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Anuradha Yadav
Ph.D. Research Scholar, Department of Agronomy, Sri Karan Narendra Agriculture University, Jobner, Rajasthan, India

Amit Kumawat
Assistant Professor, Department of Agronomy, Swami Keshwanand Rajasthan Agriculture University, Bikaner, Rajasthan, India

Suwa Lal Yadav
Assistant Professor, School of Agricultural Sciences, Raffles University, Neemrana, Rajasthan, India

Pooja Kumari Meena
Ph.D. Research Scholar, Department of Agronomy, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Asha Kumari
PhD, Research Scholar, Department of Biotechnology, JAU, Junagadh, Gujarat, India

Sampat Choudhary
Ph.D. Research Scholar, Department of Agronomy, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India

Manisha Yadav
Ph.D. Research Scholar, Department of Agronomy, Agriculture University, Jodhpur, Rajasthan, India

Corresponding Author:
Anuradha Yadav
Ph.D. Research Scholar, Department of Agronomy, Sri Karan Narendra Agriculture University, Jobner, Rajasthan, India

Nutrient dynamics and quality of chickpea as influenced by varied phosphorus sources and sulphur levels

Anuradha Yadav, Amit Kumawat, Pooja Kumari Meena, Suwa Lal Yadav, Asha Kumari, Sampat Choudhary and Manisha Yadav

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Abstract
The existing field experiment was laid out at Instructional Farm, COA, Swami Keshwanand Rajasthan Agricultural University, Bikaner, Rajasthan during *Rabi* 2021-22, to determine the nutrient content (nitrogen, phosphorus and potash), uptake (nitrogen, phosphorus and potassium) by seed, straw and total protein content and biological values of chickpea seed under different sources of phosphorus and sulphur levels. This experiment was carried out in factorial randomized block design comprising three phosphorus sources (32 kg P ha^{-1}) through DAP, SSP and PROM, three sulphur levels and control (control, 20, 40 and 60 kg ha^{-1}) with three replications. The significantly higher nutrient content and uptake enhanced by microbial activity (Rhizobacteria), and total protein content in seed, net returns and benefit-cost ratio was recorded by the application of 32 kg P_2O_5 ha^{-1} through PROM over phosphorus application through DAP and SSP. Moreover, application of 40 kg S ha^{-1} recorded higher amounts of nutrient (nitrogen, phosphorus and potassium) uptake.

Keywords: Biological value, nutrient content, protein content, microbial activity, seed and straw

Introduction
Pulses possess unique characters that augment the biological efficacy of protein and enhance soil fertility *via* atmospheric nitrogen fixation, rendering them a crucial protein source within dietary frame works. Its deep roots also allow the soil to open up, improving aeration and increased the organic matter in the soil due to excessive leaf fall (Mrunalini *et al*., 2022) [23]. It can fix nitrogen about 25-30 kg ha^{-1} through microbial symbiosis and these minimize dependency on chemical fertilizers (Reddy and Reddy, 2005) [30]. Chickpea (*Cicer arietinum* L.) is a belong of the Fabaceae family, native in South East Turkey. The word "*kikus*" in Greek means "*force*" or "*strength*". Chickpea is utilized in the form of processed whole seed (powder) and dal, but also used for making a range of sweets, sauces and snacks, which are highly recommendation for good health stomach cure illnesses and blood purification (Singh *et al*., 2018) [35]. In all over world, India is the greatest producer and acreage holder of chickpea.
The chickpea crop covers approx. 10.56 m ha area and production of 11.23 m tons with average productivity of 1063 kg/ha in the India (Anonymous, 2022) [3]. It also have 18-22% of protein, 52-70% of carbohydrates, 4-10% of fat, and adequate amounts of nutrients such as calcium, phosphorus, iron and vitamins, is a good source of dietary fibers (Grasso *et al*., 2022) [11].
Crop growth and development are primarily dependent on the root system's development in which phosphorus play a crucial role for the growth and development of roots (Malhotra *et al*., 2018) [20]. In case of leguminous pulse crops, phosphorus is the most abundant nutrient because it is essential for enhances root growth and development, where triggers their capacity for biological nitrogen fixation. It initiates the lateral and fibrous roots growth, which makes easier to work for rhizobacteria to cause nodulation, and as a result encourages the fixation of atmospheric nitrogen in leguminous crops. Phosphorus is an essential constituent of nucleic acid and energy providing molecules. The accessible most popular form of phosphate is found in phosphatic fertilizers - diammonium phosphate, single super phosphate (SSP), and triple super phosphate (TSP) (Khandelwal *et al*., 2012) [17]. *Rhizobacteria* play a crucial role in roots nodulation, leading to enhanced better growth and its development. A sufficient dose of

