Effect of foliar spray of iron (Fe)- fortified humic substances and humic acid on growth, nodulation and yield of groundnut (*Arachis hypogaea* L.) in a calcareous Vertisol

Abstract: The response to foliar application of Fe-fortified humic substances (HS) and humic acid (HA) on the growth, nodulation and yield characteristics of groundnut (*Arachis hypogaea* L.) var. TMV 2 in a calcareous Vertisol was studied in a pot culture experiment. There were 16 treatments *viz*., Absolute control (T_1), only RDF (T_2), RPP: RDF +FYM @ 7.5 t + $FeSO_4$ @ 25kg ha^{-1}+ $ZnSO_4$ @ 25 kg ha^{-1} (T_3), RDF + Foliar $FeSO_4.7H_20$ @ 0.5% (T_4), and T_5 to T_{16}, where two different concentrations, 0.25 and 0.50 % of humic substances (HS) (Humic acid + Fulvic acid) and humic acid (HA) were fortified separately with 250, 500 and 750 ppm Fe. Among all treatments, higher values of growth parameters like number of leaves, branch count and yield parameters like number of pods (19.33 pods $plant^{-1}$), pod weight (18.84 g $plant^{-1}$), kernel yield (12.85 g $plant^{-1}$), shelling % (68.25 %) and 100 kernel weight (33.28 g) were recorded in the treatment RDF + Foliar Fe- fortified HS (0.50 % HS+ Fe @ 500 ppm) (T_9) followed by treatment with RDF + Foliar Fe- fortified HA (0.50 % HA+ Fe @ 500 ppm)(T_{15}). The plant height and dry matter yield were recorded maximum under foliar spray of 0.25 % HS fortified with 500 ppm Fe (T_6) (21.83 cm and 6.27 g $plant^{-1}$ at 60 DAS; 33.83 cm and 36.75 g $plant^{-1}$ at harvest, respectively). For nodulation parameters, T_3 (only RPP) recorded the best results and remained statistically on par with treatment T_9.

Keywords : Humic substances, humic acid, growth stimulant, fortification, groundnut, calcareous soil and Vertisol

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Introduction

Improved nutritional management is essential to effectively produce crops on calcareous soils. In India, around 228.8 million hectares of land are occupied by calcareous soils, accounting for approximately 69.4% of the country's total geographic area. These soils are present in over 38 out of the 60 agro-ecological subregions within the country (Pal *et al.*,2000). Calcareousness in soil, as one of the constraints, has often produced problems in crop micronutrient nutrition. Calcareous soil, characterized by the presence of calcium carbonate in the parent material and/or a calcic horizon is considered a serious constraint in groundnut production. The presence of $CaCO_3$ directly or indirectly affects the chemistry and availability of macro and micro nutrients (Marschner, 1995). Crop nutrient management on calcareous soils differs from that on non-calcareous soils due to the influence of soil pH on soil nutrient availability and chemical interactions that affect the loss or fixation of specific nutrients.

Groundnut (*Arachis hypogaea* L.), popularly known as the "King" of oilseeds, is an important oilseed legume crop and the world's third- and fourth-most important sources of vegetable protein (28 %) and edible oil (51 %), respectively (Anonymous, 2021). The most common symptoms of impaired nutrition in groundnut grown in calcareous soils are chlorosis and stunted growth. The iron-chlorosis that appears as interveinal chlorosis of young rapidly expanding leaves also known as lime-induced iron-deficiency chlorosis (LIIC), is the most commonly observed symptom of Fe-deficiency (Singh and Dayal, 1992). Fe-deficiency chlorosis that appears 15 days after emergence (DAE) of seedlings and continues to occur on the newly emerged expanding leaves throughout the crop growth period causes significant yield reductions in groundnut in calcareous and alkaline soils. The maximum intensity of chlorosis is mainly observed during 30-70 DAE *i.e.*, the peak vegetative growth stage in the field (Singh *et al.*, 1995). The key factor related with Fe chlorosis under calcareous conditions appears to be the effect of the bicarbonate ion (HCO_3^-) on limiting Fe absorption and translocation to the leaves.

Humic substances (HS) are the reactive organic compounds in soil that form stable complexes with metallic micronutrients and contribute to their increased availability to plants. They help in maintaining micronutrients in solution and/or in bioavailable forms at pH values found in most soils (Tipping, 2002). Humic substances can contribute to Fe nutrition *via* formation of water-soluble Fe-HS heterocyclic complexes and act as natural Fe-chelates interacting with plant uptake mechanisms (Chen *et al*., 2004) The metal humic complexes are hydrophilic and soluble in nature and these soluble complexes has higher rate of absorption by the plants.

