Zinc and iron ferti-fortification in groundnut (Arachis hypogaea L.) genotypes

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ABSTRACT
The investigation was carried out to study the effect of zinc and iron ferti-fortification on plant height, yield and quality parameters of groundnut (Arachis hypogaea L.) genotypes. Among the groundnut genotypes, ICGV-00351 recorded significantly higher plant height and number of leaves at harvest (40.05 cm and 25.86 plant⁻¹), nitrogen uptake by groundnut kernels, haulm and total uptake (68.69, 52.76 and 121.45 kg ha⁻¹, respectively), gross returns, net returns and benefit cost ratio (₹ 122408 ha⁻¹ ₹ 81404 ha⁻¹ and 2.99, respectively) as compared to other genotypes. Among micronutrients application, soil application @ 25 kg ha⁻¹ and foliar application @ 0.5 % of ZnSO₄ (S₁) recorded significantly higher plant height and number of leaves at harvest (42.09 cm and 27.78 plant⁻¹), nitrogen uptake by groundnut kernels, haulm and total uptake (76.43, 57.66 and 134.10 kg ha⁻¹, respectively), gross returns, net returns and benefit cost ratio (₹ 128585 ha⁻¹ ₹ 87131 ha⁻¹ and 3.10, respectively) as compared to other treatments.

Key words: Gross returns, Haulm, Iron fortification, Micronutrients, Nitrogen uptake, Zinc.

INTRODUCTION
Groundnut (Arachis hypogaea L) is a unique crop, combining the attributes of both oilseed and legume crop in the farming system of Indian agriculture. It is a valuable crop planted in dry areas of Asia, Africa, Central and South America, Australia and Caribbean in view of its economic, food and nutritional value.

Zn and Fe deficiency is a well-documented problem in food crops, causing decreased crop yields 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. According to WHO report on the risk factors responsible for 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 developing countries (Anonymous., 2002).

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 not easily accessible by those living in 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 ferti-fortification by Zn and Fe with respect to plant height, number of leaves, nitrogen uptake and economics.

MATERIALS AND METHODS
A field experiment was conducted during rabi season of 2014-15 at Agronomy field unit, College of Agriculture, UAS, Raichur. 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 (RDF+ FYM), 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.

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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 5cm spacing away from the seed line and later 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.

Plant height was measured from the ground level up to the base of node on which the first fully opened leaf from the top was borne at harvest and expressed in centimeter. Total number of fully opened trifoliate leaves was counted in the five plants and their average was taken as number of leaves per plant. Nitrogen concentration in kernel and haulm was determined by modified micro-kjeldhal method as described by Jackson (1967) and expressed in percentage and the total uptake of N was calculated.

**Economics:** The price of the crop products prevailing in the market after the harvest was obtained from the Agriculture Produce Market Committee, Raichur and was used for the calculation of gross returns. The net returns per hectare were calculated by deducting the cost of cultivation from the gross returns. B: C ratio was worked out by using the following formula

\[
\text{Benefit: cost ratio} = \frac{\text{Gross returns (₹ ha⁻¹)}}{\text{Cost of cultivation (₹ ha⁻¹)}}
\]

**Results and Discussion**

**Performance of groundnut genotypes:** The plant height and number of leaves of groundnut differed significantly among the genotypes at different growth stages. Among the groundnut genotypes, ICGV-00351 recorded significantly higher plant height and number of leaves at harvest (40.05 cm and 25.86 plant⁻¹) as compared to other genotypes. Significantly lower plant height and number of leaves (35.38 cm and 22.76 plant⁻¹) was observed in TMV-2 at harvest. This might be due to erecting habit of genotype ICGV-00351 which resulted in vertical growth rather than horizontal spread of plants. Tripathy et al. (1999) and Virendra et al. (2008) at different locations also reported differential growth behaviour of groundnut genotypes in terms of plant height, number of branches, number of leaves, dry matter accumulation in different parts, total dry matter production, leaf area, leaf area index and chlorophyll.

