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Rajneesh Singh
Department of Agronomy, NDUAT, Faizabad, Uttar Pradesh, India

Durgesh Singh
Department of Agronomy, BAU, Bhagalpur, Bihar, India

Tej Pratap
Department of Agronomy, BAU, Bhagalpur, Bihar, India

Abhinaw Kumar Singh
Department of Agronomy, CCSHAU, Haryana, India

Hanumant Singh
Department of Soil Science, CCSHAU, Haryana, India

SK Dubey
Department of Agronomy, BAU, Bhagalpur, Bihar, India

Correspondence
Durgesh Singh
Department of Agronomy, BAU, Bhagalpur, Bihar, India

Effect of different levels of phosphorus, sulphur and biofertilizers inoculation on nutrient content and uptake of chickpea (*Cicer arietinum* L.)

Rajneesh Singh, Durgesh Singh, Tej Pratap, Abhinaw Kumar Singh, Hanumant Singh and SK Dubey

Abstract
Proper nutrition of crop plants is most important for getting good yields and quality of food products. In this contests a field experiment was conducted at Agronomy Research Farm of Narendra Deva University of Agriculture & Technology, Faizabad (U.P.) during *rabi* season of two consecutive years of 2014-15 and 2015-16 to assess the effect of phosphorus, sulphur and biofertilizers on nutrient content and uptake of chickpea (*Cicer arietinum* L.) The experiment was layout in SPD having twenty-four treatment combinations consisted of three phosphorus levels (0, 30, 60 kg P_2O_5 ha^{-1}), two sulphur levels (0, 20 kg ha^{-1}) and four seed inoculation with biofertilizers (un-inoculated, PSB, Rhizobium and PSB + Rhizobium). The application of phosphorus at 60 kg ha^{-1}, sulphur at 20 kg ha^{-1} and seed inoculation with PSB + Rhizobium significantly increased the nutrient content, uptake and yields (grain & straw yield) of chickpea over the control /un-inoculated. So, inoculation of biofertilizers with optimum level of fertilizers could able to improve the performance of crop.

Keywords: Phosphorous, Sulphur, biofertilizers- PSB & *Rhizobium,* nutrient content and uptake

Introduction
Pulse crop have capacity to enrich the soil fertility through the symbiotic nitrogen fixation and supply more protein for vegetarian peoples, along with above pulses and their crop residues are major source of high quality livestock feed. Ali and Kumar (1988) [1] very well define it in symbolic to its nomenclature, PULSE (P= People, U= Umbrella, L= Livestock, S= Soil, and E= Energy) is needed a superb energy umbrella for people as dietary proteins, for livestock as green nutritious fodder and feed, for soil as a mini nitrogen plant and green manure. Chickpea (*Cicer arietimum* L.) originated in southeastern turkey, belongs to family *fabaceae* and derived from the greek word ՝*kikus*՝ meaning force or strength. In world chickpea is known by various names like- *garbanzo* (Spanish), *pois chiche* (French), *kichar* or *chicher* (German), *chana* (Hindi) and gram or bengal gram (English) and in some countries of world (Turkey, Romania, Bulgaria, Afghanistan) it is also called ՝*nakhut*՝ or ՝*nohut*՝. Gram is mostly consumed in the form of processed whole seed and *dal* but also used for preparing a variety of snacks, sweets and condiments, which are very useful for health point of view like- stomach ailments and blood purification. In India, Madhya Pradesh (39%), Maharashtra (14%), Rajasthan (14%), Uttar Pradesh (7%), Karnataka (6%), and Gujarat (5%) are the major chickpea growing states which together account for more than 85 percent of the production. Chickpea contains 18-22 percent protein, 52-70 percent carbohydrate, 4-10 percent fat and sufficient quantity of minerals, calcium, phosphorus, iron and vitamins. It is also important for sustainable agriculture as it improves the physico-chemical and biological properties of the soil. Its deep roots also open the soil, which ensure better aeration and heavy leaf drop increases the organic matter in the soil. It can fix about 25-30 kg N ha^{-1} through symbiosis (Reddy and Reddy, 2005) [15] and these minimize dependency on chemical fertilizers. Thus, chickpea plays a vital role in improving the soil health.