Auxin-like activity of humic substances helps increase in root, leaf and shoot growth due to its interaction with metabolic and physiological processes which results in improved nutrient intake and root architecture. Humic substances significantly improve growth by positively influencing processes like maintenance of membrane stability, nutrient uptake, hormonal activity and improved photosystem II activity (Chen and Aviad., 1990). Foliar application of humic substances stimulates plant growth by increasing cell permeability and better nutrient absorption and can therefore be called as plant growth stimulant (Trevisan *et al*.,2010). Nutrient fortification of humic substances can enhance the fertilizer value of humic substances.

From literature survey, it was assumed that foliar Fe application fortified with humic substances under iron-deficient condition will improve Fe availability which might improve overall growth and development of groundnut plants. In the present study, the response of applying iron-fortified humic substances and humic acid to groundnut plants during the flowering initiation and peg initiation stages was investigated to determine their effects on the growth, nodulation, and yield components of the groundnut crop.

Material and Methods

A pot culture experiment was conducted with groundnut (*Arachis hypogaea* L.) of variety TMV-2 grown in a calcareous Vertisol, during summer-2022 at the Institute of Organic Farming, University of Agricultural Sciences, Dharwad, Karnataka. The experiment was laid out in a completely randomized design (CRD) with sixteen treatments replicated thrice and the treatment details were as follows:

T_1 **:**Absolute control (only water spray),

T_2 : RDF (25: 50: 25 kg N: P_2O_5: K_2O kg ha^{-1}, respectively),

T_3 : RPP (RDF + RDFYM @ 7.5 t ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1},

T_4 : RDF + Foliar $FeSO_4.7H_2O$ @ 0.50 % (0.50 % $FeSO_4.7H_2O$ (neutralized with lime solution before foliar spray)

T_5 : RDF + Foliar Fe-fortified humic substances (HS) (0.25 % HS+ 250 ppm Fe)

T_6 : RDF+ Foliar Fe-fortified humic substances (HS) (0.25 % HS + 500 ppm Fe),

T_7 : RDF+ Foliar Fe-fortified humic substances (HS) (0.25 % HS + 750 ppm Fe),

T_8 : RDF+ Foliar Fe-fortified humic substances (HS) (0.50 % HS+ 250 ppm Fe),

T_9 : RDF+ Foliar Fe-fortified humic substances (HS) (0.50 % HS + 500 ppm Fe),

T_{10} : RDF+ Foliar Fe-fortified humic substances (HS) (0.50 % HS + 750 ppm Fe),

T_{11}: RDF+ Foliar Fe-fortified humic acid (HA) (0.25 % HA + 250 ppm Fe),

T_{12}: RDF+ Foliar Fe-fortified humic acid (HA) (0.25 % HA+ 500 ppm Fe),

T_{13}: RDF+ Foliar Fe-fortified humic acid (HA) (0.25 % HA+ 750 ppm Fe),

T_{14}: RDF+ Foliar Fe-fortified humic acid (HA) (0.50 % HA + 750ppm Fe),

T_{15}: RDF+ Foliar Fe- fortified humic acid (HA) (0.50 % HA+ 500 ppm Fe),

T_{16}: RDF+ Foliar Fe-fortified humic acid (HA) (0.50 % HA + 250ppm Fe).

RPP- Recommended package of practices [RDF + RDFYM @ 7.5 t ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}) [Recommended package of practices for UAS, Dharwad]

HS- Humic substances (Humic acid + Fulvic acid); **HA**- Humic acid; **DAS**- Days after sowing.

Note: 1. Foliar sprays were given at two stages [30 DAS (flower initiation) and at 55 DAS (peg initiation)]

2. In T_4, 0.5 % $FeSO_4.7H_2O$ solution was neutralized with lime solution before foliar spray)

The method proposed by Schnitzer and Skinner (1968) was followed for alkali extraction of humic substances from air-dried vermicompost sample. After removal of colloidal clays, a part of the supernatant extracted was poured into a porcelain pan and dried in a hot air oven at 55 °C. Half of the supernatant was pooled for fractionation and purification of humic acid. The pH of the pooled supernatant was lowered to two, to precipitate the humic acid fraction. The collected coagulate was also further purified by treating with HCl-HF mixture. The acid mixture was separated by centrifugation as described by Stevenson (1994) and the residue obtained was washed and dried in hot water bath and expressed as percentage dry weight. Extracted humic substances (Humic acid + Fulvic acid) and humic acid were fortified separately with 250, 500 and 750 ppm Fe in two different concentrations *i.e.*, 0.25 and 0.50 % of humic substances and humic acid.

