and 45 DAS were applied as per the treatments. Zinc and iron each @ 2.25 kg ha^{-1}were dissolved in 450 liters of water and sprayed using power sprayer. FYM was uniformly applied over all the treatments.

Groundnut seeds were treated with *Trichoderma*, Rhizobium and phosphate solubilizing bacteria @ 4 g, 2.5 kg and 2.5 kg ha^{-1}, respectively. Gypsum as a soil application was applied at the rate of 500 kg ha^{-1} at 35 DAS. The furrows were opened with the help of a wooden marker. The seeds were hand dibbled and covered by soil. The sowing operation was carried on 19th November, 2014 at a spacing of 30 × 10 cm. All the genotypes were harvested on 18th March 2015. Shelling was done manually. Bold and healthy seeds of groundnut (TMV-2, K-9 and ICGV-00351) were selected for sowing. Seeds were weighed separately for each plot at the rate of 125 kg ha^{-1} (TMV-2 and K-9) and 150 (ICGV-00351) kg ha^{-1}. The seeds were winnowed, cleaned and the seed weight per net plot was recorded on hectare basis and expressed in kg ha^{-1}.

Method of measuring Leaf area per plant

The leaf area per plant was worked out by disc method on dry weight basis as per the procedure suggested by Vivekanandan *et al.* (1972).

$$LA = \frac{Wa \times A}{Wd}$$

Where,

LA = Leaf area (dm^2)
Wa = Oven dry weight of all leaves (inclusive of 10 disc weight)
d = Oven dry weight of 10 discs
A = Area of the 10 discs (dm^2)

Method for analysis of Zinc and iron uptake by plant

The zinc and iron concentration (ppm) in plant sample was determined by taking a known volume of the digested samples by adopting Atomic Absorption Spectrophotometer (AAS) method as described by Follett and Lindsay (1969).

RESULTS AND DISCUSSION

Performance of groundnut genotypes

The plant height of groundnut differed significantly among the genotypes at harvest. Among the groundnut genotypes, ICGV-00351 recorded significantly higher plant height and leaf area at harvest (40.05 cm and 5.40 dm^2 $plant^{-1}$, respectively) when compared to other genotypes. Significantly lower plant height and leaf area (35.38 cm 4.38 dm^2 $plant^{-1}$, respectively) was observed in TMV-2 at harvest (Table 1).

The pod yield of groundnut differed significantly among the genotypes. The genotype ICGV-00351 produced considerably higher pod yield (2656 kg ha^{-1}) than TMV-2 (2074 kg ha^{-1}) and was on par with K-9 (2534 kg ha^{-1}).

Groundnut genotypes showed significant influence on Zn uptake by kernels, haulm and total (kernel + haulm) Zn uptake. Significantly higher Zn uptake by kernels, haulm and total Zn uptake was recorded in genotype ICGV-00351 (59.29, 130.46 and 189.75 g ha^{-1}, respectively) than TMV-2 (40.48, 106.91 and 147.39 g ha^{-1}, respectively) except K-9 (53.07, 119.94 and 173.01g ha^{-1}, respectively) (Table 2). Tomar *et al.* (1995) also observed higher uptake of Zn in kernels and haulm of groundnut genotypes. This might be due to the positive response of genotype ICGV-00351 to micronutrients application and having inherent ability of the genotype to load high zinc content in kernel and haulm with high pod yield. Similar genetic variability of kernel micronutrients in groundnut genotypes was also reported by Arunachalam *et al.* (2013).

Effect of micronutrients application

Among micronutrients application, soil (25 kg ha^{-1})

Table 1: Plant height, leaf area and pod yield of groundnut genotypes at harvest as influenced by ferti-fortification

Micronutrient application	Plant height (cm)				Leaf area(dm^2 $plant^{-1}$)				Pod yield (kg ha^{-1})			
	Genotypes											
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1: Control (RDF+ FYM)	30.80	32.17	31.50	31.49	2.80	3.11	3.67	3.19	1453	2184	2489	2042
S_2: Soil application of $ZnSO_4$ @ 25 kg ha^{-1}	35.50	38.50	43.07	39.02	4.44	5.80	7.12	5.79	2194	2447	2887	2509
S_3: Foliar application of $ZnSO_4$ @ 0.5%	34.67	38.60	41.77	38.35	3.60	5.63	5.79	5.01	1786	2559	2554	2300
S_4: Soil application of $ZnSO_4$ @ 25 kg ha^{-1} + foliar application of $ZnSO_4$ @ 0.5%	40.90	40.67	44.70	42.09	6.28	6.63	6.00	6.30	2559	2962	2846	2789
S_5: Soil application of $FeSO_4$ @ 25 kg ha^{-1}	32.97	38.33	40.10	37.13	7.08	3.55	3.08	4.57	2293	2441	2524	2419
S_6: Foliar application of $FeSO_4$ @ 0.5%	34.57	34.40	37.37	35.45	2.40	5.04	5.00	4.15	2039	2366	2289	2231
S_7: Soil application of $FeSO_4$ @ 25 kg ha^{-1} + foliar application of $FeSO_4$ @ 0.5%	38.27	40.13	41.83	40.08	4.03	6.29	7.15	5.82	2197	2778	3002	2659
Mean	35.38	37.54	40.05	—	4.38	5.15	5.40	—	2074	2534	2656	—
	S. Em±		C. D. at 5%		S. Em±		C. D. at 5%		S. Em±		C. D. at 5%	
Genotypes (M)	0.23		0.90		0.14		0.53		58		226	
Micronutrients application (S)	0.64		1.84		0.57		1.64		95		273	
S×M	1.11		NS		0.99		NS		165		NS	
M×S	1.05		NS		0.93		NS		163		NS	