Nitrogen uptake by groundnut kernels, haulm and total uptake differed significantly among the genotypes. Significantly higher nitrogen uptake by groundnut kernels, haulm and total uptake was recorded in genotype ICGV-00351 (68.69, 52.76 and 121.45 kg ha⁻¹, respectively) than TMV-2 (49.25, 43.36 and 92.61 kg ha⁻¹, respectively) and it was found on par with K-9 (62.86 48.75 and 111.61 kg ha⁻¹, respectively). The highest N uptake can be correlated with highest kernel and haulm yield of genotype ICGV-00351.

**Effect of micronutrients application:** Among micro-nutrients application, soil (25 kg ha⁻¹) and foliar (0.5 %) application of ZnSO₄ and FeSO₄ resulted in significantly higher plant height and number of leaves in all the genotypes over control at all the stages of crop growth. At harvest, soil application of ZnSO₄ @ 25 kg ha⁻¹ + foliar application of ZnSO₄ @ 0.5 % (S₄) produced higher plant height and number of leaves (42.09 cm and 27.78 plant⁻¹) over control and other treatments. Significantly lower plant height and number of

| Table 1: Plant height (cm) and number of leaves plant⁻¹ of groundnut genotypes as influenced by ferti-fortification at harvest. |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Micronutrient application       | Plant height (cm) | Number of leaves plant⁻¹ |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                                 | Genotypes       | M₁              | M₂              | M₃              | Mean            | M₁              | M₂              | M₃              | Mean            |
| S₁: Control (RDF+ FYM)          |                 | 30.80           | 32.17           | 31.50           | 31.49           | 19.33           | 19.00           | 19.33           | 19.22           |
| S₂: Soil application of ZnSO₄ @ 25 kg ha⁻¹ |                 | 35.50           | 38.50           | 43.07           | 39.02           | 25.67           | 23.67           | 27.67           | 26.67           |
| S₃: Foliar application of ZnSO₄ @ 0.5% |                 | 34.67           | 38.60           | 41.77           | 38.35           | 19.33           | 25.33           | 27.00           | 23.89           |
| S₄: Soil application of ZnSO₄ @ 25 kg ha⁻¹ + foliar application of ZnSO₄ @ 0.5% |                 | 40.90           | 40.67           | 44.70           | 42.09           | 28.33           | 25.33           | 29.67           | 27.78           |
| S₅: Soil application of FeSO₄ @ 25 kg ha⁻¹ |                 | 32.97           | 38.33           | 40.10           | 37.13           | 22.67           | 26.33           | 24.67           | 24.56           |
| S₆: Foliar application of FeSO₄ @ 0.5% |                 | 34.57           | 34.40           | 37.37           | 35.45           | 19.00           | 24.00           | 23.33           | 22.11           |
| S₇: Soil application of FeSO₄ @ 25 kg ha⁻¹ + foliar application of FeSO₄ @ 0.5% |                 | 38.27           | 40.13           | 41.83           | 40.08           | 25.00           | 25.00           | 29.33           | 26.44           |
| **Mean** |                 | **35.38**       | **37.54**       | **40.05**       | -               | **22.76**       | **24.09**       | **25.86**       | -               |
| **For comparing means of**      |                 | **S.Em⁺**       | **C. D. at 5%** | **S.Em⁺**       | **C. D. at 5%** | **S.Em⁺**       | **C. D. at 5%** | **S.Em⁺**       | **C. D. at 5%** |
| Genotypes                       |                 | 0.23            | 0.90            | 0.48            | 1.87            | 0.48            | 1.88            | 0.88            | 2.51            |
| Micronutrients application      |                 | 0.64            | 1.84            | 0.88            | 2.51            | 1.11            | NS              | 1.52            | NS              |
| S at the same level of M        |                 | 1.11            | NS              | 1.52            | NS              | 1.05            | NS              | 1.48            | NS              |
| M at the same or different levels of S |                 | 1.05            | NS              | 1.48            | NS              |                   |                  |                  |                  |

M₁ - TMV-2, M₂ - K-9, M₃ - ICGV-00351, NS - Non significant, Foliar application at 30 and 45 DAS
leaves (31.49 cm and 19.22 plant⁻¹) was recorded in control compared to application of ZnSO₄ or FeSO₄ through soil or foliar application. The improvement in plant height due to zinc application might be attributed to proper nourishment of crop and optimum growth (Price et al., 1972).