The soil used in the pot culture experiment (**Table 1**) was clay in texture. The bulk density of the initial soil was 1.2 Mg m^{-3} with a maximum water holding capacity of 58 per cent. The soil had alkaline pH (8.58), low EC (0.46 dS m^{-1}), low organic carbon (0.51 %), high calcium carbonate (12.50 %) and a higher CEC [61.50 cmol (p^+) kg^{-1}]. The available nitrogen status was low (242.06 kg ha^{-1}), phosphorous was medium (49.20 kg ha^{-1}) and potassium was high (584.20 kg ha^{-1}). The exchangeable Ca and Mg status were higher and the available sulphur status was adequate. The status of available micronutrients Fe, Cu, Zn and Mn was sufficient.

Three groundnut seeds were sown in each grow bag filled with fifteen kilograms of air dried soil sample. One plant from each pot was uprooted at 60 days after sowing for assessment of dry matter yield and nodulation parameters like number of nodules, effective nodules and dry weight of nodules per plant. The other growth parameters like plant height, number of branches per plant and number of leaves per plant were recorded at 60 days after sowing and at harvest. The yield parameters like number of pods per plant, pod weight per plant, kernel weight per plant, haulm yield per plant, shelling percentage, harvest index and hundred kernel weight were recorded from two plants maintained in each pot at the harvest.

Shelling per cent was calculated by dividing kernel weight $plant^{-1}$ by pod weight $plant^{-1}$ as per formula given by Sigh and Oswalt, 1995. and expressed in percentage. Harvest index was worked out by dividing kernel yield by biological yield (pod yield + haulm yield) as per formula given by Singh and Stoskoff (1971) and expressed in percentage.

$$\text{Shelling percentage} = \frac{\text{Kernel weight (g plant}^{-1}\text{)}}{\text{Pod weight (g plant}^{-1}\text{)}} \times 100$$

$$\text{Harvest index (\%)} = \frac{\text{Kernel yield (g plant}^{-1}\text{)}}{\text{Pod yield (g plant}^{-1}\text{) + Haulm yield (g plant}^{-1}\text{)}} \times 100$$

Statistical analysis

The data was interpreted using Fisher's method and variance technique as outlined by Panse and Sukhatme (1985). The levels of significance used in 'F'and 't' test was p=0.05. The critical difference values were calculated wherever the 'F' test values are significant using SPSS software. The treatments were evaluated for their statistical significance using critical difference values.

Results and discussion

Growth parameters

In the present study, the effect of foliar application of Fe- fortified humic substances (HS) and humic acid (HA) extracted from vermicompost at different concentrations (0.25 and 0.50 % of HS / HA and 250, 500 and 750 ppm Fe) was studied on growth parameters of groundnut (**Table 2**).

At 60 DAS, maximum number of branches (5.00 plant^{-1}) was obtained in T_9 (RDF+ foliar spray of 0.50 % HS fortified with 500 ppm Fe) and on par results were obtained for T_{15} (RDF + foliar spray of 0.50 % HA fortified with 500 ppm Fe), T_3 (RPP) , T_7 (RDF + foliar application of 0.25 % HS fortified with 750 ppm Fe) and T_{13} (RDF + foliar spray of 0.25 % HA fortified with 750 ppm Fe) that recorded 4.67 no. of branches plant^{-1}. On similar lines as like at 60 DAS, the treatment T_9 recorded higher number of branches (6.00 plant^{-1}) at harvest and was found to be statistically on par with treatments T_3, T_7, T_{12} and $T_{15.}$ However, RDF (T_2) remained inferior to T_9 at both the stages. With respect to the number of leaves, the highest (31.33 plant^{-1}) was recorded in T_9 both at 60 DAS and at harvest (31.33 plant^{-1} and 54.00 plant^{-1}, respectively). The number of leaves recorded at 60 DAS for treatment T_7 (30.67 plant^{-1}) and T_{15} (30.33 plant^{-1}) showed on par results with treatment T_9 whereas treatment T_{15} (53.33 plant^{-1}) and T_{14} (53.33 plant^{-1}) recorded similar results to that of T_9 at harvest. The treatments RDF (T_2), RPP (T_3) and RDF + foliar spray $FeSO_4.7H_2O$ @ 0.50 % (T_4) registered significantly lower number of leaves per plant at 60 DAS and harvest as compared to T_9. Absolute control registered the lowest values of number of leaves per plant (19.33 and 45.00, respectively) during both the stages (**Table 2**).