Production of pulse crops is limit by insufficient availability of plant nutrient because majority of our farmers hardly use any manure or fertilizer for legume cultivation. However, many researchers are found that in his research, there is a possibility to enhance the productivity through optimum fertilization and management, as there is a wide gap between the average yield and yield potential of crop.

Plant nutrient, suitable cultivars and correct fertilizer have significant effect on yield and yield component (Khan *et al*. 2005) [6]. Growth and development of crops depend largely on the development of root system. Phosphorus (P) is one of the three macronutrients that plants must obtain from the soil. It is a major component of compounds whose functions relate to growth, root development, flowering, and ripening. Better root development becomes helpful for better nodulation by *Rhizobium* bacteria in pulse crops. Sufficient supply of phosphorus to plant, hastens the maturity and increases the rate of nodulation and pod development. It is also an important constituent of vital substances like phospholipids and phosphoprotein. Since legume is heavy feeder of phosphorus, therefore, application of phosphatic fertilizer to chickpea promotes the growth, nodulation and yield. Phosphorus also imparts hardiness to shoot, improves the quality and regulates the photosynthesis and covers other physico- biochemical process. Most of the phosphorus present in the soil is unavailable to plants which are made available through the activities of efficient micro- organism like bacteria, fungi and even cyanobacteria with production of organic acid and increasing phosphatase enzyme activity. To increase the phosphorus use efficiency, it is required to find out the optimum level of phosphorus for chickpea.

Sulphur is increasingly being recognized as a fourth major plant nutrient, but the importance of sulphur (S) application has not been fully recognized in fertilizer recommendations. It is a key element of higher pulse production, its major role in plants is formation of proteins, vitamins and enzymes. Besides, it is involved in biological nitrogen fixation. Deficiencies of sulphur in Indian soil is widespread due to extensive use of sulphur free fertilizer coupled with extensive cultivation of high sulphur demanding crop, Moreover, sulphur requirement of crop plants is quite high, with high yielding varieties and increased cropping intensity large amounts of nutrients are removed from the soil gradually. Year after year sulphur deficiency is becoming more critical, which severely restrict the crop yield, produce quality, nutrient use efficiency and economic returns on millions farms. Like any essential nutrient, sulphur also has certain specific function to perform in the plant. Thus, sulphur deficiencies can only be corrected by the application of proper dose of sulphur fertilizer (Tendon & Messick, 2007) [24]. Its application to alkaline soils has been reported to reduce the pH of soil (Taalab *et al.* 2008) [22].

Biofertilizers are living microorganisms which colonizes the rhizosphere and promotes growth by increasing the availability and supply of nutrients and/or growth stimulus to crop Singh *et al.*, (2016) [19]. Through the nitrogen fixation and phosphate solubilization microorganisms play an important role in augmenting the supply of nitrogen & phosphorus to the plant and also increase the nutrient use efficiency (Singh *et al.*, 2018) [17] which help in sustainable use of fertilizers (Tambekar *et al*., 2009) [23]. Generally, Indian soils are lacking in effective and specific strains of Rhizobium which are responsible for symbiotic nitrogen fixation. Some important strains are mentioned as plant growth promoting rhizobacteria (PGPR) and that can be used as biofertilizers (Kennedy *et al*., 2004) [5] i.e. *Rhizobium, Pseudomonas, Azospirillum, Azotobacter, Bacillus, Burkholdaria, Erwinia, Mycobacterium, Flavobacterium*, etc. Singh *et al.*, (2017) [18] was told that the biofertilizers are cheap and eco-friendly source for nutrient supply that can substitute a part of chemical fertilizers resulting reduce the soil, water and air pollution.

