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Effect of phosphorous and sulphur fertilization on groundnut yield in an *Inceptisol* of Raigarh, Chhattisgarh

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Abstract
The field experiment entitled "Evaluation of P and S nutrition on groundnut yield, efficiency and fractionation in an *Inceptisol* of Raigarh, Chhattisgarh'. Was conducted in farmer's field during rabi 2020-21 and 2021-22, in a factorial randomized block design (FRBD) with four levels of phosphorous as, (0, 30, 60 & 90 kg P_2O_5 ha^{-1}) and three levels of sulphur as, (0, 20 & 40 kg ha^{-1}) each with three replications. Significantly superior results of pod and haulm yield were recorded under the application of phosphorous @ 90 kg ha^{-1} and application of sulphur @40 kg ha^{-1} over control.

Keywords: Phosphorus, sulphur, yield, groundnut

Introduction
Groundnut (*Arachis hypogaea* L.) is an annual herbaceous legume crop that self-pollinates. Groundnut is the world's thirteenth most important food crop, the fourth most important source of edible oil, and the third most important source of vegetable protein (Taru *et al*., 2008) [12]. Groundnut is one of India's most important oilseed crops, ranking first in terms of area and second in terms of production. Groundnut (*Arachis hypogaea* L.) is a significant commercial oilseed crop in India, China, Brazil, Nigeria, and the United States. It is India's most important oilseed crop, accounting for up to 33% of total oilseed production and 28% of total oil seed area (Agashe *et al*., 2018) [1]. Groundnut can be grown in Chhattisgarh during both the rabi and kharif seasons. The total groundnut area in Chhattisgarh is 67.7 thousand ha^{-1}, with a production of 70.2 thousand tonnes and a productivity of 1036 kg ha^{-1}.
Phosphorus is the backbone of balanced fertilization in Indian agriculture. Every biological function in nature depends on phosphorus for the generation, transport, and storage of energy via ATP (therefore considered as energy currency) and ADP. It is the primary component of cellular metabolism and a structural component of cell membranes, nucleic acids, and other critical materials (Wiedenhoeft, 2006) [17]. Phosphorus is one of the second major plant nutrient, it is an indispensible element play and unique role in several plant metabolic and energy transformation process. Phosphorus acts as energy source (ATP) for plants. Sulphur is the next most important emerging nutrient that is showing widespread deficiency. Sulphur is now recognized as the fourth major plant nutrient after N, P, and K, as well as an essential component of balanced fertilization and nutrition for oilseed crops in general, and groundnut crops in particular. It is an essential plant nutrient best known for its critical and specific role in the synthesis of sulphur-containing amino acids such as methionine (20%) and cysteine (27%), as well as the synthesis of proteins, chlorophyll and oil.
In the present investigation groundnut (*Archies Hypogea*) is taken as test crop as it is an essential oil crop. It may be quite worthy to evaluate the effect of phosphrous and sulphur levels on groundnut yield.

Material and Method
In *Rabi* 2020-21, and 2021-22 the current experiment was adopted. Using auger, representative soil samples were obtained from 0-15 cm depth and composite samples were prepared before the experiment was laid out. The soil samples were air dried, passed through a 2 mm sieve and used for different physical-chemical analysis. The soil of the experimental field was *Inceptisol*, and sandy loam in texture which was also locally called as Matasi (in Chhattisgarh plain) and Gader (in Northen hills).

Table 1: Treatments details & Layout

S. No.	Treatments levels	Treatment combination	
	Phosphorous (kg/ha)		
I	P0	T1-P0S0	T4-P30S0
II	P30	T2-P0S20	T5-P30S20
III	P60	T3-P0S40	T6-P30S40
IV	P90		
	Sulphur (kg/ha)		
I	S0	T7-P60S0	T10-P90S0
II	S20	T8-P60S20	T11-P90S20
III	S40	T9-P60S40	T12-P90S40

1. Fertilzer application
The sources of phosphorous and sulphur were DAP and bentonite sulphur respectively whereas, common dose of N and K was applied as basal dose at the time of sowing, @ 20 kg ha^{-1} through urea and 20 kg K_2O ha^{-1}, through muriate potash respectively.