At both 60 DAS and at harvest, significantly higher growth parameters *viz*; number of branches plant^{-1} and number of leaves plant^{-1} were obtained in the treatment T_9 which received RDF + foliar spray of 0.50 % HS fortified with 500 ppm Fe compared to the treatments T_2 (RDF) and T_3 (RPP). Combined application of RDF + foliar spray of humic substances showed a significant positive effect on growth parameters in sunflower as reported by Thakur *et al*. (2013). Higher concentration of humic substances *i.e.*, 0.50 % resulted in better plant growth than the lower concentration (0.25 %). Improved plant development in groundnut crop upon foliar application of fortified humic HS and HA along with uniform soil application of recommended dose of fertilizers might be due to better cell division, cell elongation and increased physiological processes in groundnut crop as humic substances are known to promote several interconnected, hormone-mediated signalling pathways related to plant growth as reported by Garcia *et al*. (2016).

At 60 DAS, the highest dry matter production (6.27 g plant^{-1}) was observed in T_6 (RDF + foliar spray of 0.25 % HS fortified with 500 ppm Fe) and was statistically on par with treatment T_9 (RDF + foliar spray 0.50 % HS fortified with 500 ppm Fe) which recorded 6.15 g plant^{-1} of dry matter yield (**Figure 1**). The dry matter yield recorded at harvest followed the same trend as like at 60 DAS where the maximum dry matter yield was recorded for treatment T_6 (36.75 g plant^{-1}) and remained at par with T_9 (36.66 g plant^{-1}) and T_7 (36.42 g plant^{-1}). The treatments RDF (T_2) and RPP (T_3) both registered lower dry matter production per plant at 60 DAS and harvest and absolute control registered the lowest values of dry matter yield per plant (3.48 and 25.82 g plant^{-1}, respectively) during both stages.

Similarly, T_6 (RDF + foliar spray of 0.25 % HS fortified with 500 ppm Fe) recorded the highest plant height at both 60 DAS (21.83 cm) and at harvest (33.83 cm), respectively. At 60 DAS, there is very less significant difference in plant height recorded among treatments that received foliar spray of fortified humic substances and humic acid. However, lower values of plant height were recorded for RDF (18.50 cm) and absolute control (18.00 cm). At harvest, the plant height registered for T_9 that received RDF + foliar spray of 0.50 % HS fortified with 500 ppm Fe (32.83 cm) and T_{15} that received RDF + foliar spray of 0.50 % HA fortified with 500 ppm Fe (32.33 cm) remained statistically on par with T_6 which reported the maximum plant height (33.83 cm, respectively) at harvest (**Table 2**).

With respect to plant height and dry matter yield, the treatment that received RDF + foliar application of lower concentration of HS i.e., 0.25 % HS fortified with 500 ppm (T_6) was effective in improving the plant height and dry matter yield accumulation to a greater extent although it recorded on par values with treatment T_9 where RDF + foliar application of 0.50 % fortified with 500 ppm Fe was applied. The improvement in plant height and dry matter yield per plant could be mainly due to improved nutrient availability on foliar application of Fe-fortified humic substances and humic acid which resulted in shoot and root growth of groundnut plants. Similar inventories were reported by Chen and Aviad (1990). The enhanced growth characteristics of groundnut might have occurred as a result of an increase in the concentration of growth-promoting compounds in plants which stimulated different cell growth processes in response to foliar application of humic substances and humic acid reported by Teli *et al*. (2020).

Nodulation parameters

Nodulation parameters like number of nodules, number of effective nodules and dry weight of nodules per plant were recorded at 60 DAS (**Table 3**) which helps in evaluating the N-fixing capacity of the leguminous plants.

The number of nodules per plant (25.33 plant^{-1}), effective nodules per plant (17.00 plant^{-1}) and dry weight of nodules per plant (0.26 g plant^{-1}) recorded in treatment T_3 (only RPP) was found to be maximum among all the other treatments. The number of nodules (25.00 plant^{-1}) and effective nodules (16.67 plant^{-1}) registered for treatment T_9 which received RDF + 0.50 % HS fortified with 500 ppm Fe remained statistically on par with the treatment T_3 (T_9 : 25.00 nodules plant^{-1} and 16.67 effective nodules plant^{-1}, respectively). With respect to dry weight of nodules, though statistically significant but numerically slight differences were observed among the treatments that received foliar spray of Fe-fortified HS and HA, respectively. Among the treatments which received foliar spray of Fe- fortified humic substances (HS) and humic acid (HA), treatment T_9 (RDF + foliar spray 0.50 % HS fortified with 500 ppm Fe) recorded on par values with treatment that received RPP with respect to all the three nodulation parameters. Plants grown under absolute control treatment (T_1) and only RDF treatment (T_2) recorded comparatively lower number of nodules, effective nodules and dry weight of nodules per plant in comparison to RPP (T_3) and amongst all the other treatments.