Different micronutrients application also influenced nitrogen uptake by groundnut kernels, haulm and total uptake significantly. Soil (25 kg ha⁻¹) + foliar (0.5 %) application of ZnSO₄(S₄) recorded significantly higher nitrogen uptake by groundnut kernels, haulm and total uptake (76.43, 57.66 and 134.10 kg ha⁻¹, respectively) as compared to the other treatments. However, it was found at par with soil (25 kg ha⁻¹) + foliar (0.5 %) application of FeSO₄ (69.90, 52.43 and 122.32 kg ha⁻¹, respectively) (S₄) and soil (25 kg ha⁻¹)

**Table 2: Nitrogen uptake by groundnut genotypes as influenced by ferti-fortification.**

| Micronutrient application | Kernel (kg ha⁻¹) | Haulm (kg ha⁻¹) | Total uptake (kg ha⁻¹) |
|---------------------------|------------------|-----------------|-----------------------|
| Genotypes                | M₁ | M₂ | M₃ | Mean | M₁ | M₂ | M₃ | Mean | M₁ | M₂ | M₃ | Mean |
| S₁: Control (RDF+ FYM)    | 31.39 | 49.23 | 51.45 | **44.03** | 33.12 | 40.92 | 40.58 | **38.21** | 64.51 | 90.15 | 92.03 | **82.23** |
| S₂: Soil application of ZnSO₄ @ 25 kg ha⁻¹ | 54.20 | 62.06 | 74.43 | **63.56** | 48.33 | 55.34 | 52.53 | **52.06** | 102.53 | 117.40 | 126.96 | **115.63** |
| S₃: Foliar application of ZnSO₄ @ 0.5% | 39.50 | 63.55 | 67.97 | **57.01** | 50.19 | 41.97 | 51.84 | **48.00** | 89.69 | 105.52 | 119.80 | **105.00** |
| S₄: Soil application of ZnSO₄ @ 25 kg ha⁻¹ + foliar application of ZnSO₄ @ 0.5% | 63.97 | 83.69 | 81.65 | **76.43** | 54.57 | 54.69 | 63.73 | **57.66** | 118.54 | 138.38 | 145.38 | **134.10** |
| S₅: Soil application of FeSO₄ @ 25 kg ha⁻¹ | 54.36 | 62.75 | 65.53 | **60.88** | 32.40 | 51.26 | 52.35 | **45.34** | 86.76 | 114.01 | 117.87 | **106.22** |
| S₆: Foliar application of FeSO₄ @ 0.5% | 43.28 | 54.10 | 52.77 | **50.05** | 39.98 | 39.48 | 53.56 | **44.34** | 83.26 | 93.59 | 106.33 | **94.39** |
| S₇: Soil application of FeSO₄ @ 25 kg ha⁻¹ + foliar application of FeSO₄ @ 0.5% | 58.03 | 64.64 | 87.02 | **69.90** | 44.94 | 57.56 | 54.77 | **52.43** | 102.97 | 122.20 | 141.79 | **122.32** |

**Mean** 49.25 62.86 68.69 - 43.36 48.75 52.76 - 92.61 111.61 121.45 -

| Genotypes | S.Em± | C. D. at 5% | S.Em± | C. D. at 5% | S.Em± | C. D. at 5% |
|------------|--------|-------------|--------|-------------|--------|-------------|
| For comparing means of Micronutrients application | 2.61 | 10.27 | 1.12 | 4.40 | 2.88 | 11.29 |
| Genotypes S at the same level of M | 6.61 | NS | 4.59 | NS | 7.14 | NS |
| M at the same or different levels of S | 6.66 | NS | 4.40 | NS | 7.21 | NS |

M₂ - TMV-2, M₃ - K-9, M₄ - ICGV-00351, NS - Non significant, Foliar application at 30 and 45 DAS

