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

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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 dm² 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 ZnSO₄ recorded significantly higher plant height and leaf area at harvest (42.09 cm and 6.30 dm² 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 ZnSO₄, 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 ZnSO₄, 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 childbirth.

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
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of Agriculture, University 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 P₂O₅ (27.3 kg ha⁻¹) high in available K₂O (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 ZnSO₄ @ 25 kg ha⁻¹, foliar application of ZnSO₄ @ 0.5% at 30 and 45 DAS, soil application of ZnSO₄ @ 25 kg ha⁻¹ + foliar application of ZnSO₄ @ 0.5% at 30 and 45 DAS, soil application of FeSO₄ @ 25 kg ha⁻¹, foliar application of FeSO₄ @ 0.5% at 30 and 45 DAS, soil application of FeSO₄ @ 25 kg ha⁻¹ + foliar application of FeSO₄ @ 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. It is tolerant to thrips, jassids, nematodes, late leaf spot, rust, dry root rot and collar rot.

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 CO₂⁻. 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, P₂O₅ and K₂O 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 ZnSO₄ @ 25 kg and iron as FeSO₄ @ 25 kg ha⁻¹ were applied to the respective plots as per the treatments at the time of sowing. Foliar application of ZnSO₄ @ 0.5% and FeSO₄ @ 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 was uniformly applied 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 (dm²)

\( Wa = \) Oven dry weight of all leaves (inclusive of 10 disc weight)

\( d = \) Oven dry weight of 10 discs

\( A = \) Area of the 10 discs (dm²)
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 dm² plant⁻¹, respectively) when compared to other genotypes. Significantly lower plant height and leaf area (35.38 cm and 4.38 dm² 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 173.01 g 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>
<thead>
<tr>
<th>Micronutrient application</th>
<th>Plant height (cm)</th>
<th>Leaf area(dm² plant⁻¹)</th>
<th>Pod yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Genotypes</td>
<td>M₁</td>
<td>M₂</td>
<td>M₃</td>
</tr>
<tr>
<td>S₁: Control (RDF+ FYM)</td>
<td>30.80</td>
<td>32.17</td>
<td>31.50</td>
</tr>
<tr>
<td>S₂: Soil application of ZnSO₄ @ 25 kg ha⁻¹</td>
<td>35.50</td>
<td>38.50</td>
<td>43.07</td>
</tr>
<tr>
<td>S₃: Foliar application of ZnSO₄ @ 0.5%</td>
<td>34.67</td>
<td>38.60</td>
<td>41.77</td>
</tr>
<tr>
<td>S₄: Soil application of ZnSO₄ @ 25 kg ha⁻¹ + foliar application of ZnSO₄ @ 0.5%</td>
<td>40.90</td>
<td>40.67</td>
<td>44.70</td>
</tr>
<tr>
<td>S₅: Soil application of FeSO₄ @ 25 kg ha⁻¹</td>
<td>32.97</td>
<td>38.33</td>
<td>40.10</td>
</tr>
<tr>
<td>S₆: Foliar application of FeSO₄ @ 0.5%</td>
<td>34.57</td>
<td>34.40</td>
<td>37.37</td>
</tr>
<tr>
<td>S₇: Soil application of FeSO₄ @ 25 kg ha⁻¹ + foliar application of FeSO₄ @ 0.5%</td>
<td>38.27</td>
<td>40.13</td>
<td>41.83</td>
</tr>
</tbody>
</table>

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

M₁ - TMV-2, M₂ - K-9, M₃ - 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$_3$) 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 meristematic 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$_3$) (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$_4$).

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$_3$) recorded considerably higher Zn uptake by kernels, haulm and total Zn uptake (67.42, 153.61 and 221.03 g ha$^{-1}$) when compared to other treatments. However, it was found on par with soil (25 kg ha$^{-1}$) application of ZnSO$_4$ (S$_3$) 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.

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

<table>
<thead>
<tr>
<th>Micronutrient application</th>
<th>Zinc uptake (g ha$^{-1}$)</th>
<th>Genotypes</th>
<th>Kernel</th>
<th>Haulm</th>
<th>Total (kernel+haulm) uptake</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M_1$</td>
<td>$M_2$</td>
<td>$M_3$</td>
<td>Mean</td>
<td>$M_1$</td>
</tr>
<tr>
<td>$S_1$: Control (RDF+ FYM)</td>
<td>29.21</td>
<td>44.81</td>
<td>46.49</td>
<td>40.17</td>
<td>81.06</td>
</tr>
<tr>
<td>$S_2$: Soil application of ZnSO$_4$ @ 25 kg ha$^{-1}$</td>
<td>45.62</td>
<td>53.61</td>
<td>70.87</td>
<td>56.70</td>
<td>119.08</td>
</tr>
<tr>
<td>$S_3$: Foliar application of ZnSO$_4$ @ 0.5%</td>
<td>39.25</td>
<td>52.63</td>
<td>62.74</td>
<td>51.54</td>
<td>129.42</td>
</tr>
<tr>
<td>$S_4$: Soil application of ZnSO$_4$ @ 0.5%</td>
<td>53.39</td>
<td>77.34</td>
<td>71.53</td>
<td>67.42</td>
<td>144.09</td>
</tr>
<tr>
<td>$S_5$: Soil application of FeSO$_4$ @ 25 kg ha$^{-1}$</td>
<td>41.36</td>
<td>45.84</td>
<td>57.73</td>
<td>48.31</td>
<td>87.56</td>
</tr>
<tr>
<td>$S_6$: Foliar application of FeSO$_4$ @ 0.5%</td>
<td>39.71</td>
<td>41.24</td>
<td>44.13</td>
<td>41.69</td>
<td>93.72</td>
</tr>
<tr>
<td>$S_7$: Soil application of FeSO$_4$ @ 25 kg ha$^{-1}$+ foliar application of ZnSO$_4$ @ 0.5%</td>
<td>34.82</td>
<td>56.01</td>
<td>61.56</td>
<td>50.80</td>
<td>93.43</td>
</tr>
<tr>
<td>Mean</td>
<td>40.48</td>
<td>53.07</td>
<td>59.29</td>
<td>—</td>
<td>106.91</td>
</tr>
</tbody>
</table>

S.E.m±, C. D. at 5% | S.E.m±, C. D. at 5% | S.E.m±, C. D. at 5% |
| 2.14 | 8.41 | 3.18 | 12.49 | 3.57 | 14.01 |
| 2.56 | 7.36 | 6.63 | 19.01 | 7.25 | 20.79 |
| 4.44 | NS | 11.48 | NS | 12.56 | NS |
| 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*
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.

REFERENCES


