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Effect of zinc and sulphur on growth and yield of groundnut (*Arachis hypogaea*) and yield validation using SPSS model

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Abstract
A field experimental trail on groundnut was conducted during *Zaid*, 2021 at Krishi Vigyan Kendra (KVK), Department of Agronomy, SHUATS, Prayagraj (U.P.) to evaluate the effect of zinc and sulphur on growth and yield of groundnut and to validate the yield using SPSS model. The soil of the experiment plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.28%), available N (225 kg/ha), available P (19.50 kg/ha), available K (92 kg/ha). The experiment was laid out in Randomized Block Design (RBD) with ten treatments replicated thrice. In the view of this experiment, zinc and sulphur were applied thrice at different levels ($ZnSO_4$ at 20, 25, 30 kg/ha and S at 30, 45, 60 kg/ha respectively) along with RDF and control plot with RDF alone. Results revealed that significantly higher growth parameters at 60 DAS and yield parameters at harvest *viz:* plant height (22.13 cm), number of nodules/plant (192.40), plant dry weight (16.40 g), number of pods per plant (50.20), number of kernels per pod (2), seed index (40.20 g), shelling percentage (70.20%), pod yield (4.20 t/ha), seed yield (2.95 t/ha), haulm yield (4.45 t/ha) and harvest index (34.37%) were recorded with the application of $ZnSO_4$ 30 kg/ha + Sulphur 60 kg/ha. Also, there was highest percentage increase in the actual yield (26.81%) over the predicted yield through SPSS with the application of $ZnSO_4$ 30 kg/ha + Sulphur 60 kg/ha. Thus, application of 30 kg $ZnSO_4$ and 60 kg sulphur per hectare along with RDF could be a promising option for yield enhancement in groundnut.

Keywords: Zinc, sulphur, growth, yield, yield validation and SPSS

Introduction

Groundnut (*Arachis hypogaea*) is an important oilseed and supplementary food crop of the world. It is fourth most important source of edible oil and third most important source of vegetable protein. It belongs to family Leguminaceae. India occupies first place in terms of area and second in terms of production of groundnut. Groundnut crop area in India is at 40.12 lakh per ha in 2018-2019. Similarly, production is estimated at 37.70 lakh tones per ha (Vali *et al.*, 2020) [17]. It is premier oil seed crop of India popularly known as peanut, monkey nut, manila nut. Globally 50% of groundnut is used for oil extraction, 37% confectionary and 12% seed purpose (Nurezannat *et al.*, 2019) [11].

Zinc known to be the constituent of enzyme and also involved in synthesis of pyruvic decarboxylase and indole acetic acid. Zinc is required in various metabolic processes as catalysts. Zinc also increases the content of protein, calorific value, amino acid and fat in oilseed crop. Zinc catalyzes 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 auxin and promotes absorption of water. Zinc deficiency start yellowing of leaves from lamina to base, mid-rib and veins remain green. Later on, necrotic brown spots are developed and dorsal leaf veins become brown. The deficiency of zinc affects IAA synthesis and delay dehydrogenase enzyme activity leading to poor plant metabolic activity. Zinc is an important micronutrient reported deficient in Indian soils. Zinc deficiency in crop plants is a widespread nutritional disorder in variety of soils. It is assumed that application of micronutrient may increase the productivity of groundnut due to its multifarious role in plant metabolism (Radhika *et al.*, 2021) [12].

Sulphur is increasingly being recognized as the fourth major nutrient after nitrogen, phosphorus and potassium (Tandon *et al.*, 2002) [15]. It is master nutrient for oilseed production as each unit of sulphur fertilizer generates 3-5 units of edible oil.

In oilseeds sulphur plays a vital role in the development of seed and improving the quality (Naser *et al*, 2013) [10]. Sulphur helps in synthesis of cystine, methionine, chlorophyll, vitamins (B, biotin and thiamine), metabolism of carbohydrates, oil content, protein content and also associated with growth and metabolism, especially by its effect on the proteolytic enzymes (Najar *et al*., 2011) [9]. Sulphur deficiency results in poor flowering, fruiting, cupping of leaves, reddening of stems, petiole and stunted growth. Since groundnut is rich both in oils and protein, requirement of sulphur for this crop is substantial high. Sulphur improves the chlorophyll, nodulation, increases the availability of other nutrients (Singh *et al*., 2007) [14].