Humic substances stimulated the legume-rhizobium symbiosis which enhanced the nodulation. Syed *et al.* (2017) reported similar finding in which foliar application of humic substances and humic acid increased nodulation. Application of humic substances (humic +fulvic acid) was effective in enhancing biological nitrogen fixation but higher doses of humic + fulvic acid application (HFA) showed adverse effects as reported by Kirac and Coskan (2017).

Yield parameters

Foliar application of Fe- fortified humic substances (HS) and humic acid (HA) of different concentration resulted in improvement of yield attributing components of groundnut crop (**Table 4**). Significantly higher yield parameters like number of pods plant^{-1} (19.33), pod weight plant^{-1} (18.84 g plant^{-1}), kernel yield plant^{-1} (12.85 g plant^{-1}), shelling percentage (68.25 %), harvest index (35.04 %) and hundred seed weight (33.38 g) were recorded under T_9 (RDF + foliar spray of 0.50 % HS fortified with 500 ppm Fe) which remained statistically on par with T_{15} where RDF + foliar spray of 0.50 % concentration of HA fortified with 500 ppm Fe was applied. It was very clear that increase in the concentration of both humic substances (HS) and humic acid (HA) from 0.25 to 0.50 %, an increase in the values of yield parameters *viz*; number of pods plant^{-1}, pod yield plant^{-1}, kernel yield plant^{-1}, shelling percentage, harvest index and hundred seed weight were recorded. However, lower values of all the parameters were recorded for treatment T_2 (only RDF) and T_3 (only RPP) compared to plants treated with foliar application of Fe- fortified humic substances and humic acid.

Among the treatments, the maximum haulm yield (20.73 g plant^{-1}) was recorded under T_6 (RDF+ foliar spray of 0.25 % HS fortified with 750 ppm Fe) followed by T_5 (RDF+ foliar spray of 0.25 % HS fortified with 250 ppm Fe) that registered 19.38 g plant^{-1}. It was observed that lower concentration of humic substances (HS) *i.e.*, 0.25 % was more effective in increasing the haulm yield of groundnut as compared to higher concentration (0.50 %). Further, the haulm yield was significantly less under RDF application (15.87 g plant^{-1}) as compared to RPP. Absolute control registered significantly the lowest haulm yield (13.84 g plant^{-1}).

Foliar spray of 0.50 % of humic substances (humic acid + fulvic acid) (HS) fortified with iron was found to be slightly more effective in improving the yield components of groundnut than 0.50 % humic acid (HA) that might be due to the presence of smaller size, highly reactive and soluble fulvic acid component in humic substances (HS) where higher amount of carboxyl groups is present but this fulvic acid component is absent in only humic acid (HA) spray. Significantly lower growth parameters were reported in the treatment that received only soil application of recommended dose of NPK (RDF) and recommended package of practice (RPP) due to reduced availability and supply of nutrients to the crop grown in calcareous soil. The enhanced crop performance through increased yield and yield parameters might have occurred as a result of increased plant hormonal responses that increased cell membrane permeability of root cells, better root growth and nutrient absorption. The results were in conformity with Reddy *et al*. (2020) in groundnut. Sharma *et al.* (2018) also reported improvement in growth and yield parameters of soyabean plants on foliar application of humic acid + Fe (organic Fe). The positive effect on yield parameters due to combined use of recommended dose of chemical fertilizers (NPK) along with foliar spray of fortified humic substances and humic acid was mainly due to improved availability and balanced supply of plant nutrients.

Conclusions

Foliar application of Fe- fortified HS and HA of both 0.25 % (low) and 0.50 % (high) at flower initiation and peg initiation stage of groundnut crop grown in a calcareous Vertisol significantly enhanced the growth and yield of groundnut over the treatments that received only recommended package of practices (RPP) and recommended dose of fertilizers (RDF). Between the two concentrations of humic substances and humic acid, *i.e*., 0.25 % and 0.50 %, higher concentration of humic substances *i.e.*, 0.50 % was more effective in improving the plant growth and yield parameters when fortified with 500 ppm iron. Higher concentration of iron *i.e*., 750 ppm iron adversely affected the growth and yield of groundnut crop as a toxicity effect. Among all the treatments, RDF + foliar spray of 0.50 % HS and HA fortified with 500 ppm Fe (T_9) showed the best results in improving the growth and yield of the groundnut crop followed by RDF+ foliar spray of 0.50 % humic acid fortified with 500 ppm Fe (T_{15}), The treatment that received only RPP (T_3) recorded the highest nodulation characteristics (number of nodules, effective nodules and dry weight of nodules per plant) and treatment T_9 where RDF + foliar spray 0.50 % HS fortified with 500 ppm Fe was applied recorded on par values with treatment T_3 with respect to all the three nodulation parameters.

