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Effect of sulphur and spacing on growth and yield of groundnut (*Arachis hypogea* L.)

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Abstract
A field experiment was conducted during *Zaid* 2021 at Crop Research Farm, Department of Agronomy, Niani Agricultural Institute, Sam Higginbottom University of Agriculture Technology And Sciences, Prayagraj, Uttar Pradesh, India. The experiment was laid out in Randomized Block Design with Ten treatments each replicated thrice on the basis of one year experimentation. The treatments consisted of Sulphur 45 kg/ha, Sulphur 60 kg/ha, Sulphur 75 kg/ha and three levels of spacing 25 cm x 25 cm, 20 cm x 20 cm, 30 cm x 10 cm the results showed that Treatment6 (Sulphur at 60 kg/ha + 30 x 10 cm,) was recorded significantly higher plant height (39.09 cm), maximum number of nodules/plant (8.07), higher plant dry weight (22.03 g/plant), Crop growth rate (5.33 g/m^2/day), maximum number of pods, maximum number of kernels /pod, number of pods/plant (27.46), kernels/pod (2.06), test weight (39.20 g), pod yield (3.63 t/ha), seed yield (1.56 t/ha), haulm yield (5.92 t/ha), harvest index (21.44%) and shelling (69.04%).

Keywords: Groundnut, sulphur, spacing, growth and yield

Introduction
Groundnut (*Arachis hypogaea* L.) is known to be a unique and important legume cum oilseed crop of India accounting 33% of world's groundnut area and about 27.3% production. It belongs to Leguminoseae family. It is also known as peanut, monkey nut, earthnut, manila nut and goober. It is world's largest source of edible oil and ranks 13th among the food crops as well as 4th most important oilseed crops of the world. It is a leading oilseed crop in India with an area of 5.95 million hectares and production of 8.254 million tone of groundnut at average productivity of 1071 kg ha-1 during summer season (groundnut outlook report, 2020-2021) [11]. It is a multipurpose crop contains 45% to 51% high quality hydrogenated edible oil and 26% dietary proteins, 24.2% soluble carbohydrates and minerals. The kernels also rich in vitamin E, K and all B vitamins except B12 (Naiknaware *et al*., 2015) [8].

Groundnut is considered to be the most important food legume and oilsed crops of India, which is cultivated in 4.91 million ha area with the production of 6.73 million tonnes and average productivity of 1.86 t/ha (DES, 2021). Groundnut, being an unpredictable legume, its response to nutrient application is always not optimistic. Groundnut oil is composed of mixed glycerides and contains a high percentage of unsaturated fatty acids, such as oleic (50 to 65 percent) and linoleic acid (18 to 30 percent). Groundnut contains amino acids including cysteines which are essential for animal growth. The groundnut cake obtained after oil extraction is rich in protein and considered as valuable organic manure and animal feed, which contains 7 to 8% N, 1.5% P and 1% K. Important reasons for low average yield of groundnut at farmers field were the use of low seed rate and improper agronomic practices, to overcome this issue the appropriate utilization of micro nutrients like sulphur, gypsum etc are the most important which contribute substantially to the seed yield of groundnut (Dileep kumar and Vikram Singh 2019) [2].

Sulphur is the fourth major nutrient and plays an important role in the nutrition of oil-seed crop and as a constituent of sulphur containing amino acids cystine, cysteine and methionine (Gangadhara *et al*., 1990) [4]. In oil seed crops it is also involved in the formation of glucocides or glucosinolates which on hydrolysis increase the oil content. One of the main functions of sulphur in proteins or polypeptides is the formation of disulphide bonds between polypeptide chains. Disulphide linkages are important in stabilizing and determining the configuration of proteins. The application of sulphur increased the uptake of various macro and micro nutrients in groundnut (Singh, 1999) [12]. Among the sources, application of gypsum increased the seed yield of mustard as compared with single super phosphate.

Application of S in combination with balanced amounts of other nutrients significantly increased the oil content of mustard (5-6%). Sulphur application also has marked effect on soil properties and is used as soil amendment such as gypsum and pyrite to improve the availability of other nutrients in soil. Sulphur (S) is essential for the growth and development, plays a key role in plant metabolism, indispensable for the synthesis of essential oils, plays a vital role in chlorophyll formation required for development of cells.