phosphorus nutrient speeds up the formation and development of pods and the pods matures early (Singh *et al*., 2018) [37].
Sulphur play an important role in the photosynthesis, chlorophyll, nutrient metabolism processes and also a vital component for the synthesis of enzymes, vitamins, and proteins in plants (Shah *et al*., 2022) [32]. Studies on the effects of phosphorus and sulphur on legumes are therefore more crucial than those on nitrogen as the latter is corrected by symbiosis with *Rhizobium* bacteria. Thus, the present study of phosphorus and sulphur nutrients to legumes is higher valuable than that of nitrogen, but later stage is being fixed by *Rhizobacterial* symbiosis (Jamal *et al*., 2010) [15]. In addition, nowadays sulphur is most recognized as major plant nutrient, along with nitrogen (N), Phosphorous (P) and potassium (K). Sulphur has numerous oxidizing functions in soil and plant nutrition and constituent of certain amino acids such as methionine, cystine and cysteine with Fe-S proteins known as ferrodoxin (Narayan *et al*., 2023) [24]. The acidity produced by oxidation helps to solubilizing plant nutrients and reclamation of alkali soils. Sulphur is also known to promote nodulation in legumes thereby triggers the N fixation. Gypsum is preferred most suitable source of sulphur, because of diverse role in soil especially in saline and alkaline soils (Kheir *et al*., 2018) [18]. The present research study entitled “nutrient dynamics and quality of chickpea as influenced by varied phosphorus sources and sulphur levels” was carried out to know the effects of phosphorus and sulphur on nutrient content, uptake and quality of chickpea.

Methods and Materials

Experimental site

The existing study was carried out during *Rabi*, 2021 at the Instructional Farm, COA, SKRAU, Bikaner, Rajasthan. In the research study plot size was 4.2 m x 4.0 m, under sandy loam texture which was lightly alkaline in reaction, very low organic carbon 0.09, available nitrogen 115.4 kg ha^{-1}, phosphorus 14.5 kg ha^{-1} and sulphur 7.3 kg ha^{-1} but medium in available potassium 212.35 kg ha^{-1}. The GNG-1851 cultivar was taken under 30 cm x 10 cm geometry.

Treatment details and its application

The 12 treatment combinations were applied as basal dose under factorial randomized block design with three replications. The treatment details were given below table

Treatments code	Details
Phosphorus source (32 kg ha^{-1})	
P_1	DAP
P_2	SSP
P_3	PROM
Sulphur levels (kg ha^{-1})	
S_0	Control
S_1	20
S_2	40
S_3	60

The phosphorus was applied through most availability form DAP, SSP and PROM fertilizer and weighted quantity of gypsum for sulphur was applied as per treatment combinations.

Crop cultivation details

The field was prepared after harvest of pre sown *kharif* crop with help of ploughing thoroughly with tractor drawn lough disk followed by cross harrowing and planking. The standard package of practices were followed throughout during crop growth period.

Plant analysis

In the present analysis at the time of threshing, seed and straw samples were collected from each plot as per treatment wise and washed, dried in oven at 60-85 °C temperature till constant weight was obtained. The samples were then separately powdered using a Willey Mill and the contents of Nitrogen, Phosphorous, and potassium were measured as per the standard procedures listed below.

Nitrogen: Plant samples were crushed, digested with sulfuric acid and hydrogen peroxide in digestion block and observed brown to red color after adding Nessler's reagent, and was estimated by a colorimetric method (Snell and Snell, 1939) [37]. A proportion of nitrogen was computed and expressed in per cent.

Phosphorus: The Vanadomolybdo phosphoric acid yellow color method was used to assess the phosphorus content from seed and straw of chickpea and samples were digested with Di-acid (HNO_3: $HClO_4$) mixture (Jackson, 1973) [14]. The intensity of color were tested in spectrophotometer.

Potassium: A flame photometer was used to measure the potassium level of samples digested in Di-acid. The strength of emission is proportional to the concentration of K, which is measured in a flame photometer using a K filter, when potassium atoms are excited in a flame and release a flame-specific wavelength (Jackson, 1973) [14].