Weather affects crop growth at different phenological phases and is therefore, responsible for variation in yields from year-to-year and place-to-place. A number of statistical techniques such as multiple regressions, principal component analysis (Jain *et al.*, 1984) [4], Markov chain analysis (Ramasubramanian *et al.*, 1999) [13] and agro-meteorological models (Walker, 1989) [18] have been used to quantify the response of crops to weather. Multiple regression models were used to forecast crop yields in India (e.g., Appa Rao, 1983; Mahi *et al.*, 1991) [1, 7]. Time series analysis is used to analyze yield trends and to predict yields under different scenarios.

Materials and Methods

A field trial was conducted during *Zaid*, 2021 at Krishi Vigyan Kendra (KVK), Department of Agronomy, SHUATS, Prayagraj (U.P.), India which is located at 25.40˚ N latitude, 81.85 ˚ E longitude, and 98 m altitude above the mean sea level (MSL). The soil of the experiment plot was sandy loam in texture, nearly neutral in soil reaction (pH 7.1), low in organic carbon (0.28%), available N (225 kg/ha), available P (19.50 kg/ha), available K (92 kg/ha). Nutrient sources were Urea, Single Super Phosphate, Murate of Potash, Zinc Sulphate and Sulphur Bentonite to fulfill the requirement of Nitrogen, Phosphorus, Potassium, Zinc and Sulphur respectively. The experiment was laid out in Randomized Block Design (RBD) with ten treatments replicated thrice. The treatments were 1- Zinc 20 kg/ha + Sulphur 30 kg/ha, 2- Zinc 20 kg/ha + Sulphur 45 kg/ha, 3- Zinc 20 kg/ha + Sulphur 60 kg/ha, 4- Zinc 25 kg/ha + Sulphur 30 kg/ha, 5- Zinc 25 kg/ha + Sulphur 45 kg/ha, 6- Zinc 25 kg/ha + Sulphur 60 kg/ha, 7- Zinc 30 kg/ha + Sulphur 30 kg/ha, 8- Zinc 30 kg/ha + Sulphur 45 kg/ha, 9- Zinc 30 kg/ha + Sulphur 60 kg/ha and 10- control (25:60:40 NPK kg/ha). RDF of 25:60:40 NPK kg/ha was used in all treatments as basal dose, also Zinc Sulphate and Sulphur Bentonite were applied basally. Seeds were dibbled manually at the seed rate of 60 kg/ha. The growth parameters of the plants were recorded at frequent intervals from germination up until harvest and finally, the yield parameters were recorded after harvest. These parameters were statistically analyzed using analysis of variance (ANOVA) as applicable to Randomized Block Design. SPSS (Statistical Product and Service Solutions) was used to compute Pearson’s correlation between observed yield and weather parameters, and with combination of weather parameters. Sum of weather parameters and sum product of different weather parameters and correlation coefficient has been derived. Multiple regressions between dependent variable (yield) and independent variables (time, sum and sum products for different weather parameters) were carried out. Regression equation was written using the regression formula.

Results and Discussion

Plant height (cm)

The significantly taller plant height (22.13 cm) at 60 DAS was recoded in treatment 9 with $ZnSO_4$ 30 kg/ha + Sulphur 60 kg/ha. However, the treatments with $ZnSO_4$ 25 kg/ha + Sulphur 60 kg/ha, $ZnSO_4$ 20 kg/ha + Sulphur 60 kg/ha and $ZnSO_4$ 30 kg/ha + Sulphur 45 kg/ha were statistically at par with $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha. The minimum plant height (18.93 cm) was recorded with the treatment $ZnSO_4$ 20kg/ha + Sulphur 30 kg/ha.

The plant height exhibited increasing trend with corresponding increase in level of sulphur at all the growth stages. Application of sulphur at 60 kg/ha produced the tallest plants and proved superior to all other doses of applied sulphur at all growth stages. Sulphur has also been reported to help in lowering the soil pH which is the main reason for greater availability and mobility of nutrients especially P, Fe, Mn and Zn. The present investigation is in cognizance with the findings Gowthami *et al.* (2017) [3] and Kamera *et al.* (2011) [6].