M_1- TMV-2, M_2- K-9, M_3 - ICGV-00351, NS - Non significant, foliar application at 30 and 45 DAS

Table 2: Zinc uptake by groundnut genotypes as influenced by ferti-fortification

Micronutrient application	Zinc uptake (g ha^{-1})											
	Kernel				Haulm				Total (kernel+haulm) uptake			
	Genotypes											
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
S_1: Control (RDF+ FYM)	29.21	44.81	46.49	40.17	81.06	98.77	107.40	95.74	110.26	143.59	153.89	135.91
S_2: Soil application of $ZnSO_4$@ 25 kg ha^{-1}	45.62	53.61	70.87	56.70	119.08	148.89	144.95	137.64	164.70	202.50	215.83	193.34
S_3: Foliar application of $ZnSO_4$ @ 0.5%	39.25	52.63	62.74	51.54	129.42	112.55	136.66	126.21	168.66	165.18	199.40	177.75
S_4: Soil application of $ZnSO_4$@ 25 kg ha^{-1} + foliar application of $ZnSO_4$@ 0.5%	53.39	77.34	71.53	67.42	144.09	143.57	173.17	153.61	197.47	220.94	244.71	221.03
S_5: Soil application of $FeSO_4$@ 25 kg ha^{-1}	41.36	45.84	57.73	48.31	87.56	126.38	126.81	113.58	128.92	172.23	184.55	161.90
S_6: Foliar application of $FeSO_4$ @ 0.5%	39.71	41.24	44.13	41.69	93.77	84.58	118.71	99.02	133.48	125.82	162.84	140.71
S_7: Soil application of $FeSO_4$@ 25 kg ha^{-1} + foliar application of $FeSO_4$@ 0.5%	34.82	56.01	61.56	50.80	93.43	124.81	105.52	107.22	128.24	180.82	167.08	158.71
Mean	40.48	53.07	59.29	—	106.91	119.94	130.46	—	147.39	173.01	189.75	—

	S.Em±	C. D. at 5%	S.Em±	C. D. at 5%	S.Em±	C. D. at 5%
Genotypes (M)	2.14	8.41	3.18	12.49	3.57	14.01
Micronutrients application (S)	2.56	7.36	6.63	19.01	7.25	20.79
S × M	4.44	NS	11.48	NS	12.56	NS
M × S	4.64	NS	11.09	NS	12.16	NS

M_1- TMV-2, M_2 - K-9, M_3 - ICGV-00351, NS - Non significant, foliar application at 30 and 45 DAS

and foliar (0.5 %) application of $ZnSO_4$ and $FeSO_4$ resulted in significant higher plant height in all the genotypes over control at all the stages of crop growth. At harvest, soil (25 kg ha^{-1}) and foliar (0.5 %) application of $ZnSO_4$ (S_4) produced higher plant height and leaf area at harvest (42.09 cm and 6.30 dm^2 plant^{-1}, respectively), over the other treatments (Table 1). The improvement in plant height due to zinc application might be attributed to proper nourishment of crop and optimum growth. Addition of FYM might help in the release of micronutrients favourable for the crop growth. Also, there is an increase activity of meristamatic cells and cell elongation with the application of micronutrients as they were known to have favourable effect on the metabolic process (Price *et al.* 1972).

The pod yield of groundnut was influenced significantly due to different micronutrients application. Significantly higher pod yield of groundnut was recorded with combined application of $ZnSO_4$ as soil (25 kg ha^{-1}) and foliar (0.5 %) application (S_4) (2789 kg ha^{-1}) over other treatments *viz*., control (2042 kg ha^{-1}), soil application of $ZnSO_4$ (2509 kg ha^{-1}), foliar application of $ZnSO_4$ (2300 kg ha^{-1}), soil application of $FeSO_4$ (2419 kg ha^{-1}) and foliar application of $FeSO_4$ (2231 kg ha^{-1}) (Table 1). However, it was found on par with soil (25 kg ha^{-1}) and foliar (0.5 %) application of $FeSO_4$ (2659 kg ha^{-1}) (S_7).

Different micronutrients application also influenced Zn uptake by kernels, haulm and total Zn uptake significantly. Soil (25 kg ha^{-1}) and foliar (0.5 %) application of $ZnSO_4$ (S_4) recorded considerably higher Zn uptake by kernels, haulm and total Zn uptake (67.42, 153.61 and 221.03 g ha^{-1}, respectively) when compared to other treatments. However, it was found on par with soil (25 kg ha^{-1}) application of $ZnSO_4$ (S_2) with respect to the uptake of Zn (137.64 g ha^{-1}) in haulm (Table 2). The increase in Zn uptake was due to the better and greater availability of Zn at the root zone. Similar results were also recorded by Pattar *et al.* (1999) and Patel *et al.* (2007). Debroy *et al.* (2013) also observed increased Zn uptake in kernels and haulm due to soil and foliar application of zinc in greengram.

CONCLUSION

Among the genotypes, ICGV-00351 gave best response to zinc and iron application through soil (25 kg ha^{-1}) and foliar (0.5 %) application of $ZnSO_4$ at 30 and 45 DAS as compared to TMV-2 and it were comparable with K-9. Soil (25 kg ha^{-1}) and foliar (0.5 %) application of $ZnSO_4$ at 30 and 45 DAS was found to be more effective in increasing pod yield and zinc uptake in the kernel, net returns and BC ratio.

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