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Research Article

EFFECT OF SULPHUR AND NANO FE APPLICATION ON GROWTH, YIELD ATTRIBUTES AND YIELD OF *KHARIF* GROUNDNUT (*Arachis hypogaea* L.) UNDER MIDDLE GUJARAT CONDITIONS

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Abstract: A field experiment was conducted at the College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand,Gujarat during *kharif* season of the year 2021. The soil in the experimental plot was loamy sand that was slightly alkaline (pH 8.18) with good drainage and moisture retention capacity. The experimental soil was low in organic carbon (0.24%), low in available nitrogen (211.02 kg/ha), medium in available phosphorous (29.63 kg/ha), medium in available potash (152.14 kg/ha), medium in available sulphur (10.04 mg/kg) and medium in available iron (5.56 mg/kg). The experiment was laid out in randomized block design with 10 treatments replicated four times and applied ethrel @ 100 ppm as a seed treatment for breaking seed dormancy. The treatments details areT_1: RDF (12.5:25:00 NPK kg/ha), T_2: RDF + 20 kg S/ha through gypsum, T_3: RDF + 20 kg S/ha through gypsum + 250 ppm nano Fe foliar spray,T_4: RDF + 40 kg S/ha through gypsum, T_5:RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray, T_6:RDF + 20 kg S/ha through bentonite sulphur , T_7:RDF + 20 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray, T_8: RDF + 40 kg S/ha through bentonite sulphur, T_9:RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray, T_{10}:RDF + 250 ppm nano Fe foliar spray. The effect of sulphur and nano Fe application registered significant impact on the quality parameters of groundnut *viz*., oil and protein content. Application of treatment T_9: RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray was reported significantly higher oil (49.10%) and protein (24.79%) content. However, it did not differ significantly with treatment T_3: RDF + 20 kg S/ha through gypsum + 250 ppm nano Fe foliar spray, T_4: RDF + 40 kg S/ha through gypsum, T_5: RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray, T_7: RDF + 20 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray and T_8: RDF + 40 kg S/ha through bentonite sulphur.

Keywords: *Groundnut, Sulphur and nano Fe*

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Introduction

Groundnut (*Arachis hypogaea* L.) is the most important edible oilseed cum pulse in the world. It belongs to Fabaceae family. Groundnut is called the king of oilseeds. It is also known by the names of wonder nut, poor men's cashew nut, monkey nut and manilla nut. The protein content in groundnut is around 26%. The oil content in groundnut ranges from 45-52% and is mainly used in cooking and also in the preparation of vanspati ghee, soap making, fuels, cosmetics, lubricants etc. Groundnut oil contains 20 per cent saturated and 80 per cent unsaturated fatty acids. Poly saturated fatty acid is of two types *i.e*., oleic (40-50%) and linoleic (24-35%) [1]. Globally, groundnut covers 295 lakh hectares with the production of 487 lakh tonnes with the productivity of 1647 kg/ha. With annual all-season coverage of 55.6 lakh hectares, globally, India ranks first in groundnut acreage and is the second largest producer of groundnut in the world with 101 lakh tonnes with a productivity of 1816 kg/ha in 2020-21. Groundnut is cultivated in one or more (*kharif, rabi* and *summer*) seasons, but nearly 80% of acreage and production comes from kharif crop (June-October). India has exported total 6.64 lakh tonnes groundnut during April to January 2020-21 [2].

Nano fertilizer refers to a product that delivers nutrient to crops in one of three ways: the nutrient can be encapsulated inside nano-materials such as nano tubes or nano porous materials, covered with a thin protective polymer layer and delivered as nano scale particles or emulsions. They can be synthesized either by fortifying nutrients singly or in combination on to the adsorbents with nano-dimension. Fertilizer particle coated with nano membranes facilitate in slow and steady release of nutrients. It helps to reduce loss of nutrients while improving fertilizer use efficiency of crops [3].

According to the report of Iranian Nanotechnology Initiative Council (2009), Iranian researchers have produced the first nano organic iron chelated fertilizers in the world. Sulphur plays an important role in groundnut metabolism. It is a secondary essential plant nutrient factor that plays a role in the formation of protein alongside nitrogen and phosphorus. The application of sulphur fertilizer and groundnut crop have been found effective through increasing the number of pegs, pods/plant and shelling percentage etc. It is one of the plant nutrients that play an important and specific role in the synthesis of sulphur containing amino acids like methionine (20%) and cysteine (27%) and synthesis of proteins and oil content. Moreover, it is also associated with the co-enzyme-A metabolism of carbohydrates, synthesis of vitamins (biotin and thiamine), proteins and fats. Sulphur deficiency and the consequent crop responses have been reported throughout the world, particularly in oilseed crops like peanuts [4].

