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Effect of biofertilizers and gypsum levels on growth and yield of groundnut (*Arachis hypogaea*)

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Abstract
A field experimental trail on groundnut was conducted during *Kharif,* 2021 at Crop Research Farm (CRF), Department of Agronomy, SHUATS, Prayagraj (U.P.) to evaluate the effect of biofertilizers and gypsum levels on growth and yield and of groundnut. 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, two kinds of biofertilizers were used for seed treatment and three levels of gypsum (200, 300 and 400 kg/ha) 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 (44.47 cm), plant dry weight (14.80 g), number of pods per plant (25.00), number of kernels per pod (2), seed index (40.33 g), shelling percentage (74.00%), pod yield (3.64 t/ha), seed yield (2.69 t/ha), haulm yield (4.45 t/ha) and harvest index (33.29%) were recorded with the application of *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed + 400 kg/ha Gypsum. Thus, with the use of *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed + 400 kg/ha Gypsum per hectare along with RDF could be a promising option for yield enhancement in groundnut.

Keywords: Bradyrhizobium, trichoderma harzianum, gypsum, growth, yield

Introduction
Groundnut (*Arachis hypogaea*) is an important oilseed and a grain legume. It belongs to family Leguminaceae and is fourth most important source of edible oil and third most important source of vegetable protein also known as "The King of Oilseeds". 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) [34]. 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) [22]. According to Satish *et al.* (2011) [30], groundnut is primarily used for extraction of oil, with an analysis of about 46.70%. It is also consumed directly because of its high food value, which is again due to its higher content of protein (22.0%), carbohydrate (10.0%) and minerals (3.0%).
Castro *et al.* (1999) [6] reported increased yield when peanut crops were inoculated with rhizobium. The efficient development of peanut depends on its association with rhizobia which nodulate it, to enhance its nitrogen-fixing ability. *Bradyrhizobium* spp. is an agronomically significant gram-negative bacterium capable of forming root nodules on peanut roots and fixing atmospheric nitrogen (Isava *et al.*, 1999) [15]. Biological nitrogen-fixing (BNF) bacteria, such as *Rhizobium* and *Bradyrhizobium* species, produce auxins, cytokinins, abscisic acid, vitamins, riboflavin, lipochitooligosaccharides, and lumichrome that stimulate plant growth and nitrogen-fixation in legumes (Hardarson, 1993) [12].
Trichoderma species in several crops, including peanut (Podile *et al.*, 2002) [18], are efficient in controlling soil- and seed-borne fungal diseases (Kubicek *et al.*, 2001) [20]. The potential of *T. harzianum* as biocontrol agent in peanuts has been widely studied for reducing aflatoxin contamination by *Aspergillus flavus* (Emma *et al.*, 2008) [9], crown rot by *A. niger* (Kishore *et al.*, 2001) [18], stem rot by *Sclerotium rolfsii* and *Rhizoctonia solani* (Eald *et al.*, 1984) [8], and brown root rot by *Fusarium solani* (Federico *et al.*, 2007) [10]. Several mechanisms adopted by *Trichoderma*, such as the increased ingestion and translocation of less available soil minerals (Baker 1989 and Kleifeld *et al.*, 1992) [4, 19], have been suggested to influence the development of plants. Some studies also reported the antagonistic properties of these secondary metabolites

which act as growth promoting factors. Horace *et al.* (1986) [13] documented the isolation, recognition, and biological activity of 6-pentyl-apyrone a secondary metabolite produced by *T. harzianum* that has been involved as regulators of plant development. It is believed that secondary metabolites of *Trichoderma* can serve as auxin-like compounds that usually have the optimum activity between 10^5 and 10^6 M, but can have inhibitory effect at higher concentrations (Thimann 1986, Cleland 1972 and Brenner *et al.*, 1981) [33, 7, 5].