Materials and Methods

Experimental site

A field experiment was conducted at the Agronomy Research Farm of Narendra Deva University of Agriculture & Technology, Kumarganj, Faizabad (U.P.) situated at sub-tropical climate zone of indo-gangetic plains and 26.47^0N latitude and 82.12^0E longitude at an altitude of 113 metres from mean sea level receiving 1200 mm annual rainfall, during *rabi* season of two consecutive years of 2014-15 and 2015-16 to assess the effects of phosphorus, sulphur and biofertilizers on performance of chickpea. The soil of the experimental field was silty loam in texture with low organic carbon (0.31%) and nitrogen (175.40 kg ha^{-1}) and medium in phosphorus (16.30 kg ha^{-1}) and potassium (238 kg ha^{-1}).

Experimental treatments

In this experiment there was twenty-four treatment combinations involved in which, three phosphorus levels (0, 30 & 60 kg P_2O_5 ha^{-1}), two Sulphur levels (0 & 20 kg ha^{-1}) and four seed inoculation with biofertilizers (un-inoculated, PSB, Rhizobium and PSB + Rhizobium), The chickpea variety ‘Avrodhi’ was treated with biofertilizers and sown at the rate of 80 kg seed ha^{-1} in split plot design with three replications. The experimental plot area was 18 m^2 and biofertilizers inoculated seeds were sown in the plot at the row spacing of 30 cm. while, plant to plant spacing was 10 cm. Nitrogen and potash were applied uniformly to each treatment @ 30 and 40 kg ha^{-1} through urea & MOP. To evaluate the effects of different treatments observation were taken at and/or after harvesting. The grain yields were recorded on plot basis and then converted in to q ha^{-1}.

Results and Discussion

Nutrient content

It is evident from the data given in Table-1 that the maximum nitrogen content (3.13% in grain & 0.61% in straw), phosphorous (0.41% in grain & in straw 0.12%), sulphur (0.33% in grain & 0.21% in straw) was found with the application of 60 kg P_2O_5 ha^{-1}, which was significantly higher over other levels of P_2O_5 during both the years. Whereas, in case of Sulphur 20 kg ha^{-1} application was recorded significantly higher. Inoculation with bio-fertilizers had significant effect on nutrient content in seed and straw both. The highest nitrogen (3.14% in grain & 0.62% in straw), phosphorous (0.41% in grain & in straw 0.13%), sulphur (0.34% in grain & 0.21% in straw) content was obtained where seed was inoculated with PSB + Rhizobium and it was significantly higher over rest of the treatments during both the years.

This may be ascribed as with increase in supply of phosphorus, sulphur and biofertilizers it may increase the availability of N and P in soil and these nutrients might be absorbed in more quantity by the well-developed roots of chickpea plant, which ultimately increased the contents of N and P in the plants. Singh and Ram was also done a research in 1992 and found that the same results with increasing levels of applied phosphorus, Kumar *et al*., (2005) [8] with increased level of sulphur and Naagar and Meena (2004) [12]; Singh *et al.,* (2018) [17] with combined inoculation of biofertilizers.

Nutrient uptake

Optimum levels of phosphorous, sulphur and biofertilizers will able to enhance the nutrient uptake of crops by increasing the root growth and development. Finding of my research (fig.-1, 2 & 3) also shows the similar results in that the maximum nitrogen uptake (68.64 kg ha^{-1} in grain & 15.34 kg ha^{-1} in straw), phosphorous (9.17 kg ha^{-1} in grain & 3.30 kg ha^{-1} in straw), sulphur (7.45 kg ha^{-1} in grain & 05.54 kg ha^{-1} in straw) was found with the application of 60 kg P_2O_5 ha^{-1}, which was significantly higher over other levels of P_2O_5 during both the years. Whereas, in case of Sulphur 20 kg ha^{-1} application was recorded significantly higher. Inoculation of seeds with bio-fertilizers had also significant effect on nutrient uptake in seed and straw both. The highest nitrogen (68.09 kg ha^{-1} in grain & 15.65 kg ha^{-1} in straw), phosphorous (9.1 kg ha^{-1} in grain & 3.27 kg ha^{-1} in straw), sulphur (7.39 kg ha^{-1} in grain & 5.5 kg ha^{-1} in straw) uptake was obtained where seed was inoculated with PSB + Rhizobium. Interaction effect of treatments was found non-significant.