Gypsum ($CaSO_4 \cdot 2H_2O$) is a general name for a mineral compound called calcium sulphate. It is having an equal or better effect on groundnut as other S containing fertilizers. Formation of vitamins and chlorophyll is affected by the application of gypsum [5]. Calcium is a secondary plant nutrient which plays an important role in enhancing production and productivity of groundnut. For groundnut production, calcium nutrition is also considered as a yield limiting factor. Sulphur bentonite is one of the concentrated sources of sulphur which contains 90% S and 10% bentonite clay which serves as binder during manufacture and as a dispersing agent after addition to soils.

With this background information a field trial was undertaken to study at College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand during *kharif* season of the year 2021

Table-1 Plant population, plant height and number of branches/plant of kharif groundnut as influenced by different treatments

Treatments	Plant population/meter row length		Periodical plant height (cm)			Number of branches/plant
	25 DAS	Harvest	30 DAS	60 DAS	Harvest	
T_1 - RDF (12.5:25:00 NPK kg/ha)	7.08	7.03	11.25	23.06	43.89	7.36
T_2 - RDF + 20 kg S/ha through Gypsum	7.25	7.18	12.16	25.78	48.92	8.04
T_3 - RDF + 20 kg S/ha through Gypsum + 250 ppm Nano Fe foliar spray	7.28	7.23	12.15	27.45	52.12	8.63
T_4 - RDF + 40 kg S/ha through Gypsum	7.60	7.53	13.07	29.09	54.21	9.23
T_5 - RDF + 40 kg S/ha through Gypsum + 250 ppm Nano Fe foliar spray	7.65	7.58	13.12	30.67	57.63	10.01
T_6 - RDF + 20 kg S/ha through Bentonite sulphur	7.33	7.25	12.62	26.32	50.05	8.40
T_7 - RDF + 20 kg S/ha through Bentonite sulphur + 250 ppm Nano Fe foliar spray	7.38	7.28	12.65	28.01	53.05	9.03
T_8 - RDF + 40 kg S/ha through Bentonite sulphur	7.70	7.63	13.55	29.54	54.87	9.55
T_9 - RDF + 40 kg S/ha through Bentonite sulphur + 250 ppm Nano Fe foliar spray	7.78	7.70	13.59	31.15	58.10	10.45
T_{10} - RDF + 250 ppm Nano Fe foliar spray	7.10	7.05	11.22	24.74	46.02	7.78
S.Em. ±	0.27	0.26	0.61	1.18	1.99	0.40
C.D. at 5 %	NS	NS	NS	3.44	5.79	1.16
CV %	7.33	7.26	9.73	8.59	7.69	9.00

Table-2 Number of pods/plant, seed index, harvest index, shelling (%), pod yield and haulm yield of kharif groundnut as influenced by different treatments

Treatments	Number of pods/plant	Seed index (g)	Harvest index(%)	Shelling (%)	Pod yield (kg/ha)	Haulm yield (kg/ha)
T_1 - RDF (12.5:25:00 NPK kg/ha)	19.82	43	24.53	62.39	1521	2750
T_2 - RDF + 20 kg S/ha through Gypsum	21.07	46	25.99	64.96	1931	3446
T_3 - RDF + 20 kg S/ha through Gypsum + 250 ppm Nano Fe foliar spray	22.16	47.75	27.5	67.53	2235	3946
T_4 - RDF + 40 kg S/ha through Gypsum	23.27	49.75	28.93	69.22	2382	4268
T_5 - RDF + 40 kg S/ha through Gypsum + 250 ppm Nano Fe foliar spray	26.02	51.25	30.03	70.83	2590	4675
T_6 - RDF + 20 kg S/ha through Bentonite sulphur	21.5	47	26.42	66.26	2047	3669
T_7 - RDF + 20 kg S/ha through Bentonite sulphur + 250 ppm Nano Fe foliar spray	22.61	48.75	28.06	68.41	2332	4142
T_8 - RDF + 40 kg S/ha through Bentonite sulphur	23.96	50.25	29.49	70.11	2492	4442
T_9 - RDF + 40 kg S/ha through Bentonite sulphur + 250 ppm Nano Fe foliar spray	27.16	52	31.04	71.61	2737	4943
T_{10} - RDF + 250 ppm Nano Fe foliar spray	20.48	44.75	25.35	63.25	1632	2922
S.Em. ±	0.89	1.97	1.46	2.12	94	185
C.D. at 5 %	2.6	NS	NS	NS	273	537
CV %	7.84	8.18	10.56	6.28	8.59	9.44