2. Tested variety
Groundnut cultivar TAG-24 was taken as a test crop. It is a semi-spreading variety recommended for cultivation in sandy and loamy soils of India. It is a medium seeded variety with light pink color and contains 44-48% oil. It takes about 110-115 days to mature and gives an average yield of 27.03 quintals/ha.

3. Cultivation Details
a) Field preparation
The field was initially ploughed by disc plough followed by cross harrowing and planking to bring the field into good tilth for proper germination and establishment of seedlings. Thereafter, beds of 5.0 m x 4.0 m were prepared as per plan of layout.

b) Harvesting, threshing and winnowing
At maturity, after leaving two border rows on each side along the length and 0.5 m along width on both sides, a net area of 5.0 m x 4.0 m was harvested separately from each plot. The harvested material of each plot was tied up in bundles, tagged and kept on threshing floor for drying. Dried bundles of haulms from individual plot were weighed separately to record haulm yield. Threshing was done manually followed by winnowing. After cleaning, pod yield/plot was recorded and later on converted into yield/ha.

c) Pod Yield
After threshing, winnowing and cleaning, the produce of each plot was weighed separately and converted in terms of pod yield in kg/ha.

4. Soil analysis
1) Soil Texture
Soil Texture of the soil was determined by International pipette method as described by Piper (1967) [9].

2) Soil pH
Soil pH was determined in 2.5:1 water-soil suspension after stirring for 30 minutes, by glass electrode pH meter as suggested by Piper (1966) [8].

3) Electrical conductivity
The soil sample used for pH determination was allowed to settle down for 24 hours. Electrical conductivity of soil was determined with the help of direct reading conductivity meter using soil: water suspension as described by Jackson (1973) [4] and expressed as dS m^{-1}.

4) Organic carbon
Organic carbon was determined by Walkley and Black's rapid titration method (1934) which is expressed in g kg^{-1}.

5) Available N
The available nitrogen in soil was determined by alkaline potassium permanganate method as described by Subbiah and Asija (1956) [14].

6) Available P
Soil available phosphorus was determined by using 0.5M $NaHCO_3$ (pH 8.5) solution (Olsen extractant. Phosphorus in the extract was determined calorimetrically by using spectrophotometer at 660 nm wavelength as suggested by Olsen *et al*., (1965) [18].

7) Available K
It was extracted with neutral normal ammonium acetate (NH4OAc, pH 7.0) and the soil: extractant ratio was 1:5 and shaking time was 5 minutes. Potassium in soil was determined by flame photometer as described by Jackson (1973) [4].

8) Available Sulphur
Available sulphur was determined by Turbidimetric method using 0.15% Calcium chloride dihydrate (CaCl2.H2O) extractant. Sulphur in the extract was determined calorimetrically by using spectrophotometer at 420 nm wavelength as described by Williams and Steinbergs (1969) [16].

Results and Discussion
The pod and haulm yield of groundnut in an experiment by the phosphorous and sulphur levels are discussed below.

1) Pod yield of groundnut
Phosphorous
Groundnut pod yield was significantly influenced by application of phosphorous at different levels and there was a significant increase in pod yield with increasing levels of phosphorous upto 90 kg ha^{-1} in both the years. The highest pod yield as, (25.28, 26.80 and 26.04 q ha^{-1}) during both the years and their mean, respectively, was observed under applied P_2O_5 @ 90 kg ha^{-1}. The application of P_2O_5 @ 90 kg ha^{-1} was significantly superior yield over 0 and 30 kg P ha^{-1}. However, it was at par with 60 kg P_2O_5 ha^{-1}. The lowest pod yield as, (18.35, 20.33 and19.34 q ha^{-1}) during both the seasons and in their mean, respectively, was observed under phosphorous omitted plot (P0). The increase in seed yield due to phosphorus application might be due to improvement in plant growth and vigour as P plays important role in plant metabolism, finally leading to enhanced seed yield. Similar findings were also reported by Mahmoodi *et al*., (2005) [19]. Phogat *et al*., (2018) [20] also found that application of phosphorous significantly increased the seed yield of black gram.