Plant density is one of the important factors which play a vital role in enhancing the production and productivity of groundnut. Plant density (plant spacing) is an efficient management tool for maximizing grain yield by increasing capture of solar radiation within the canopy thereby increasing land use efficiency. Sub optimal plant stand in groundnut has been identified as one of the major constraints to realize full production potential. In wider row spacing, solar radiation falling within the rows gets wasted particularly during the early stages of crop growth, whereas in closer row spacing upper part of the crop canopy may be well above the light saturation capacity but the lower leaves remain starved of light and contribute negatively towards yield. The dense plant population reduces the yield due to reduction in the photo- synthetically active leaf area caused by mutual shading.Hence, optimum plant population is required for better utilization of growth resources like light, moisture and nutrients, which consequently reduces the risk of yield reduction and ensures higher productivity and returns per unit area (Gadade *et al.*, 2018) [3]. Hence the present investigation was carried out to find out "Effect of Sulphur and Spacing on Growth and Yield of Groundnut (*Arachis hypogea* L.)"

Materials and Methods

A field experiment was conducted during *Zaid* season of 2021, at Crop research farm of Department of Agronomy at Sam Higginbottom University of Agriculture, Technology, And Sciences, Prayagraj (U.P) India. Which is located at 25º 24' 42" N latitude, 81º 50' 56" E longitude and 98 m altitude above the mean sea level (MSL). The crop (KADIRI 6) was sown in 27 April 2021. The experiment was laid out in Randomized Block Design comprising of 10 treatments which are replicated thrice. Each treatment net plot size is 9 m^2. Sulphur were applied and spacing was maintained as per the treatment details in combinations as follows, with T_1: Sulphur at 45 kg/ha +20 x 20 cm, T_2: Sulphur at 45 kg/ha +25 x 25 cm, T_3: Sulphur at 45 kg/ha +30 x 10 cm, T_4: Sulphur at 60 kg/ha +20 x 20 cm, T_5: Sulphur at 60 kg/ha +25 x 25 cm, T_6: Sulphur at 60 kg/ha +30 x 10 cm, T_7: Sulphur at 75 kg/ha +20 x 20 cm, T_8: Sulphur at 75 kg/ha +25 x 25 cm, T_9: Sulphur at 75 kg/ha +30 x 10 cm, T_{10}: Control are used. The growth parameters and yield, production were recorded at harvest from randomly selected plants in each plot. The data was computed and analysed by following statistical method of Gomez and Gomez (1984).

Results and discussion

Effect of sulphur and spacing on growth parameters of groundnut

Plant height (cm)

Treatment 6 (Sulphur at 60 kg/ha +30 cm x 10 cm) recorded maximum plant height 39.09 cm. However, plant height 38.87 cm with Treatment 5 (Sulphur at 60 kg/ha +25 cm x 25 cm) and 38.50 cm with Treatment 9 (Sulphur at 75 kg/ha +30 cm x 10 cm) were found at par with Treatment6 compared to control plot.

The significant and highest plant height was with application of sulphur may be due to along with sulphur, other macro and micronutrients are also available which are considered important for the growth and development of plant. It seems to have promoted meristematic activities causing higher apical growth and expansion of the photosynthetic surface. (Raja *et al*., 2007) [10] & (Dileep *et al*., 2011) [2]. Furthur the spacing practices had significant effects on plant height may be due to an optimum spacing resulted in lesser competition for sunlight, water, nutrients and space between the plants which resulted in higher plant height. Similar findings were reported by (Gadade *et al*., 2018) [3].

Plant dry weight (g/plant)

Treatment6 (Sulphur at 60 kg/ha +30 cm x 10 cm) recorded significantly maximum dry weight (22.03 g). However, 21.89 g in Treatment5 (Sulphur at 60 kg/ha +25 cm x 25 cm) and 21.61 g in Treatment9 (Sulphur at 75 kg/ha +30 cm x 10 cm) were statistically at par with Treatment6 (Sulphur at 60 kg/ha +30 cm x 10 cm) compared to control plot.

The significant and highest Dry weight was the application of Sulphur plays plant metabolic activity, which may lead to the increase in photosynthesis. Similar results were observed by Sisodiya *et al*. (2016) [17] Further the highest dry matter production was observed in 30x10 cm spacing due to better photosynthetic activity, due to greater exposure of sunlight, and increased availability of nutrients. The results were in accordance with to the findings of Gadade *et al*. (2018) [3].