Materials and Methods

A field experiment was conducted at the College Agronomy Farm, B. A. College of Agriculture, Anand Agricultural University, Anand (Gujarat) during *kharif* season of the year 2021. The soil in the experimental plot was loamy sand that was slightly alkaline (pH 8.18) with good drainage and moisture retention capacity. The experimental soil was low in organic carbon (0.24%), low in available nitrogen (211.02 kg/ha), medium in available phosphorous (29.63 kg/ha), medium in available potash (152.14 kg/ha), medium in available sulphur (10.04 mg/kg) and medium in available iron (5.56 mg/kg). The experiment was laid out in randomized block design with 10 treatments replicated four times and applied ethrel @ 100 ppm as a seed treatment for breaking seed dormancy. The treatments details areT_1: RDF (12.5:25:00 NPK kg/ha), T_2: RDF + 20 kg S/ha through gypsum, T_3: RDF + 20 kg S/ha through gypsum + 250 ppm nano Fe foliar spray,T_4: RDF + 40 kg S/ha through gypsum, T_5:RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray, T_6:RDF + 20 kg S/ha through bentonite sulphur , T_7:RDF + 20 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray, T_8: RDF + 40 kg S/ha through bentonite sulphur, T_9:RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray, T_{10}: RDF + 250 ppm nano Fe foliar spray. For the present investigation, the groundnut cultivar GG-34 was selected. Regional Research Station, Anand Agricultural University, Anand (Gujarat) published this variety in 2018. It takes 117-125 days to reach maturity. With a yield potential of 3715 kg/ha, it has dark green foliage, a Spanish bunch type of growth pattern, rose red colour kernel, lower infestation of jassids, thrips and tikka and rust disease resistance.

Soil analysis was made after taking a composite common soil sample from the entire experimental area initially and after harvest, the samples were drawn separately from each net plot and subjected to chemical analysis. The conventional procedures were used to determine the major soil physico-chemical parameters such as soil texture, organic carbon, EC, pH and available soil nutrients such as N, P_2O_5, K_2O, S and Fe. The statistical analysis of the various growth, yield and quality characters studied during investigation was carried out by using statistical method appropriate to Randomized Block Design by computer system at the computer center, Department of the Agricultural Statistics, BACA, AAU, Anand, Gujarat as per the procedure described by Cochran and Cox (1967) [6]. The variances of different sources of variation in ANOVA were tested by "F-test" and compared with the value of Table-F at 5% level of significance. To elucidate the treatment effect, summary tables along with S.Em. ± and CD at 5% are given in chapter "experimental results" and their analysis of variance are given in the Appendices at the end.

Results and Discussion

Effect of treatments on growth attributes

The data pertaining to the effect of sulphur and nano Fe application on plant population per meter row length recorded at initial (25 DAS) and at harvest stage. The data indicated that effect of different treatments shows non-significant response on plant population at initial and harvest stages. It indicated that a uniform plant population found under all the treatments, which showed that different treatments had non-significant influence on plant population. The data present in [Table-1] clearly shows that the periodical plant height of *kharif* groundnut was progressively increased with advancement of crop age. The plant height increased vigorously up to 60 days of crop growth. Subsequently plant height continued to increase at gradually slower rate up to harvest. The treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) recorded significantly higher plant height at 60 DAS (31.15 cm) and at harvest (58.10 cm), respectively. However, it was found at par with the treatment T_4 (RDF + 40 kg S/ha through gypsum), T_5 (RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray), T_7 (RDF + 20 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) and T_8 (RDF + 40 kg S/ha through bentonite sulphur).

Significantly lower plant height of 23.06 and 43.89 cm was recorded in treatment T_1 RDF (12.5:25:00 NPK kg/ha)at 60 DAS and harvest, respectively.