Sulphur
Pod yield of groundnut was significantly influenced by

applied sulphur levels. The highest pod yield as, (24.70, 25.94 and 25.32 q ha^{-1}) during both the seasons and in their mean, respectively, was observed under applied sulphur @ 40 kg ha^{-1} over S omitted plot (S0) in. However, it was at par with application of 20 kg S ha^{-1}. The lowest pod yield as, (20.42, 21.92 and 21.17 q ha^{-1}) during both the years and in their mean, respectively, was observed under S omitted plot (S0) during. The positive impact of sulphur application might be due to application of sulphur might have increased the availability of nutrient to pod plant due to improved nutritional environment, which in turn, favourably influenced the energy transformation activation of enzymes, chlorophyll synthesis as well as increased carbohydrate metabolism Similar findings are reported by (Baviskar, 2005) [2], Singh *et al*., (2005) [13] observed that applying S at 20, 40, and 60 kg ha^{-1} increased pod yield by 18.8, 27.5 and 29.2 percent above the control in all soils.

Interaction P x S

The interaction effect of phosphorus and sulfur levels on pod yield of groundnut could not reach to the level of significance.

Table 1: Effect of phosphorous and sulphur levels on pod and haulm yield of groundnut

Treatments	Pod yield			Haulm yield		
	2020-21	2020-21-22	Mean	2020-21	2020-21-22	Mean
P levels (kg ha^{-1})						
0	18.35c	20.33c	19.34c	28.18c	29.64c	28.91c
30	21.98b	23.01b	22.50b	31.81b	33.47b	32.64b
60	24.93a	25.77a	25.46a	35.90a	37.25a	36.77a
90	25.28a	26.80a	26.04a	36.36a	38.86a	37.61a
SEm ±	0.89	0.84	0.85	1.21	1.22	1.19
CD (P=0.05)	2.62	2.45	2.48	3.54	3.586	3.504
S levels (kg ha^{-1})						
0	20.42b	21.92b	21.17b	30.10b	31.67b	30.88b
20	22.78a	24.07a	23.51a	33.31a	34.78a	34.19a
40	24.70a	25.94a	25.32a	35.78a	37.97a	36.87a
SEm ±	0.77	0.72	0.73	1.04	1.06	1.03
CD (P=0.05)	2.27	2.12	2.15	3.06	3.11	3.03
Interaction						
SEm ±	1.55	1.45	1.47	2.09	2.12	2.07
CD (P=0.05)	NS	NS	NS	NS	NS	NS
CV (%)	11.86	10.46	10.88	10.95	10.54	10.55

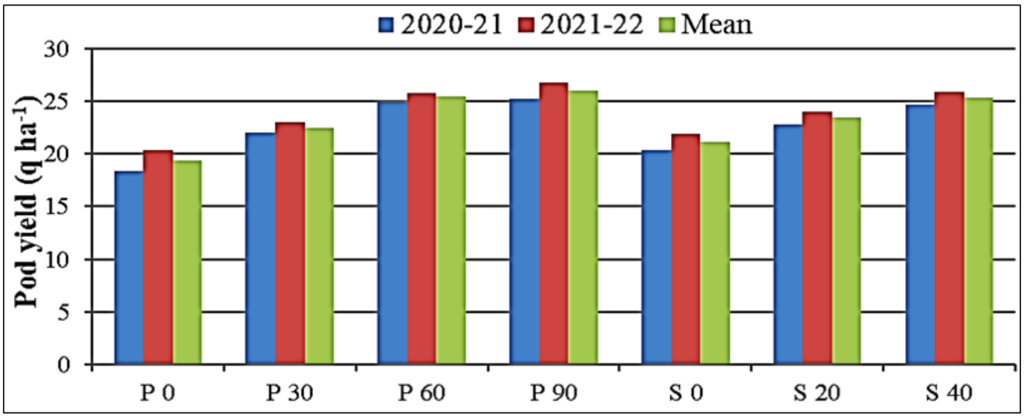

Fig 1: Effect of phosphorous and sulphur levels on pod yield (q ha^{-1}) of groundnut