Protein content: The protein content in seed was measured by multiplying the percentage of nitrogen concentration in seed by 6.25 (A.O.A.C., 1960) [1].

Nutrient uptake (kg ha^{-1}): The nutrient uptake was measured by the following formula.

Nutrient uptake =Percent nutrient content in seed or straw x Seed or straw yield (kg ha^(-1))/100

Net returns: The cost of cultivation for each treatment was analysed from the gross returns worked out for the respective treatment to retain at net returns per treatment.

Net returns=Gross return-cost of cultivation

Benefit: Cost ratio

In the present study, benefit: cost ratio was calculated to ascertain economic viability of the treatment using B:C ratio formula:

B:C ratio=Net returns (ha^{-1})/ Cost of cultivation (ha^{-1})

Statistical analysis

In the statistical analysis, researcher used to methodology described by Panse and Sukhatme (1985) [25] was followed to statistically analyze the data collected for different treatment in order to analyze the significance of variance level at 5%. The “F” test was determined at 5% percent and one percent levels of significance after the crucial differences were computed to evaluate the significance of treatment means.

Results and Discussion

Nutrients Nitrogen, Phosphorous and potash content as affected by Phosphorus Sources

The data presented in table 1, apparently observed that the nutrient N, P and K in seed and straw of chickpea significantly affected with various phosphorus sources. Among the sources of phosphorus and application through PROM significantly higher the nutrient content in seed and straw as compared to DAP and SSP. However, potassium content in seed and straw was found non-significant with different sources of phosphorus. Application of P_2O_5 (32 kg) through PROM boosting the Nitrogen, Phosphorous and potassium content their absorption in seed and straw as compared to 32 kg P_2O_5 ha^{-1} through DAP and SSP.

The physico-chemical properties, fertility status and microbial biomass and their population in soil were all enhanced by the addition of PROM, and as a result, these the nutrients become readily available for crop. The well-developed root system of the plant may have contributed to the rise in nitrogen content by making more phosphorus available to soil microorganisms. As a result, promotes the growth of *Rhizobacteria* with enhances atmospheric biological nitrogen fixation that's improve nitrogen content (Tondan, 1991) [39]. Fertility status of the soil which was found to be deficient in N and P but medium in K, may be responsible for the improved phosphorus availability in the soil, which boosted macronutrient content with P fertilization. Increased K buildup in the crop was the outcome of enhanced plant root systems brought about by increased nutrient availability. The findings of many researches were in agreement with this investigation. Here some of the findings of Singh *et al*. (2015) [34], Aechra *et al*. (2017) [2], Yadav *et al*. (2017) [41] and Bairwa *et al*. (2019) [5], Ramamoorthy and Ariraman (2023) [28] are in agreement with these results.

Nutrient uptake by seed and straw

The data existing in table 2, revealed that increase in nutrient uptake by chickpea was observed on with various sources of phosphorus. The application of 32 kg P_2O_5 ha^{-1} through PROM significantly increased the uptake of nitrogen by 39.01, 20.54 per cent in seed, 27.62, 14.10 per cent in straw and 34.60, 18.09 per cent total uptake by plant of chickpea, phosphorus by 51.19, 25.00 per cent in seed, 41.07, 21.66 cent in straw and 46.34, 21.66 per cent total uptake and potassium uptake by 39.25, 17.60 per cent in seed, 24.75, 13.83 per cent in straw and 26.88, 14.41 per cent total uptake by plant of chickpea as compared to 32 kg P_2O_5 ha^{-1} through DAP and SSP, respectively. This might be due to application of phosphorus through PROM increased the yield and nutrient content in seed and straw of chickpea. Thus, higher yields and nutrient content in seeds and straw have led to enhance uptake of nitrogen, phosphorous and potassium. Application of *Rhizobacteria* formulation on roots may be the cause of the increase in protein content of seed linked to improved nitrogen availability, hence enhancing nitrogen uptake in crop. Additionally, PROM has been shown to improve the physical state of soil, which enhances nutrient intake. The findings of Singh *et al*. (2015) [34], Aechra *et al*. (2017) [2], Yadav *et al*. (2017) [41] and Bairwa *et al*. (2019) [5] and Karada *et al*. (2023) [16] are in agreement with these results.