The plant height of groundnut was increased might be due to application of sulphur improves chemical and biological properties of soil by maintaining optimum soil pH and increasing nutrient availability. It also has a synergistic relationship with primary nutrients, allowing plants to easily uptake the nutrient, which directly contributes to cell elongation and cell division, resulting in improved vegetative growth and ultimately increased plant height. Another possible explanation is that sulphur, as a component of the Fe-S protein ferredoxin, which is responsible for the transfer of electrons during light reactions,

Table-3 Economics of kharif groundnut as influenced by different treatments

Treatments	Pod Yield (Kg/ha)	Haulm Yield (Kg/ha)	Gross Realization (Rs./ha)	Total Cost of cultivation (Rs./ha)	Net Realization (Rs./ha)	BCR
T_1 - RDF (12.5:25:00 NPK kg/ha)	1521	2750	104365	47905	56460	2.18
T_2 - RDF + 20 kg S/ha through Gypsum	1931	3446	132407	48485	83922	2.73
T_3 - RDF + 20 kg S/ha through Gypsum + 250 ppm Nano Fe foliar spray	2235	3946	153167	50348	102819	3.04
T_4 - RDF + 40 kg S/ha through Gypsum	2382	4268	163366	48777	114589	3.35
T_5 - RDF + 40 kg S/ha through Gypsum + 250 ppm Nano Fe foliar spray	2590	4675	177700	50928	126772	3.49
T_6 - RDF + 20 kg S/ha through Bentonite sulphur	2047	3669	140393	49086	91307	2.86
T_7 - RDF + 20 kg S/ha through Bentonite sulphur + 250 ppm Nano Fe foliar spray	2332	4142	159864	50949	108915	3.14
T_8 - RDF + 40 kg S/ha through Bentonite sulphur	2492	4442	170864	50266	120598	3.40
T_9 - RDF + 40 kg S/ha through Bentonite sulphur + 250 ppm Nano Fe foliar spray	2737	4943	187791	52130	135661	3.60
T_{10} - RDF + 250 ppm Nano Fe foliar spray	1632	2922	111924	49768	62156	2.25

plays an essential part in photosynthetic processes and chlorophyll formation, both of which are associated to plant growth. As well as, the application of nano Fe particles increased photosynthesis, respiration, biosynthesis of phytohormones, chlorophyll content and electron transfer in redox reactions. Such results were in close accordance with the findings reported by Noman *et al*. (2015) [7], Rui *et al*. (2016) [8] and Harish *et al*. (2019) [9].

The number of branches per plant was found significantly higher (10.45) in treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) over other treatments. However, it was remained at par with application of T_5 (RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray) and T_8 (RDF + 40 kg S/ha through bentonite sulphur). Significantly lower number of branches per plant (7.36) was observed under treatment T_1RDF (12.5:25:00 NPK kg/ha). By application of treatment observed higher branches might due to sulphur, as a component of the Fe-S protein ferredoxin and sulphur-containing amino acids, enhances photosynthetic processes and chlorophyll content in the growing region which ultimately increasing cell division and tissue growth. Iron has an important role in the synthesis of chlorophyll, photosynthesis improvement and plant growth regulation. These results are in close conformity with the findings of El-Metwally *et al*. (2018) [10] and Yadav *et al*. (2015) [11].

Effect of treatments on yield attributes and yield

Data regarding to the effect of sulphur and nano Fe application on number of pods per plant recorded at harvest are presented in [Table-2]. A statistical analysis of data indicated that the treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) recorded significantly higher number of pods per plant (27.16). It did not differ significantly with treatment T_5 (RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray). Significantly lower number of pods per plant (19.82) was observed under treatment T_1 RDF (12.5:25:00 NPK kg/ha). This might be because sulphur plays an important role in carbohydrate metabolism, energy transformation and storage, as well as sulphur and nano Fe increasing plant physiological and bio-chemical activities necessary for proper development of plant. As a result, it has a positive impact on pods. These results are in close conformity with the findings of Giri *et al*. (2011) [12], Banu *et al*. (2017) [13] and El-Metwally *et al*. (2018). While in case of seed index, a perusal of results given in [Table-2] indicated that the seed index was non-significantly affected by different treatments. Numerically higher and lowerseed index 52.00 and 43.00 g was recorded in treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) and treatment T_1 RDF (12.5:25:00 NPK kg/ha), respectively. Data pertaining to harvest index and shelling percentage at harvest as influenced by different treatments during investigation are presented in [Table-2]. The results revealed that response of treatments on harvest index found to be non-significant. Numerically higher and lower harvest index (31.04%) and (24.53%) was recorded in treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) and treatment T_1RDF (12.5:25:00 NPK kg/ha). While in case of shelling percentage an appraisal of data given in [Table-2] indicated that the effect of different treatments on shelling percentage was found to be non-significant. The maximum shelling percentage (71.61) was recorded in treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) and lowest shelling percentage (62.39) was recorded in treatment T_1 RDF (12.5:25:00 NPK kg/ha).