Nodules/plant

Significantly maximum nodules/plant 8.07 was observed in Treatment6 (Sulphur at 60 kg/ha +30 cm x 10 cm). However, nodules/plant 7.87 with Treatment5 (Sulphur at 60 kg/ha +25 cm x 25 cm) and 7.66 with Treatment9 (Sulphur at 75 kg/ha +30 cm x 10 cm) were found at par with Treatment6 compared to control plot.

The significant and maximum number of nodules/plant with application of sulphur which might have increase of nodulation, root growth, nitrogen fixation, Solaimalai *et al*., (2020) [15].

Yield attributes and yield

Pods/plant

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum No. of pods/plant (27.46). However, 27.19 pods/plant in T_5 (Sulphur at 60 kg/ha +25 x 25 cm) and 26.86 in T_9 (Sulphur at 75 kg/ha +30 x 10 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha +30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

The increment in number of pods per plant and seed yield with increasing dose of sulphur application might be better for root growth, cell multiplication, elongation and cell expansion in the plant body by higher dose of sulphur application, which ultimately increased the seed yield Kundu *et al*. (2010) [6]. Higher number of pods/plant might have been possible due to more vigour and strength attained by the plants as a result of better photosynthetic activities with sufficient availability of light, and supply of nutrients in balanced quantity of the plants at growing stages Hamakareem *et al.* (2016) [5].

Kernals/pod

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum Kernals/pod (2.06). However, 2.02 Kernals/pod in T_5 (Sulphur at 60 kg/ha +25 x 25 cm) and 1.98 in T_9 (Sulphur at 75 kg/ha +30 x 10 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha +30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

Increase in value of yield contributing characters with higher doses of sulphur was due to the facts that the adequate sulphur was available during the entire period of crop growth for better vegetative growth and development of groundnut plants. The results were found to be similar with Sharma *et al*. (2004) [14].

Test weight (g)

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum test weight (39.20 g). However, 38.86 g test weight in T_5 (Sulphur at 60 kg/ha +25 x 25 cm) and 38.53 in T_9 (Sulphur at 75 kg/ha +30 x 10 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha +30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

The increment in number of pods per plant and seed yield with increasing dose of sulphur application might be better for root growth, cell multiplication, elongation and cell expansion in the plant body by higher dose of sulphur application, which ultimately increased the seed yield Dutta and Patra *et al*. (2005) [1].

Better availability of moisture and moderation of soil temperature which led to greater uptake of nutrients and reduced number of days taken to meet the required heat units for proper growth and development of plants and ultimately the yield attributes. The results were recorded similar with Onat *et al.* (2017) [9].

Pod yield (t/ha)

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum pod yield (3.63 t/ha). However, 3.54 t/ha pod yield in T_5 (Sulphur at 60 kg/ha +25 x 25 cm) and 3.42 t/ha in T_9 (Sulphur at 75 kg/ha +30 x 10 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha +30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

Sulphur accelerated nutrient uptake which helped the plants to put optimum growth and later on get converted in to reproductive phase. The results were in accordance with Wadile *et al.* (2005) [18].

Increase in pod yield might be due to under 30 × 10 cm because the less intra row spacing in other treatments increases competition in solar radiation that ultimately stunt growth of some intra row plant in vegetative phase and they were unable to reach reproductive phase even though the yield contributing variables were high when compared to the recommended spacing, the productivity was low due to the lesser plant population reached to reproductive phase. The findings were in accordance with Gadade *et al*. (2018) [3].

Seed yield (t/ha)

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum seed yield (1.56 t/ha). However, 1.53 t/ha seed yield in T_5 (Sulphur at 60 kg/ha + 25 x 25 cm) and 1.49 t/ha in T_9 (Sulphur at 75 kg/ha +30 x 10 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha + 30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

The optimum spacing 30x15 cm helped plant to receive sufficient amount of heat, water and nutrients from soil which increased number of pods/plant, seeds/pod and test weight which directly helped in increase of seed yield in groundnut. The results were similar to Singh *et al*. (2007) [13].