The primary nutrients calcium and sulphur also plays an important role in enhancing production and productivity of groundnut. Sulphur is very crucial for the formation of sulphur containing amino acids and oil synthesis and it is also improves both yield and quality of crops. Calcium nutrition is also considered a yield limiting factor for groundnut production. Calcium absorbed by the roots is not translocated to the developing pod whereas calcium required for pod formation is absorbed directly from soil solution (Yadav *et al.*, 2015) [35]. Groundnut plants need high level of calcium during pod filling stage to obtain better yield of quality kernels and its deficiency directs to unfilled pods (Reddy, 2006) [26]. Gypsum is readily available source of calcium as well as sulphur for crops and sulphur is necessary for improving the oil content in groundnut (Rao *et al.*, 2013) [25]. Application of gypsum improves soil structure which favours effective pegging in groundnut (Agasimani *et al.*, 1992) [2]. Sulphur and calcium are applied together are considered to be very important in the pod zone for the developments of pegs (Geethalakshmi *et al.*, 1998) [11]

Materials and Methods

A field trial was conducted during *Kharif*, 2021 at Crop Research Farm (CRF), 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 and Gypsum to fulfill the requirement of Nitrogen, Phosphorus, Potassium, Calcium and Sulphur respectively. The experiment was laid out in Randomized Block Design (RBD) with ten treatments replicated thrice. The treatments were 1-*Bradyrhizobium* 4g/kg seed + 200 kg/ha Gypsum, 2-*Bradyrhizobium* 4g/kg seed + 300 kg/ha Gypsum, 3-*Bradyrhizobium* 4g/kg seed + 400 kg/ha Gypsum, 4-*Trichoderma harzianum* 4g/kg seed + 200 kg/ha Gypsum, 5-*Trichoderma harzianum*4g/kg seed + 300 kg/ha Gypsum, 6-*Trichoderma harzianum*4g/kg seed + 400 kg/ha Gypsum, 7-*Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum*2g/kg seed + 200 kg/ha Gypsum, 8-*Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum*2g/kg seed + 300 kg/ha Gypsum, 9-*Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum*2g/kg seed + 400 kg/ha Gypsum, 10-Control: 25 kg N/ha: 60 kg P_2O_5/ha: 40 kg K_2O/ha. RDF of 25:60:40 NPK kg/ha was used in all treatments as basal dose, also Gypsum was applied by the side of the plants on 45th day and it is incorporated into the soil by earthing up immediately. Seeds were dibbled manually at the seed rate of 100 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.

Results and Discussion

Plant height (cm)

The significantly taller plant height (44.47 cm) at 60 DAS was recoded in treatment 9 with *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed +400 kg/ha Gypsum. However, the treatments with *Bradyrhizobium* 4g/kg seed + 400 kg/ha Gypsum, *Trichoderma harzianum* 4g/kg seed +400 kg/ha Gypsum and *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed +300 kg/ha Gypsum were statistically at par with the treatment *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed +400 kg/ha Gypsum.

Treatments co-inoculated with Bradyrhizobium enhanced the synthesis of chlorophyll and height growth, resulting in significant increases in plant dry weight and yield (Nellipally *et al.*, 2020) [21]. Plant height increased with the increasing dose of gypsum from 0 to 400 kg/ha (Adhikari *et al.*, 2003) [1]. This may be attributed due to better plant development through efficient utilization of soil resources by the plant, where primary growth elephant was available in sufficient amount (Kalaiyarasan *et al.*, 2003) [17].

Number of nodules per plant

The significantly higher number of nodules/plant (111.80) at 60 DAS were recorded with the treatment 9 with *Bradyrhizobium* 4g/kg seed + 400 kg/ha Gypsum. However, treatments *Bradyrhizobium* 4g/kg seed + 300 kg/ha Gypsum, *Bradyrhizobium* 4g/kg seed + 200 kg/ha Gypsum *and Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed + 400 kg/ha Gypsum were statistically at par with treatment *Bradyrhizobium* 4g/kg seed + 400 kg/ha Gypsum.

Inoculation of peanut with bradyrhizobia exerted a great improvement in nodulation status, which led to significant increases in number and dry weight of nodules in comparison to the uninoculated treatment. The presence of native rhizobia of peanut in the experimental soil is of inadequate number, having a low efficiency of nitrogen fixation. These results point out to the necessity of using effective strains of Bradyrhizobium (Badawi *et al.*, 2011) [3]. The effect of gypsum on no. of root nodules found significant. The number of nodules at this stage varied from 76 to 146. Sounda *et al*. (2005) [32] exerted similar effects on the growth and nodulation of groundnut. Nodule number per plant and nodule dry weight per plant increased with increasing Ca rate applied by gypsum (Salke *et al.*, 2010) [29].

Plant dry weight (g)

The significantly maximum dry weight (14.80 g) was recorded with treatment 9 with *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed + 400 kg/ha Gypsum. However, treatments with *Bradyrhizobium* 4g/kg seed + 400 kg/ha Gypsum and *Trichoderma harzianum* 4g/kg seed + 400 kg/ha Gypsum were statistically at par with treatment *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed + 400 kg/ha Gypsum.