Table 1 : Initial properties of the soil used for pot culture experiment

Sl. No.	Properties	Value
I. Physical properties		
1.	Particle size distribution (%)	
	Sand	28.20
	Silt	26.40
	Clay	45.40
2	Texture	Clay
3	Bulk density (Mg m^{-3})	1.20
4	MWHC (%)	58.0
II. Chemical properties		
1.	Soil pH (1:2.5)	8.58
2.	EC (dS m^{-1}) (1:2.5)	0.46
3.	Organic carbon (g kg^{-1})	5.10
4.	Calcium carbonate (%)	12.50
5.	Cation exchange capacity [cmol (p^+) kg^{-1}]	61.50
III. Available macronutrients (kg ha^{-1})		
1.	Nitrogen	245.00
2.	Phosphorus (P_2O_5)	49.20
3.	Potassium (K_2O)	584.20
IV. Secondary nutrients		
1.	Exchangeable calcium [cmol (p^+) kg^{-1}]	48.50
2.	Exchangeable magnesium [cmol (p^+) kg^{-1}]	13.55
3.	Available sulphur (kg ha^{-1})	32.50
V. DTPA-extractable micronutrients (mg kg^{-1})		
i.	Iron	5.80
ii.	Copper	1.10
iii.	Manganese	9.40

iv.	Zinc	1.15
VI. Water soluble iron (mg kg^{-1})		1.05

Table 2: Effect of foliar spray of Fe- fortified humic substances and humic acid on plant height, number of branches per plant and number of leaves per plant of groundnut

Tr. No.	Treatments	Plant height (cm)		No. of branches per plant		No. of leaves per plant	
		At 60 DAS	At harvest	At 60 DAS	At harvest	At 60 DAS	At harvest
T_1	Absolute control (Only water spray)	18.00	26.67	3.33	4.33	19.33	45.00
T_2	RDF (25: 50: 25 kg N: P_2O_5: K_2O ha^{-1}, respectively)	18.50	28.67	4.00	5.00	20.00	44.67
T_3	RPP	20.00	31.50	4.67	5.67	26.00	49.67
T_4	RDF + Foliar spray of $FeSO_4.7H_2O$ @ 0.50 %	18.67	29.33	4.33	5.33	26.00	45.33
T_5	RDF + Foliar spray of Fe- HS (0.25 % HS + 250 ppm Fe)	20.00	30.50	3.67	5.00	26.00	47.67
T_6	RDF + Foliar spray of Fe- HS (0.25 % HS + 500 ppm Fe)	21.83	33.83	4.33	5.00	27.33	49.67
T_7	RDF + Foliar spray of Fe- HS (0.25 % HS + 750 ppm Fe)	21.33	31.63	4.67	5.67	30.67	50.67
T_8	RDF + Foliar spray of Fe- HS (0.50 % HS + 250 ppm Fe)	21.50	30.77	4.33	5.00	26.33	51.00
T_9	RDF + Foliar spray of Fe- HS (0.50 % HS + 500 ppm Fe)	21.67	32.83	5.00	6.00	31.33	54.00
T_{10}	RDF + Foliar spray of Fe- HS (0.50 % HS + 750 ppm Fe)	21.50	29.00	4.00	5.00	25.33	49.33
T_{11}	RDF + Foliar spray of Fe- HA (0.25 % HA + 250 ppm Fe)	19.50	30.17	4.33	5.00	26.33	46.33
T_{12}	RDF + Foliar spray of Fe- HA (0.25 % HA + 500 ppm Fe)	20.17	30.50	4.33	5.67	27.67	51.00
T_{13}	RDF + Foliar spray of Fe- HA (0.25 % HA + 750 ppm Fe)	21.50	31.33	4.67	5.00	28.00	51.00
T_{14}	RDF + Foliar spray of Fe- HA (0.50 % HA + 250 ppm Fe)	21.17	31.00	4.33	5.33	28.00	52.33
T_{15}	RDF + Foliar spray of Fe- HA (0.50 % HA + 500 ppm Fe)	21.50	32.33	4.67	5.67	30.33	53.33
T_{16}	RDF + Foliar spray of Fe- HA (0.50 % HA + 750 ppm Fe)	21.17	30.50	4.33	5.00	28.33	46.00
S.Em. (±)		**0.68**	**0.71**	**0.33**	**0.26**	**1.26**	**1.43**
CD (P=0.05)		**1.96**	**2.04**	**0.96**	**0.76**	**3.63**	**4.12**

RPP - Recommended package of practices [RDF + RDFYM @ 7.5 t ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}) ;