**Table 3: Economics of groundnut production as influenced by ferti-fortification.**

| Micronutrient application | Gross returns (₹ ha⁻¹) | Net returns (₹ ha⁻¹) | BC ratio |
|---------------------------|------------------------|----------------------|----------|
| Genotypes | M₁ | M₂ | M₃ | Mean | M₁ | M₂ | M₃ | Mean | M₁ | M₂ | M₃ | Mean |
| S₁: Control (RDF+ FYM) | 67508 | 100745 | 114378 | **94210** | 29529 | 62766 | 74899 | **55731** | 1.78 | 2.65 | 2.90 | **2.44** |
| S₂: Soil application of ZnSO₄ @ 25 kg ha⁻¹ | 101445 | 113224 | 132817 | **115829** | 62899 | 74678 | 92771 | **76783** | 2.63 | 2.94 | 3.32 | **2.96** |
| S₃: Foliar application of ZnSO₄ @ 0.5% | 83143 | 117526 | 117702 | **106124** | 42756 | 77139 | 75815 | **65237** | 2.06 | 2.91 | 2.81 | **2.59** |
| S₄: Soil application of ZnSO₄ @ 25 kg ha⁻¹ + foliar application of ZnSO₄ @ 0.5% | 118170 | 136246 | 131338 | **128585** | 77216 | 95292 | 88884 | **87131** | 2.89 | 3.33 | 3.09 | **3.10** |
| S₅: Soil application of FeSO₄ @ 25 kg ha⁻¹ | 105331 | 112791 | 116472 | **111531** | 67069 | 74529 | 76710 | **72769** | 2.75 | 2.95 | 2.93 | **2.88** |
| S₆: Foliar application of FeSO₄ @ 0.5% | 94149 | 108779 | 106031 | **102986** | 54092 | 68722 | 64474 | **62429** | 2.35 | 2.72 | 2.55 | **2.54** |
| S₇: Soil application of FeSO₄ @ 25 kg ha⁻¹ + foliar application of FeSO₄ @ 0.5% | 101674 | 128262 | 138116 | **122684** | 61334 | 87922 | 96276 | **81844** | 2.52 | 3.18 | 3.30 | **3.00** |

**Mean** 95917 116796 122408 - 56414 77293 81404 - 2.43 2.95 2.99 -

| Genotypes | S.Em± | C. D. at 5% | S.Em± | C. D. at 5% | S.Em± | C. D. at 5% |
|------------|--------|-------------|--------|-------------|--------|-------------|
| For comparing means of Micronutrients application | 2.59 | 10.19 | 2.59 | 10.19 | 0.07 | 0.28 |
| Genotypes S at the same level of M | 7390 | NS | 7390 | NS | 0.20 | NS |
| M at the same or different levels of S | 7318 | NS | 7318 | NS | 0.20 | NS |

M₂ - TMV-2, M₃ - K-9, M₄ - ICGV-00351, NS - Non significant, Foliar application at 30 and 45 DAS
application of ZnSO₄ (S₂) with respect to haulm uptake (52.06 kg ha⁻¹). The increased uptake of nutrients may be due to favourable effect of Zn on metabolic process (Price et al., 1972). Higher uptake of nutrient might be due to better growth leading to enhanced dry matter production and its partitioning.

**Economics of groundnut production as influenced by genotypes and micronutrients application:** Among the genotypes, significantly higher gross returns, net returns and benefit cost ratio (₹ 122408 ha⁻¹ ₹ 81404 ha⁻¹ and 2.99, respectively) was noticed in genotype ICGV-00351 than the genotype TMV-2 (₹ 95917 ha⁻¹, ₹ 56414 ha⁻¹ and 2.43, respectively) and it was on par with K-9 (₹ 116796 ha⁻¹, ₹ 77293 ha⁻¹ and 2.95, respectively).

The crop with soil (25 kg ha⁻¹) and foliar (0.5 %) application of ZnSO₄ (S₂) recorded significantly higher gross returns, net returns and benefit cost ratio (₹ 128585 ha⁻¹ ₹ 87131 ha⁻¹ and 3.10, respectively) compared to control and other treatments.

**CONCLUSION**
- Among the groundnut genotypes, ICGV-00351 fetched higher net returns and recorded higher BC ratio than TMV 2.
- Enrichment of groundnut genotypes with zinc was found maximum when ZnSO₄ was applied through soil @ 25 kg ha⁻¹ + foliar spray @ 0.5 % @ 30 and 45 DAS as compared to foliar application alone. Similarly, iron was also enriched in groundnut genotypes, when FeSO₄ was applied through soil @ 25 kg ha⁻¹ + foliar spray @ 0.5% @ 30 and 45 DAS.

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