The uptake of nitrogen and phosphorus by crop followed the patterns of dry matter production as well as nutrient contents in plant. Application of phosphorus, sulphur and biofertilizers accelerated the uptake of nitrogen, phosphorus and sulphur significantly. It may be due to (i) increase in nutrient contents. (ii) vigorous root growth which accelerate the better nutrient absorption. (iii) profuse shoot growth and ultimately, higher dry matter production. PSB + Rhizobium inoculation significantly increased the number of nodules and fresh & dry weight of nodules $plant^{-1}$ mainly due to the fact that the nitrogenase enzyme present in the bacteria gets introduced through infection causes nodule formation. Application of PSB facilitates the root development *vis-à-vis* nodule formation and proper development of nodules by increasing the availability of phosphorus through the mobilizing the unavailable phosphorus present in the soil. These results are in agreement with those of Meena *et al.* (2005) [10]; Swarnkar *et al.* (2010) [21]; Singh *et al.*, (2018) [17] who have also reported a significant increase in NPK uptake with increased phosphorus levels and Kumar *et al.* (2005) [8] with increased levels of sulphur. Khan *et al.*, (2005) [6] and Parmeanik and Singh (2003) [14] who have also reported an increase in nutrient uptake with application of biofertilizers in chickpea.

Grain and straw yields

Significant result was observed with different doses of phosphorus, sulphur and seed inoculation with biofertilizers on the grain yield of chickpea during both the years but interaction of all factors was found non-significant. It is evident from the data (pooled) given in Table 1 that the maximum grain yield (21.76 q ha^{-1}) was recorded with the application of 60 kg P_2O_5 ha^{-1}, (21.51 q ha^{-1}) with the application of 20 kg S ha^{-1} and (21.53 q ha^{-1}) with inoculation of PSB + Rhizobium which was significantly higher over control. Table 1 also shows that the maximum straw yield (25.06 q ha^{-1}) was recorded with application of 60 kg P_2O_5 ha^{-1} which was significantly higher over 30 kg P_2O_5 ha^{-1} and control. Straw yield was also found significant due to application of 20 kg S ha^{-1} and seed inoculation with PSB + Rhizobium. The maximum straw yield by the application of S (24.82 q ha^{-1}) was found with 20 kg S ha^{-1} and PSB + Rhizobium seed inoculation.

Phosphorous application accelerated the production of photosynthates and their translocation from source to sink, which ultimately gave the higher values of yield contributing characters. Increase in yield contributing characters has also been reported by Bahadur *et al.* (2002) [2]; Khan *et al.* (2005) [6]; Meena *et al.* (2006) [11] and Kumar *et al.* (2007) [7] with increasing levels of phosphorus and sulphur (Chaudhary and Goswami, 2005) [4]. The increase in yields with biofertilizers was mainly due to the increase in almost all growth and yield contributing characters (Singh *et al.*, 2017) [18], which ultimately resulted a significant increase in grain and straw yields. The results of present investigation are in close conformity with those of Bhuiyan *et al.* (1998) [3] and Sarna *et al.* (2008) [16]. This was mainly due to fact that the better availability of N and P caused well developed root system having higher nitrogen fixing capacity resulting better growth and development of plants and better diversion of photosynthates towards sink, even use of single or combination of biofertilizers might be much advantageous for farmers (Singh *et al.*, 2018) [17]. The findings of Bahadur *et al.* (2002) [2]; Meena *et al.* (2002) [9] and Parmanik and Singh (2003) [14] also confirm the results obtained during the study on yield contributing characters of chickpea.

Protein content in grain

Better root growth and development of crop enhance the yield as well as quality of food products. Results shown in Fig. 4 clearly shows that the optimum levels of fertilizers and biofertilizers inoculation significantly enhance the protein content of grain. Maximum protein content was recorded (19.60%) with the application of 60 kg P_2O_5 ha^{-1}, (19.44%) in case of sulphur 20 kg ha^{-1} and (19.74%) was obtained where seed was inoculated with PSB + Rhizobium and it was significantly higher over rest of the treatments during both the years whereas, interaction effect of treatments was found non-significant.