HS - Humic substances (Humic acid + Fulvic acid); **HA**- Humic acid

Foliar spray given at two stages (30 DAS, flower initiation; 55 DAS, peg initiation); **DAS** - Days after sowing

Table 3: Effect of foliar spray of iron (Fe)- fortified humic substances and humic acid on number of nodules and dry weight of nodules at 60 DAS

Tr. No.	Treatments	Number of nodules per plant	Number of effective nodules per plant	Dry weight of total nodules (g plant^{-1})
T_1	Absolute control (Only water spray)	18.67	10.67	0.18
T_2	RDF (25: 50: 25 kg N: P_2O_5: K_2O ha^{-1}, respectively)	21.33	13.33	0.21
T_3	RPP	25.33	17.00	0.26
T_4	RDF + Foliar spray of $FeSO_4.7H_2O$ @ 0.50 %	24.67	15.00	0.24
T_5	RDF + Foliar spray of Fe- HS (0.25 % HS + 250 ppm Fe)	23.00	14.67	0.22
T_6	RDF + Foliar spray of Fe- HS (0.25 % HS + 500 ppm Fe)	23.67	15.00	0.23
T_7	RDF + Foliar spray of Fe- HS (0.25 % HS + 750 ppm Fe)	24.00	16.33	0.24
T_8	RDF + Foliar spray of Fe- HS (0.50 % HS + 250 ppm Fe)	23.00	15.67	0.24
T_9	RDF + Foliar spray of Fe- HS (0.50 % HS + 500 ppm Fe)	25.00	16.67	0.25
T_{10}	RDF + Foliar spray of Fe- HS (0.50 % HS + 750 ppm Fe)	24.00	15.00	0.23
T_{11}	RDF + Foliar spray of Fe- HA (0.25 % HA + 250 ppm Fe)	22.00	14.00	0.22
T_{12}	RDF + Foliar spray of Fe- HA (0.25 % HA + 500 ppm Fe)	23.67	15.33	0.23
T_{13}	RDF + Foliar spray of Fe- HA (0.25 % HA + 750 ppm Fe)	23.67	15.67	0.24
T_{14}	RDF + Foliar spray of Fe- HA (0.50 % HA + 250 ppm Fe)	23.00	15.67	0.23
T_{15}	RDF + Foliar spray of Fe- HA (0.50 % HA + 500 ppm Fe)	24.00	16.00	0.24
T_{16}	RDF + Foliar spray of Fe- HA (0.50 % HA + 750 ppm Fe)	22.33	15.00	0.23
S.Em. (±)		**0.60**	**0.80**	**0.01**
CD (P=0.05)		**1.74**	**2.27**	**0.04**

RPP **-** Recommended package of practices [RDF + RDFYM @ 7.5 t ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}**)**

HS - Humic substances (Humic acid + Fulvic acid); **HA**- Humic acid

Foliar spray given at two stages (30 DAS, flower initiation; 55 DAS, peg initiation); **DAS** - Days after sowing

Table 4: Effect of foliar spray of iron (Fe)- fortified humic substances and humic acid on yield components of groundnut

Tr. No.	Treatments	Number of pods per plant	Pod weight (g plant^{-1})	Haulm yield (g plant^{-1})	Kernel Yield (g plant^{-1})	Shelling percentage	Harvest index (%)	Hundred kernel weight (g)
T_1	Absolute control (Only water spray)	11.00	11.98	13.84	7.15	59.62	27.68	29.98
T_2	RDF (25: 50: 25 kg N: P_2O_5: K_2O ha^{-1}, respectively)	13.67	14.27	15.87	8.70	60.99	28.87	30.97
T_3	RPP	15.67	15.71	17.45	9.88	62.98	29.81	32.42
T_4	RDF + Foliar spray of $FeSO_4.7H_2O$ @ 0.50 %	14.00	15.08	16.60	9.40	62.44	29.66	32.17
T_5	RDF + Foliar spray of Fe- HS (0.25 % HS + 250 ppm Fe)	15.33	14.96	19.38	9.79	65.45	28.50	32.12
T_6	RDF + Foliar spray of Fe- HS (0.25 % HS + 500 ppm Fe)	15.67	16.02	20.73	10.53	65.79	28.68	32.29
T_7	RDF + Foliar spray of Fe- HS (0.25 % HS + 750 ppm Fe)	16.33	17.06	19.36	11.24	66.00	30.91	32.48
T_8	RDF + Foliar spray of Fe- HS (0.50 % HS + 250 ppm Fe)	18.33	17.19	17.03	11.54	67.17	33.73	33.01
T_9	RDF + Foliar spray of Fe- HS (0.50 % HS + 500 ppm Fe)	19.33	18.84	17.81	12.85	68.25	35.05	33.28
T_{10}	RDF + Foliar spray of Fe- HS (0.50 % HS + 750 ppm Fe)	16.33	16.28	16.26	10.65	65.41	32.73	32.14
T_{11}	RDF + Foliar spray of Fe- HA (0.25 % HA + 250 ppm Fe)	14.67	14.42	15.60	9.03	62.89	30.16	32.06
T_{12}	RDF + Foliar spray of Fe- HA (0.25 % HA + 500 ppm Fe)	15.00	15.87	16.09	10.00	63.34	31.33	32.41
T_{13}	RDF + Foliar spray of Fe- HA (0.25 % HA + 750 ppm Fe)	16.00	16.33	16.39	10.88	66.67	33.26	32.46
T_{14}	RDF + Foliar spray of Fe- HA (0.50 % HA + 250 ppm Fe)	17.00	17.88	15.50	11.47	64.16	34.37	32.78
T_{15}	RDF + Foliar spray of Fe- HA (0.50 % HA + 500 ppm Fe)	18.33	18.19	16.34	12.25	67.34	35.47	33.17
T_{16}	RDF + Foliar spray of Fe- HA (0.50 % HA + 750 ppm Fe)	16.67	16.19	14.11	10.08	62.26	33.30	32.40
S.Em. (±)		**0.59**	**0.45**	**0.41**	**0.21**	**1.68**	**0.76**	**0.32**
CD (P=0.05)		**1.69**	**1.30**	**1.18**	**2.04**	**4.81**	**2.26**	**0.91**