Quality parameter

In the analysis, the data shown in table 1, that application of 32 kg P_2O_5 ha^{-1} through PROM increased the protein content in seed significantly by 8.93 and 4.97 per cent, respectively as compared to DAP and SSP, respectively. The higher protein content in seed that has been linked to increased nitrogen availability could be the result of *Rhizobia* properly establishing on roots, which would increase nitrogen uptake of crop. Application of PROM is known to improve the physical state of the soil, which enhances the protein content. According to Bairwa *et al*. (2019 [5], Kumar *et al*. (2023) [19], Waghmare *et al*. (2024) [40] and Manoj *et al*. (2023) [21] these results are consistent with their findings.

Economics: A significant increase in net returns was observed with application of different phosphorus sources. The highest net returns (₹87206) was recorded with the application of 32 kg P_2O_5 ha^{-1} through PROM, which was higher by 61183, 71313 over 32 kg P_2O_5 ha^{-1} through DAP and SSP, respectively.

Nutrients Nitrogen, Phosphorous and potassium as affected by different sulphur level

The data presented in table 1, showed that nutrient (nitrogen**,** phosphorus and potassium) content in seed and straw of chickpea was found non-significant due to different levels of sulphur. However, the rise in sulphur levels had no discernible effect on N, P and K content of seed and straw. These results are in line with those of Singh *et al*. (2015) [34], Aechra *et al.* (2017) [2], Yadav *et al.* (2017) [41], Bairwa *et al.* (2019) [5] and Ramamoorthy and Ariraman (2023) [28].

Nutrient uptake as affected by sulphur

In this study, the application of sulphur approximately 40 kg ha^{-1} was found significantly higher in case of nutrient (nitrogen**,** phosphorus and potassium) uptake by chickpea over control and 20 kg ha^{-1} but it remains at par with 60 kg ha^{-1} sulphur. It also revealed that 40 kg ha^{-1} of sulphur can be better strategy for the supplementation of nutrients presented as table 2. Nutrient uptake and accumulation in vegetative parts may have risen due to increased nutrition availability in the root zone and increased cellular metabolic activity. When fertilizer was applied, there would be an increase in the amount of nutrients absorbed as a function of biomass production and biomass's nutrient content. Bahadur and Tiwari (2014) [4] reported that an increase in sulphur application up to 30 kg ha^{-1} significantly higher content and uptake of the nitrogen, phosphorus and sulphur both in seed and straw of chickpea as compared to 15 kg ha^{-1} and control. According to Chiaiese *et al*. (2004) [6] applying sulphur to chickpea increased the amount of sulphur present in both grain and stover. Das (2017) [7], also mentioned that sulphur and nitrogen worked together to enhance the uptake of other nutrients. Sulphur application increased the number of root nodules along with nitrogen fixation (Scherer *et al*., 2006) [31], which may have encouraged the production of more above-ground dry matter, increased nutrient uptake, which in turn raised nutrient content in grain and stover along with better seed and stover production. These findings regarding the total uptake of nutrients are also evaluated by the researchers (Dharwe *et al*. (2019) [9], Italiya *et al*. (2019) [13], Singh and Singh (2012) [12] and Hadole *et al*. (2024) [12].

Quality parameter

Sulphur is a constituent of protein and other valuable substances like oil, hence the application of sulphur observed a positive result on an increase in protein content in seeds of chickpea. Srinivasulu *et al*. (2015) [38] mentioned that the application of 20 and 40 kg ha^{-1} of sulphur enhanced the protein content by 7.5 and 8.0% respectively, as compared the control. Das *et al*. (2016) [8] also studied that regardless of applying 20 kg ha^{-1} of sulphur greatly enhanced the protein content upto 3%. These result's relation to protein content is in complete supported with Mir *et al*. (2013) [22] and Patel *et al*. (2014) [26]. An higher in protein content with respect application of increased doses of sulphur, due to increased root activity and translocation of higher nitrogen and sulphur resulting in the synthesis of more sulphur-containing amino acids such as methionine, cysteine and cystine (Ramkala and Gupta, 1999) [29]. The data presented in table1, reveals that highest protein content in seed was found with application of 60 kg S ha^{-1}, but increased non-significantly than application of 40, 20 kg S ha^{-1} and control. These results align with the findings of Patel *et al*. (2023) [27], Manoj *et al*. (2023) [21] and Dautaniya *et al*. (2023) [10].