Number of nodules per plant

The significantly higher number of nodules/plant (192.40) at 60 DAS were recorded with the treatment $ZnSO_4$ 30 kg/ha + Sulphur 60 kg/ha. However, treatments 9 with $ZnSO_4$ 25 kg/ha + Sulphur 60 kg/ha and $ZnSO_4$ 20kg/ha + Sulphur 60 kg/ha were found statistically at par with the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha.

These might be due to role of Zn and Mo in enzymes activities as they are essential constituents of N_2 fixing enzymes complex “nitrogenase” which are responsible for increase in leg hemoglobin which ultimately increase nodulation and N-fixation (Radhika *et al.*, 2021) [12].

Plant dry weight (g)

The significantly maximum dry weight (16.40 g) was recorded with treatment 9 with $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha. However, treatments with $ZnSO_4$ 25 kg/ha + Sulphur 60 kg/ha and $ZnSO_4$ 20kg/ha + Sulphur 60 kg/ha was found statistically at par with the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha.

It was noted that dry matter increased progressively with increasing level of sulphur. The improvement of shoot length, number of primary and secondary branches/plant and leaf area index were mainly responsible for the increased dry matter in 60 kg/ha sulphur (Nurezannat *et al.*, 2019) [11].

Crop growth rate (g/m^2/day) and Relative growth rate (g/g/day)

Between 60-80 DAS Crop Growth Rate was recorded highest (21.89 g/m^2/day) in treatment 8 with $ZnSO_4$ 30kg/ha + Sulphur 45 kg/ha which showed significant difference with other treatments.

Between 60-80 DAS Relative Growth Rate was recorded significantly highest (0.034 g/g/day) in treatment 4 with $ZnSO_4$ 25 kg/ha + Sulphur 30 kg/ha. However, treatments with Control, $ZnSO_4$ 30kg/ha + Sulphur 30 kg/ha, $ZnSO_4$ 20kg/ha + Sulphur 45 kg/ha, $ZnSO_4$ 30kg/ha + Sulphur 45 kg/ha, $ZnSO_4$ 25kg/ha + Sulphur 45 kg/ha and $ZnSO_4$ 20kg/ha + Sulphur 30 kg/ha were found to be statistically at par with the treatment $ZnSO_4$ 25 kg/ha + Sulphur 40 kg/ha.

The improved nutritional environment at cellular level and leaf chlorophyll content appears to have increased the photosynthetic rate. Thus, it is obvious that the improved growth and development of the crop plants in the present investigation might be the result of enhanced metabolic activities and photosynthetic rate resulting in improvement in the accumulation of dry matter at the successive growth stages further leads to increase the crop growth rate and relative growth rate in all stages of plants. Present investigation is in cognizance with the findings of (Das *et al.*, 2016) [2].

Yield attributes

The significantly higher number of pods/plant (50.20) were found with treatment 9 $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha. However, treatments with $ZnSO_4$ 25kg/ha + Sulphur 60 kg/ha and $ZnSO_4$ 20kg/ha + Sulphur 60 kg/ha were found to be statistically at par with the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha.

Number of kernels/pod were significantly higher (2) in treatment 9 with $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha and the treatments with $ZnSO_4$ 25 kg/ha + Sulphur 60 kg/ha, $ZnSO_4$ 20kg/ha + Sulphur 60 kg/ha, $ZnSO_4$ 30kg/ha + Sulphur 45 kg/ha and $ZnSO_4$ 20kg/ha + Sulphur 45 kg/ha were found statistically at par with the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha.

Seed index was found significantly highest (40.20 g) in treatment 9 with $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha. However, treatments with $ZnSO_4$ 25kg/ha + Sulphur 60 kg/ha and $ZnSO_4$ 20kg/ha + Sulphur 60 kg/ha were found to be statistically at par with the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha.

Shelling percentage was found significantly highest (70.20%) in treatment 9 with $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha. However, treatments with $ZnSO_4$ 25kg/ha + Sulphur 60 kg/ha, $ZnSO_4$ 20kg/ha + Sulphur 60 kg/ha and $ZnSO_4$ 30kg/ha + Sulphur 45 kg/ha were found to be statistically at par with the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha.