RPP - Recommended package of practices [RDF + RDFYM @ 7.5 t ha^{-1} + $FeSO_4$ @ 25 kg ha^{-1} + $ZnSO_4$ @ 25 kg ha^{-1}) ;

HS - Humic substances (Humic acid + Fulvic acid); **HA**- Humic acid

Foliar spray given at two stages (30 DAS, flower initiation; 55 DAS, peg initiation); **DAS** - Days after sowing

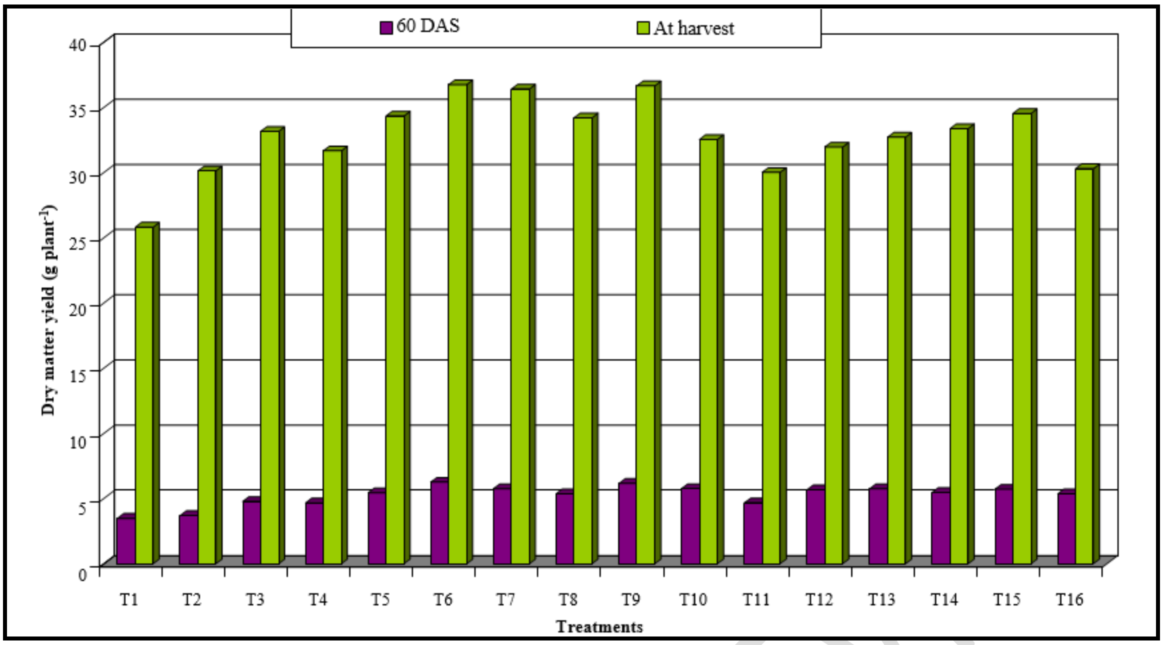

Fig. 1: Effect of foliar spray of iron (Fe)-fortified humic substances and humic acid on dry matter accumulation of groundnut

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