Economics

Net returns increased significantly influenced in level of Sulphur from 0 upto 40 kg ha^{-1}. Application of sulphur at 40 kg ha^{-1} significantly higher the net returns (₹82990) over control and 20 kg ha^{-1}, respectively. Benefit- cost ratio increased significantly with increase in level of Sulphur from 0 upto 40 kg ha^{-1}. Application of sulphur at 40 kg ha^{-1} measured highest benefit cost ratio (2:34) as compared to control of 20 kg ha^{-1}.

Table 1: Effect of various sources of phosphorus and sulphur levels on nutrient content in seed and straw of chickpea

Treatments	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)		Protein content in seed (%)
	Seed	Straw	Seed	Straw	Seed	Straw	
Sources of phosphorus (32 kg ha^{-1})							
DAP	3.437	1.188	0.382	0.197	0.351	1.104	21.48
SSP	3.567	1.251	0.414	0.216	0.373	1.136	22.29
PROM	3.743	1.284	0.452	0.237	0.383	1.165	23.40
SEm±	0.071	0.026	0.010	0.007	0.010	0.020	0.44
CD (P=0.05)	0.208	0.076	0.030	0.021	NS	NS	1.30
Levels of sulphur (kg ha^{-1})							
0	3.464	1.190	0.396	0.203	0.354	1.102	21.65
20	3.546	1.235	0.414	0.214	0.367	1.130	22.16
40	3.642	1.266	0.425	0.224	0.375	1.150	22.76
60	3.677	1.273	0.430	0.226	0.380	1.157	22.98
SEm±	0.082	0.030	0.012	0.008	0.011	0.023	0.51
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of different sources of phosphorus and sulphur levels on nutrient uptake by seed and straw of chickpea

Treatments	Nitrogen uptake (kg ha^{-1})			Phosphorus uptake (kg ha^{-1})			Potassium uptake (kg ha^{-1})		
	Seed	Straw	Total	Seed	Straw	Total	Seed	Straw	Total
Sources of phosphorus (32 kg ha^{-1})									
DAP	60.05	37.90	97.95	6.68	6.33	13.01	6.14	35.15	41.29
SSP	69.25	42.39	111.65	8.08	7.34	15.42	7.27	38.52	45.79
PROM	83.48	48.37	131.85	10.10	8.93	19.04	8.55	43.85	52.39
SEm±	2.56	1.57	3.69	0.36	0.36	0.68	0.32	1.41	1.68
CD (P=0.05)	7.51	4.60	10.81	1.07	1.06	1.98	0.95	4.15	4.93
Levels of sulphur (kg ha^{-1})									
0	55.81	34.17	89.98	6.40	5.84	12.25	5.71	31.64	37.34
20	67.54	42.29	109.83	7.92	7.38	15.29	7.00	38.64	45.64
40	78.79	46.86	125.66	9.21	8.31	17.52	8.10	42.56	50.66
60	81.56	48.23	129.79	9.62	8.61	18.22	8.47	43.85	52.32
SEm±	2.96	1.81	4.26	0.42	0.42	0.78	0.37	1.63	1.94
CD (P=0.05)	8.67	5.31	12.49	1.23	1.22	2.29	1.09	4.79	5.69

Table 3: Effect of application of different sources of phosphorus and levels of sulphur on economics of chickpea

Treatments	Net returns (₹ ha^{-1})	Benefit- cost ratio
Sources of phosphorus (32 kg ha^{-1})		
DAP	61183	1.72
SSP	71313	2.00
PROM	87206	2.49
SEm±	2524	0.07
CD (P=0.05)	7403	0.21
Levels of sulphur (kg ha^{-1})		
0	53990	1.55
20	69946	1.98
40	82990	2.34
60	86010	2.41
SEm±	2914	0.08
CD (P=0.05)	8548	0.24

Conclusion

In the study, from the existing experiment, it is concluded that the application of 32 kg ha^{1} P_2O_5 through PROM and 40 kg ha^{-1} of sulphur gave the better results as comparison to other remaining treatments. The significantly higher nutrients content and uptake was observed with the application of 32 P_2O_5 kg ha^{-1}

through PROM and 40 kg ha^{-1} of sulphur under sandy loam soil of Bikaner region. It can be a better strategy in nutrient deficient areas for the supplementation of phosphorus and sulphur.

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