The increase in protein content in seed was mainly due to significant increase in nitrogen content in seed with increasing levels of phosphorus (Meena *et al.*, 2006) [11], sulphur (Kumar *et al.*, 2005) [8] and inoculation of biofertilizers (Singh *et al.*, 2018) [17]. Rhizobium inoculation and PSB application significantly increased the protein in seed because of better nodule development *vis-a-vis* nitrogen fixation and its utilization towards protein synthesis due to better availability of nutrients like nitrogen and phosphorus. The results are in agreement with work of Meena *et al.* (2002) [9], Naagar and Meena (2004) [12] and Nishita and Jashi (2010) [13] who have also reported an increase in protein content in seed with application of biofertilizers.

Table 1: Nitrogen, phosphorus and sulphur content of chickpea as influenced by different levels of phosphorus & sulphur and inoculation of biofertilizers (pooled data of 2 years)

Treatment	Nitrogen content (%)		Phosphorus content (%)		Sulphur content (%)		Grain yield (q ha-1)	Straw yield (q ha-1)
	Grain	Straw	Grain	Straw	Grain	Straw	90 DAS	90 DAS
Phosphorus levels (kg ha^{-1})								
0	2.97	0.59	0.39	0.11	0.32	0.20	18.75	21.58
30	3.08	0.61	0.40	0.12	0.33	0.21	20.10	22.97
60	3.13	0.61	0.41	0.12	0.33	0.21	21.76	25.06
SEm±	0.01	0.003	0.002	0.001	0.002	0.001	0.34	0.37
CD (P=0.05)	0.05	0.011	0.007	0.002	0.006	0.004	1.10	1.18
Sulphur levels (kg ha^{-1})								
0	2.96	0.59	0.39	0.12	0.32	0.20	18.89	21.58

20	3.16	0.62	0.41	0.12	0.34	0.21	21.51	24.82
SEm±	0.01	0.003	0.002	0.001	0.001	0.001	0.28	0.30
CD (P=0.05)	0.04	0.009	0.006	0.002	0.005	0.003	0.89	0.96
Bio-fertilizers								
Un-inoculation	2.95	0.58	0.39	0.12	0.31	0.20	19.07	21.81
PSB	3.05	0.60	0.40	0.12	0.33	0.20	19.70	22.50
Rhizobium	3.09	0.61	0.40	0.12	0.33	0.21	20.50	23.66
PSB+ Rhizobium	3.14	0.62	0.41	0.13	0.34	0.21	21.53	24.82
SEm±	0.01	0.003	0.002	0.001	0.002	0.001	0.34	0.39
CD (P=0.05)	0.05	0.010	0.007	0.002	0.005	0.003	1.00	1.12
Intractions	NS	NS	NS	NS	NS	NS	NS	NS