Treatments co-inoculated with Bradyrhizobium and Trichoderma enhanced the synthesis of chlorophyll and height growth, resulting in significant increases in plant dry weight and yield and has the highest survival rate, shoot and root biomass, followed by the treatment inoculated with

Bradyrhizobium alone. (Nellipally *et al.*, 2020) [21]. These findings agree with Badawi *et al*. (2011) [3] conclusions that, co-inoculations resulted to significant difference in the biomass of plants compared to the control.

Crop growth rate (g/m²/day) and Relative growth rate (g/g/day)

Between 60-80 DAS Crop Growth Rate was recorded highest (22.89 g/m²/day) in treatment 9 with *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed +400 kg/ha Gypsum which showed significant difference with other treatments.

Between 60-80 DAS Relative Growth Rate was recorded significantly highest (0.0354 g/g/day) in treatment 5 with *Trichoderma harzianum* 4g/kg seed+ 300kg/ha Gypsum which showed significant difference with other treatments.

Yield attributes

The significantly higher number of pods/plant (25.00), seed index (4.33 g) and shelling percentage (74.00%) were found with treatment 9 *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed +400 kg/ha Gypsum. However, treatments with *Bradyrhizobium* 4g/kg seed+ 400kg/ha Gypsum and *Trichoderma harzianum* 4g/kg seed+ 400kg/ha Gypsum were statistically at par with the treatment *Bradyrhizobium* 2g/kg seed+ *Trichoderma harzianum* 2g/kg seed+ 400kg/ha Gypsum. Number of kernels/pod (2) were significantly higher in treatment 9 with *Bradyrhizobium* 2g/kg seed+ *Trichoderma harzianum* 2g/kg seed+ 400kg/ha Gypsum. However, treatments with *Bradyrhizobium* 4g/kg seed+ 400kg/ha Gypsum, *Trichoderma harzianum* 4g/kg seed+ 400kg/ha Gypsum, *Bradyrhizobium* 4g/kg seed+ 300kg/ha Gypsum and *Trichoderma harzianum* 4g/kg seed+ 300kg/ha Gypsum were statistically at par with the treatment *Bradyrhizobium* 2g/kg seed+ *Trichoderma harzianum* 2g/kg seed+ 400kg/ha Gypsum.

The rise in number of pods per plant could be attributed to sulphur's crucial involvement in energy storage and transformation, carbohydrate metabolism and enzyme activation, all of which improves plant's photosynthetic activity (Ruskar Banu *et al.*, 2017) [27]. The pods/plant significantly increased with the increase in gypsum levels. Higher number of kernels/pod were highest under 400 kg/ha gypsum, followed by 200 kg/ha. Shelling percentage increased with increasing level of gypsum, due to the fact that gypsum appeared at early flowering reduced the number of empty pods. The 100-kernel weight was highest with gypsum 400 kg/ha (Adhikari *et al.*, 2003) [1]. The results are in cognizance with the findings of Ismael *et al.* (1999) [16] and Ingole *et al.* (1998) [14].

Yield

Significantly higher pod yield (3.64 t/ha), seed yield (2.69 t/ha) and haulm yield (4.45 t/ha) were found in treatment 9 with *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed +400 kg/ha Gypsum. However, treatments with *Bradyrhizobium* 4g/kg seed+ 400kg/ha Gypsum and *Trichoderma harzianum* 4g/kg seed+ 400kg/ha Gypsum were statistically at par with the treatment *Bradyrhizobium* 2g/kg seed+ *Trichoderma harzianum* 2g/kg seed+ 400kg/ha Gypsum. Harvest index of (33.29%) was observed in the treatment 9 with *Bradyrhizobium* 2g/kg seed+ *Trichoderma harzianum* 2g/kg seed+ 400kg/ha Gypsum. However, treatments with *Bradyrhizobium* 4g/kg seed+ 400kg/ha Gypsum, *Trichoderma harzianum* 4g/kg seed+ 400kg/ha Gypsum, *Bradyrhizobium* 2g/kg seed+ *Trichoderma harzianum* 2g/kg seed+ 300kg/ha Gypsum and *Bradyrhizobium* 4g/kg seed+ 400kg/ha Gypsum were statistically at par with the treatment *Bradyrhizobium* 2g/kg seed+ *Trichoderma harzianum* 2g/kg seed+ 400kg/ha Gypsum.