Seed index also increased significantly when the level of sulphur increased progressively from 15 to 60 kg/ha (Yadav *et al.*, 2017) [16]. The improvement in yield attributes of groundnut might be due to better nutritional environment in the root zone for growth and development. Therefore, overall growth with the application of sulphur in deficient soil could be ascribed to its pivotal role in several physiological and biochemical processes which are of vital importance for the development of the plants. Besides, sulphur is involved in the formation of S containing amino acids, vitamins and has direct role in root developmental processes (Jat *et al.* 2009) [5].

Yield

Significantly higher pod yield (4.20 t/ha), seed yield (2.95 t/ha) and haulm yield (4.45 t/ha) were found in treatment 9 with $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha. However, treatments with $ZnSO_4$ 25 kg/ha + Sulphur 60 kg/ha, $ZnSO_4$ 20kg/ha + Sulphur 60 kg/ha and $ZnSO_4$ 30kg/ha + Sulphur 45 kg/ha were found to be statistically at par with the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha. Harvest index of (34.37%) was observed in the treatment $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha which showed significant difference other treatments.

The higher seed yield may be attributed to higher total dry matter accumulation due to better total nitrogen as well as Zn and Fe uptake and their translocation to the reproductive parts and improvement in yield attributing characters like number of pods/plant, pod weight, 100 kernel weight and shelling percentage. The data on haulm yield also differed significantly due to micronutrient application. Soil application of $ZnSO_4$ at 25 kg/ha + foliar application of $ZnSO_4$ at 0.5% recorded significantly higher haulm yield (3080 kg/ha) (Gowthami *et al.*, 2017) [3]. Similar results were also observed by Meena *et al.*, (2007) [8]. The marked improvements in pods, kernel and haulm yields due to applying sulphur could be ascribed to overall improvement in vigour and crop growth, as reflected in plant height, dry matter accumulation and number of nodules/plant. The improved growth due to S fertilization coupled with increased photosynthesis on one hand and greater mobilization of photosynthates towards reproductive structures, on the other, might have been responsible for significant increase in yields of groundnut. (Yadav *et al.*, 2019) [16].

Yield validation using SPSS model

The multi-regression analysis using SPSS has been employed for the estimation of groundnut yield. The regression for SPSS model is

$$Y = 3.156 + (0.061*Time) + (0.004*Z11)$$

Here, Z11 is the sum product of maximum temperature.

The yield obtained in treatment 9 with $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha (4.20t/ha) showed 26.81% increase over the predicted yield through SPSS model (3.074 t/ha).

Table 1: Effect of Zinc and Sulphur on growth and growth attributes of groundnut

S No.	Treatments	60 DAS			60-80 DAS	
		Plant height (cm)	Number of nodules/plant	Plant dry weight (g)	Crop growth rate (g/m^2/day)	Relative growth rate (g/g/day)
1.	20 kg/ha $ZnSO_4$ + 30 kg/ha Sulphur	18.93	129.40	12.33	17.89	0.0313
2.	20 kg/ha $ZnSO_4$ + 45 kg/ha Sulphur	19.33	139.53	13.60	21.11	0.0330
3.	20 kg/ha $ZnSO_4$ + 60 kg/ha Sulphur	21.27	175.27	15.93	20.56	0.0287
4.	25 kg/ha $ZnSO_4$ + 30 kg/ha Sulphur	19.17	131.27	12.40	20.55	0.0347
5.	25 kg/ha $ZnSO_4$ + 45 kg/ha Sulphur	19.63	146.60	14.00	20.55	0.0317
6.	25 kg/ha $ZnSO_4$ + 60 kg/ha Sulphur	21.40	185.00	16.33	20.33	0.0279
7.	30 kg/ha $ZnSO_4$ + 30 kg/ha Sulphur	19.30	136.00	13.20	20.56	0.0330
8.	30 kg/ha $ZnSO_4$ + 45 kg/ha Sulphur	20.83	149.80	14.40	21.89	0.0325
9.	30 kg/ha $ZnSO_4$ + 60 kg/ha Sulphur	22.13	192.40	16.40	20.55	0.0281
10.	CONTROL	16.63	122.07	11.60	18.89	0.0341
	F-Test	S	S	S	NS	S
	S.Em (±)	0.45	5.96	0.17	1.03	0.0014
	CD (p=0.05)	1.35	17.71	0.52	--	0.0042