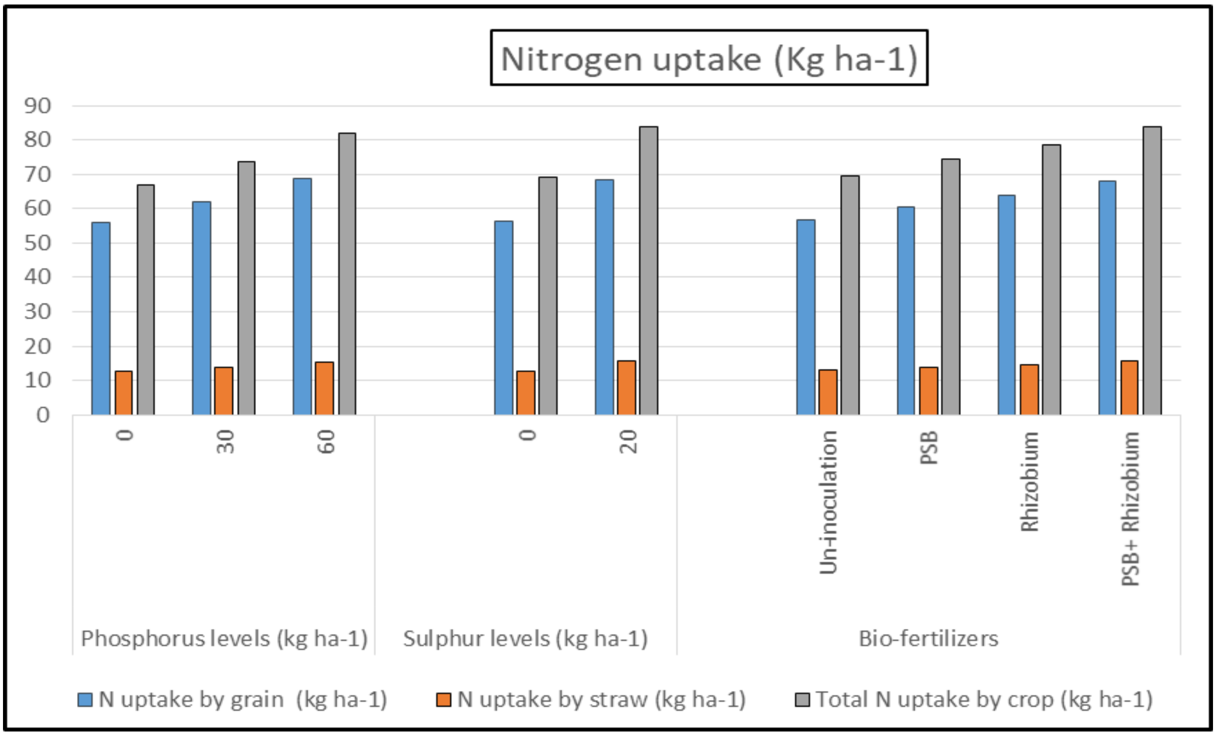

Fig 1: Nitrogen uptake of chickpea (grain + straw) as influenced by different levels of phosphorus & sulphur and inoculation of biofertilizers (pooled data of 2 years)