Haulm yield (t/ha)

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum seed yield (5.92 t/ha). However, 5.86 t/ha seed yield in T_5 (Sulphur at 60 kg/ha +25 x 25 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha +30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

Harvest Index (%)

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum harvest index (%) (21.44%). However, 21.15% harvest index in T_5 (Sulphur at 60 kg/ha +25 x 25 cm) and 20.92% in T_9 (Sulphur at 75 kg/ha +30 x 10 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha +30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

Shelling (%)

Treatment T_6 (Sulphur at 60 kg/ha +30 x 10 cm) recorded maximum shelling (%) (69.04%). However, 68.79% shelling in T_5 (Sulphur at 60 kg/ha +25 x 25 cm) and 68.33% in T_9 (Sulphur at 75 kg/ha +30 x 10 cm) which were statistically at par with T_6 (Sulphur at 60 kg/ha +30 x 10 cm) T_9 (60 kg/ha S + 60×20 cm) compared to control plot.

Table 1: Effect of Bio-fertilizers and Plant Growth Regulators on growth attributes of pearl millet

Treatments	Plant height (cm)	Noduels/plant	Dry weight (g/plant)
1. Sulphur at 45 kg/ha +20cm x 20cm	36.47	5.99	20.22
2. Sulphur at 45 kg/ha +25cm x 25cm	36.82	6.27	20.35
3. Sulphur at 45 kg/ha +30cm x 10cm	37.76	7.17	21.03
4. Sulphur at 60 kg/ha +20cm x 20cm	37.42	6.85	20.76
5. Sulphur at 60 kg/ha +25cm x 25cm	38.87	7.87	21.89
6. Sulphur at 60 kg/ha +30cm x 10cm	39.09	8.07	22.03
7. Sulphur at 75 kg/ha +20cm x 20cm	37.15	6.51	20.57
8. Sulphur at 75 kg/ha +25cm x 25cm	38.14	7.39	21.35
9. Sulphur at 75 kg/ha +30cm x 10cm	38.50	7.66	21.61
10. Control	36.17	5.71	20.02
F- test	S	S	S
S.Em(±)	0.20	0.19	0.18
C. D. (P = 0.05)	0.60	0.57	0.53

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

S. No	Treatments	Pods/plant	Kernals/pod	Test weight (g)	Pod yield (t/ha)	Seed yield (t/ha)	Haulm Yield (t/ha)	Harveting index (%)	Shelling (%)
1.	Sulphur at 45 kg/ha +20 x 20cm	24.92	1.69	36.36	3.05	1.19	5.27	18.46	65.76
2.	Sulphur at 45 kg/ha +25 x 25cm	25.29	1.73	36.69	3.10	1.23	5.43	18.84	66.05
3.	Sulphur at 45 kg/ha +30 x 10cm	26.14	1.87	37.45	3.29	1.38	5.58	19.98	67.35
4.	Sulphur at 60 kg/ha +20 x 20cm	25.89	1.83	37.19	3.23	1.34	5.53	19.54	66.97
5.	Sulphur at 60 kg/ha +25 x 25cm	27.19	2.02	38.86	3.54	1.53	5.86	21.15	68.79
6.	Sulphur at 60 kg/ha +30 x 10cm	27.46	2.06	39.20	3.63	1.56	5.92	21.44	69.04
7.	Sulphur at 75 kg/ha +20 x 20cm	25.58	1.77	36.93	3.18	1.27	5.49	19.24	66.56
8.	Sulphur at 75 kg/ha +25 x 25cm	26.45	1.91	37.79	3.35	1.44	5.66	20.44	67.85
9.	Sulphur at 75 kg/ha +30 x 10cm	26.86	1.98	38.53	3.42	1.49	5.75	20.92	68.33
10.	Control	24.61	1.63	36.17	2.96	1.13	5.22	18.11	65.23
F-test		S	S	S	S	S	S	S	S
S. EM (±)		0.23	0.04	0.23	0.08	0.03	0.04	0.18	0.24
C. D. (P = 0.05)		0.69	0.12	0.70	0.22	0.08	0.12	0.54	0.71

Conclusion

Based on the findings of the investigation it may be concluded that treatment with sulphur 60kg/ha and spacing 30 cm x 10 cm performed exceptionally in all growth and yield parameters and in obtaining maximum yield of groundnut. Hence, sulphur 60kg/ha and spacing 30 cm x 10 cm may be more preferable and can be recommended to the farmers.

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