Table 2: Effect of Zinc and Sulphur on yield and yield attributes of groundnut

S No.	Treatment combinations	No. of pods/plant	No. of kernels/Pod	Seed Index(g)	Shelling (%)	Pod yield (t/ha)	Seed yield (t/ha)	Haulm Yield (t/ha)	Harvest Index (%)
1.	20 kg/ha $ZnSO_4$ + 30 kg/ha Sulphur	39.40	1.80	37.00	69.00	3.74	2.58	3.99	33.13
2.	20 kg/ha $ZnSO_4$ + 45 kg/ha Sulphur	42.80	1.93	38.00	69.60	3.86	2.69	4.11	33.43
3.	20 kg/ha $ZnSO_4$ + 60 kg/ha Sulphur	48.60	2.00	39.73	69.80	4.05	2.83	4.30	33.87
4.	25 kg/ha $ZnSO_4$ + 30 kg/ha Sulphur	40.20	1.80	37.20	69.20	3.76	2.61	4.01	33.83
5.	25 kg/ha $ZnSO_4$ + 45 kg/ha Sulphur	44.80	1.93	38.20	69.60	3.90	2.72	4.15	33.73
6.	25 kg/ha $ZnSO_4$ + 60 kg/ha Sulphur	49.40	2.00	40.00	70.00	4.10	2.89	4.35	33.88
7.	30 kg/ha $ZnSO_4$ + 30 kg/ha Sulphur	41.60	1.87	37.80	69.40	3.82	2.65	4.07	33.87
8.	30 kg/ha $ZnSO_4$ + 45 kg/ha Sulphur	46.20	1.93	38.40	69.80	3.95	2.76	4.20	33.85
9.	30 kg/ha $ZnSO_4$ + 60 kg/ha Sulphur	50.20	2.00	40.20	70.20	4.20	2.95	4.45	34.37
10.	CONTROL	38.20	1.73	36.00	69.33	3.40	2.36	3.65	33.51
	F-Test	S	S	S	S	S	S	S	NS
	S.Em (±)	0.55	0.04	0.17	0.14	0.09	0.07	0.09	0.69
	CD (p=0.05)	1.64	0.13	0.50	0.43	0.28	0.20	0.28	--

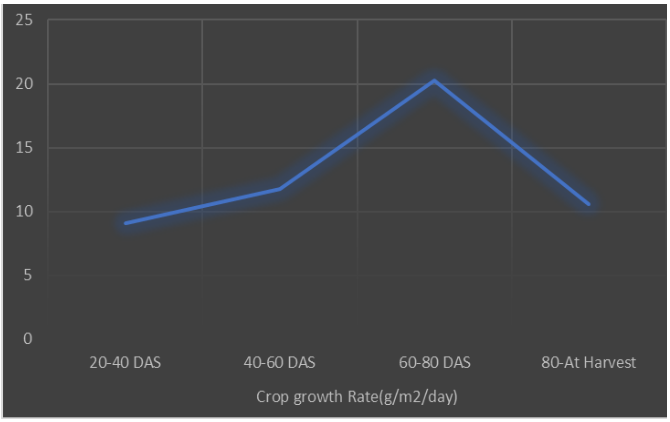

Fig 1: Crop Growth Rate ($g/m^2/day$)

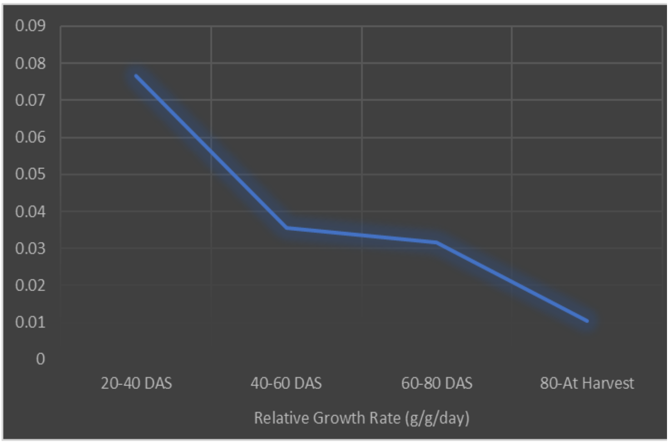

Fig 2: Relative Growth Rate (g/g/day)

Conclusion

Based on my research trail, the treatment combination of $ZnSO_4$ 30kg/ha + Sulphur 60 kg/ha was found to be more productive. Although the findings are based on one season further research is needed to confirm the findings and their recommendation.

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