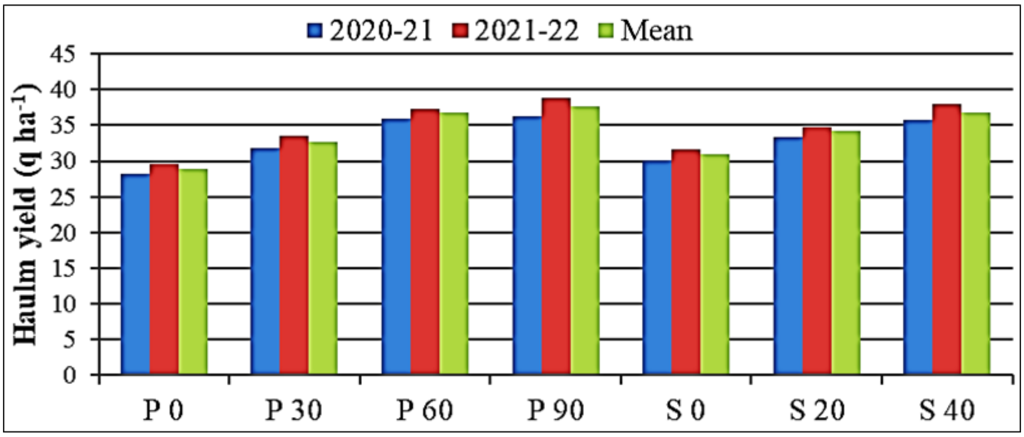

Fig 2: Effect of phosphorous and sulphur levels on haulm yield (q ha^{-1}) of groundnut

2) Haulm yield (q ha^{-1})

Phosphorous

Groundnut haulm yield was positively influenced with the application of phosphorous upto 90 kg ha^{-1} during both the years. The application of 90 kg P_2O_5 ha^{-1} showed significantly superior result as, (36, 38.86 and 37.61 q ha^{-1}) during both the years and in their mean, respectively, over rest of the treatment except crop receiving 60 kg P_2O_5 ha^{-1}which gives at par result with 90 kg P_2O_5 ha^{-1}. The lowest haulm yield as, (28.18, 29.64 and 28.91) during both the years and in their mean, respectively, was found under S omitted plot (S0).

The significant increased in haulm yield might be due to increased supply of phosphorus to plant in P deficient soil. The supply of phosphorus to soil might have accelerated cell division and enlargement, in plants favouring increased growth and yield. These results are in line with findings of (Mouri *et al*., 2018) [6], Dhage *et al*., (2014) [3]. Miravat *et al*., (2006) [5]. They discovered that raising the phosphorus fertiliser rate from 30 to 60 kg P_2O_5/fad boosted vegetative growth, yield and its components over 30 kg ha^{-1} & control.

Sulphur

Groundnut haulm yield was significantly influenced with application of sulphur and there was significant increase in haulm yield with increasing levels of sulphur up to 40 kg ha^{-1} during both the years. Application of sulphur @ 40 kg ha^{-1} gives significantly superior yield as, (35.78, 37.97 and 36.87) during both the years and in their mean, respectively, over control. However, it was at par with application of S @ 20 kg ha^{-1}. The lowest haulm yields as, (30.10, 31.67 and 30.88) during both the years and in their mean, respectively, was observed under S omitted plot (S0).

These results corroborate the findings of Dhage *et al*., (2014) [3] and Rao *et al*., (2013) [11] in soybean.

Interaction P x S

The interaction effect of phosphorus and sulfur levels on haulm yield of groundnut could not reach to the level of significance.

Conclusions

Pod and haulm yield of groundnut differed significantly due to applied phosphorous and sulphur levels over control. Phosphorous and Sulphur applied @ 90 kg ha^{-1} and @ 40 kg ha^{-1} showed significantly superior pod and haulm yield over 30 kg P ha^{-1} and 0 kg S ha^{-1}, respectively and lowest in control, however it was at par with applied P @ 60 kg ha^{-1} and applied S @ 20 kg ha^{-1} during both the seasons and in their mean, respectively.

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