The increase in haulm and kernel yield due to application of gypsum was attributed to concomitant influence of Sulphur released from the gypsum on availability of other nutrients from the soil and their extraction by the plant seems to have provided congenial nutritional environment for the plants. Further, calcium plays an important role in the reproductive development of the groundnut crop, thereby increased the pod yield (Sagar *et al.*, 2020) [28]. Application of reduced NPK fertilizers with FYM + 300 kg/ha gypsum resulted to 2521.98 kg/ha seed yield. All gypsum treatments had also positive effect on yield components and 300 kg/ha gypsum with full dose of NPK fertilizers or reduced dose of NPK fertilizers + 10 t/ha FYM were the optimum level for obtaining the higher pod and seed yields of groundnuts (Seran 2016) [31]. Calcium content both in pod and haulm also increased along with the increase in the level of gypsum. More yield of pod and haulm and higher concentration of Ca with increasing levels of gypsum resulted in higher uptake of this nutrient either by pod and haulm and ultimately the total uptake (Patro *et al.*, 2016) [23]. Production of plant growth regulating substances like IAA, gibberellic acid (GA) and cytokinins by *Rhizobium* and PSB could also be responsible for the increased pod and haulm yields of groundnut. Zalate *et al.* (2009) [36]

Table 1: Effect of Biofertilizers and Gypsum levels on growth and growth attributes of groundnut

S No.	Treatment Combinations	60 DAS			60 DAS- 80 DAS	
		Plant Height (cm)	Number of Nodules/plant	Dry weight (g)	Crop Growth Rate (g/m²/day)	Relative Growth Rate (g/g/day)
1.	Bradyrhizobium 4g/kg seed + 200 kg/ha Gypsum	39.40	105.47	13.07	21.94	0.0348
2.	Bradyrhizobium 4g/kg seed + 300 kg/ha Gypsum	42.20	107.00	13.40	22.72	0.0351
3.	Bradyrhizobium 4g/kg seed + 400 kg/ha Gypsum	43.57	111.80	14.53	22.45	0.0328
4.	Trichoderma harzianum 4g/kg seed + 200 kg/ha Gypsum	39.47	97.07	13.00	21.56	0.0347
5.	Trichoderma harzianum 4g/kg seed + 300 kg/ha Gypsum	41.53	97.73	13.20	22.67	0.0354
6.	Trichoderma harzianum 4g/kg seed + 400 kg/ha Gypsum	43.37	98.20	14.27	22.78	0.0336
7.	Bradyrhizobium 2g/kg seed +Trichoderma harzianum 2g/kg seed + 200 kg/ha Gypsum	40.33	100.53	13.13	22.17	0.0350
8.	Bradyrhizobium 2g/kg seed + Trichoderma harzianum 2g/kg seed + 300 kg/ha Gypsum	42.83	102.00	13.67	22.78	0.0346
9.	Bradyrhizobium 2g/kg seed + Trichoderma harzianum 2g/kg seed + 400 kg/ha Gypsum	44.47	105.00	14.80	22.89	0.0329

10.	Control	39.23	92.47	12.53	20.78	0.0346
	F-test	S	S	S	NS	NS
	SEm (±)	0.56	2.78	0.36	0.77	0.0015
	CD (p=0.05)	1.66	8.27	1.08	--	--

Table 2: Effect of Biofertilizers and Gypsum levels on yield and yield attributes of groundnut