A perusal of results given in [Table-2] indicated that the pod yield of groundnut was significantly differed with different treatments. Significantly higher pod yield (2737 kg/ha) was found in treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray). It was found statistically at par with treatmentT_5 (RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray)and treatment T_8 (RDF + 40 kg S/ha through bentonite sulphur). However, the lower pod yield was recorded in treatment T_1 RDF (12.5:25:00 NPK kg/ha). The magnitude of mean increase in pod yield with T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) was 79.95, 67.71, 41.74, 33.71, 22.46, 17.36, 14.90, 9.83 and 5.68% over treatments T_1, T_{10}, T_2, T_6, T_3, T_7, T_4, T_8 and T_5, respectively. The main reason behind increasing higher pod yield might be due to availability of sulphur helps in improving photosynthetic activity, seed formation, as well as the synthesis of amino acids, chlorophyll, proteins and stimulating nodulation, which may be attributed to an increase in total biomass production that was directly reflected in increment in pod yield of groundnut. Additionally, nano Fe fertilisers make it easier for plants to use nutrients, which improves pigment formation, photosynthesis rate, dry material production and overall plant growth. This result was found similar with findings of Kadam *et al*. (2000) [14], Salke *et al*. (2012) [15], Meena *et al*. (2013) [16], El-Metwally *et al*. (2018), Pandey *et al*. (2018) [17] and Manasa *et al*. (2019) [18].

A perusal of results given in [Table-2] indicated that the haulm yield was significantly differed with different treatments. Significantly higher haulm yield (4943 kg/ha) was recorded with treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray which was remained statistically at par with treatment T_5 (RDF + 40 kg S/ha through gypsum + 250 ppm nano Fe foliar spray) and treatment T_8 (RDF + 40 kg S/ha through bentonite sulphur). Significantly lower haulm yield (2750 kg/ha) was found with treatment T_1 RDF (12.5:25:00 NPK kg/ha), but it did not differ significantly with treatment T_{10} (RDF + 250 ppm Nano Fe foliar spray). The magnitude of mean increase in haulm yield with T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) was 79.74, 69.16, 43.44, 34.72, 25.26, 19.34, 15.81, 11.28 and 5.73% over treatments T_1, T_{10}, T_2, T_6, T_3, T_7, T_4, T_8 and T_5, respectively.

It could be because sulphur and iron fertilization improved cell enlargement, elongation and division, resulting in an overall improvement in plant tissues and faster and more uniform vegetative growth of the crop. The result was in conformity with findings of Noman *et al*. (2015),Veeranagappa *et al*. (2015)[19], Li *et al*. (2015) [20], Kannan *et al*. (2016) [21], Rui *et al*. (2016), El-Metwally *et al*. (2018) and Nurezannat *et al*. (2019) [22].

Economics

Based on prevailing market price of groundnut and different variable and non-variable inputs, the cost of production, gross realization and net realization along with BCR were calculated for different treatments are presented in [Table-3].

The details of income, total expenses and BCR of individual treatment were worked out and presented in [Table-3]. The cost of production per hectare was also worked out and given in appendix-I. Maximum gross realization (1,87,791 Rs./ha), net realization (1,35,661 Rs./ha) and BCR (3.60) was obtained under treatment T_9 (RDF + 40 kg S/ha through bentonite sulphur + 250 ppm nano Fe foliar spray) followed by treatment T_5 (RDF + 40 kg S/ha through Gypsum + 250 ppm Nano Fe foliar spray) as 3.49.

Conclusion

On the basis of results obtained from present investigation, it could be concluded that for securing higher pod yield, net realization and BCR from *kharif* groundnut, cv. GG 34 raised on loamy sand soils of middle Gujarat conditions, it is advisable the crop should be fertilized with RDF (12.5:25:00 NPK kg/ha) and applied either 40 kg S/ha through bentonite sulphur or 40 kg S/ha through gypsum as basal along with two spray of nano Fe @250 ppm at 30 and 45 DAS.

Application of research: Study of Sulphur and nano Fe application on growth, yield attributes and yield of *kharif* groundnut (*Arachis hypogaea* l.)

Research Category: Agronomy

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Study area / Sample Collection: College Agronomy Farm, B. A. College of Agriculture, Anand

Cultivar / Variety / Breed name: Groundnut (*Arachis hypogaea* L.)

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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