S. No.	Treatment Combinations	At Harvest							
		No. of pods/plant	No. of kernels/Pod	Seed Index (g)	Shelling (%)	Pod yield (t/ha)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest Index (%)
1.	Bradyrhizobium 4g/kg seed + 200 kg/ha Gypsum	19.47	1.73	34.10	71.73	3.24	2.32	4.18	31.29
2.	Bradyrhizobium 4g/kg seed + 300 kg/ha Gypsum	20.67	1.87	36.70	72.83	3.45	2.51	4.28	32.50
3.	Bradyrhizobium 4g/kg seed + 400 kg/ha Gypsum	24.67	1.93	39.60	73.60	3.61	2.66	4.40	33.16
4.	Trichoderma harzianum 4g/kg seed + 200 kg/ha Gypsum	19.33	1.67	33.50	71.50	3.21	2.30	4.16	31.13
5.	Trichoderma harzianum 4g/kg seed + 300 kg/ha Gypsum	20.43	1.87	36.17	72.47	3.40	2.46	4.24	32.22
6.	Trichoderma harzianum 4g/kg seed + 400 kg/ha Gypsum	23.67	1.93	39.40	73.43	3.55	2.62	4.36	33.06
7.	Bradyrhizobium 2g/kg seed +Trichoderma harzianum 2g/kg seed + 200 kg/ha Gypsum	19.40	1.80	34.40	72.07	3.29	2.37	4.20	31.66
8.	Bradyrhizobium 2g/kg seed +Trichoderma harzianum 2g/kg seed +300 kg/ha Gypsum	21.47	1.93	37.27	73.00	3.48	2.54	4.31	32.63
9.	Bradyrhizobium 2g/kg seed +Trichoderma harzianum 2g/kg seed +400 kg/ha Gypsum	25.00	2.00	40.33	74.00	3.64	2.69	4.45	33.29
10.	Control	17.53	1.60	30.43	70.00	3.00	2.10	4.00	30.00
	F-test	S	S	S	S	S	S	S	S
	SEm (±)	0.51	0.06	0.54	0.23	0.03	0.03	0.04	0.27
	CD (p=0.05)	1.53	0.17	1.61	0.68	0.10	0.08	0.11	0.81

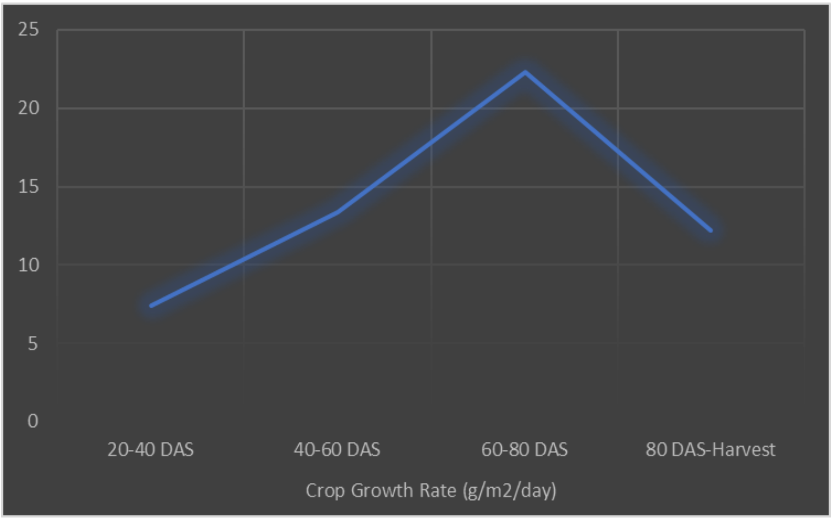

Fig 1: Crop Growth Rate (g/m^2/day)

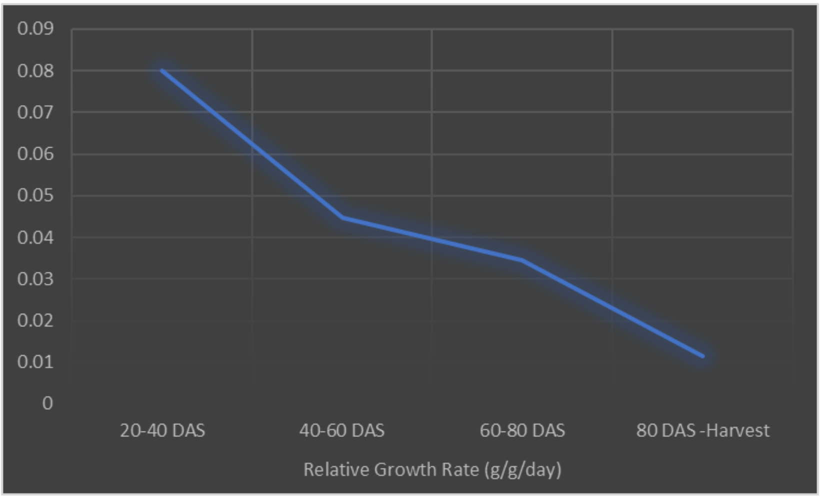

Fig 2: Relative Growth Rate (g/g/day)

Conclusion

Based on my research trail, the treatment combination of *Bradyrhizobium* 2g/kg seed + *Trichoderma harzianum* 2g/kg seed + 400kg/ha Gypsum 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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