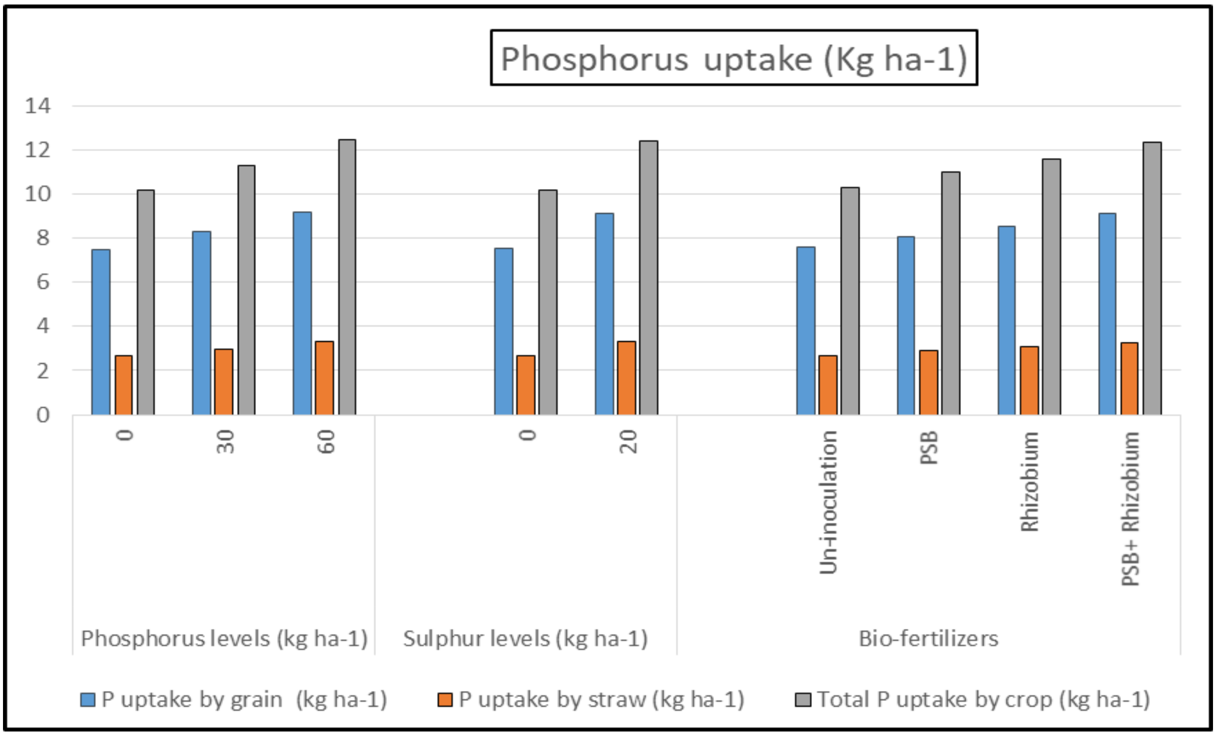

Fig 2: Phosphorus uptake of chickpea (grain + straw) as influenced by different levels of phosphorus & sulphur and inoculation of biofertilizers (pooled data of 2 years)

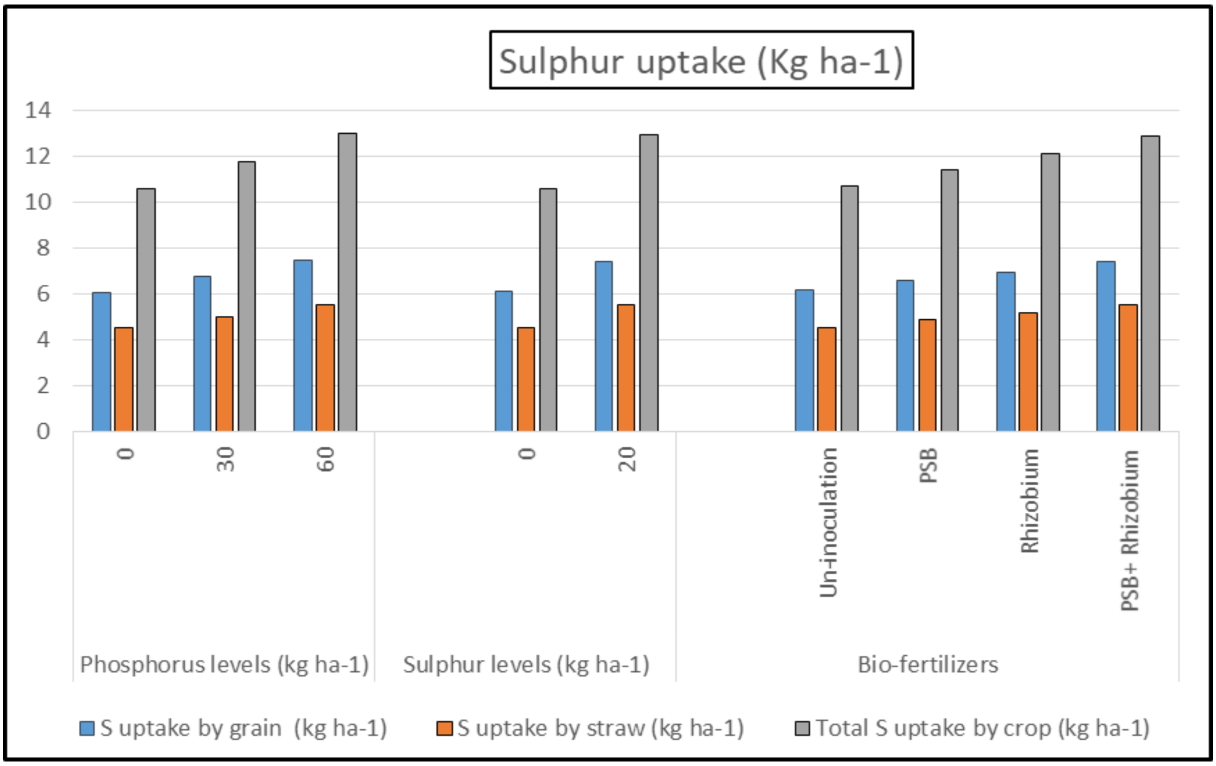

Fig 3: Sulphur uptake of chickpea (grain + straw) as influenced by different levels of phosphorus & sulphur and inoculation of biofertilizers (pooled data of 2 years)

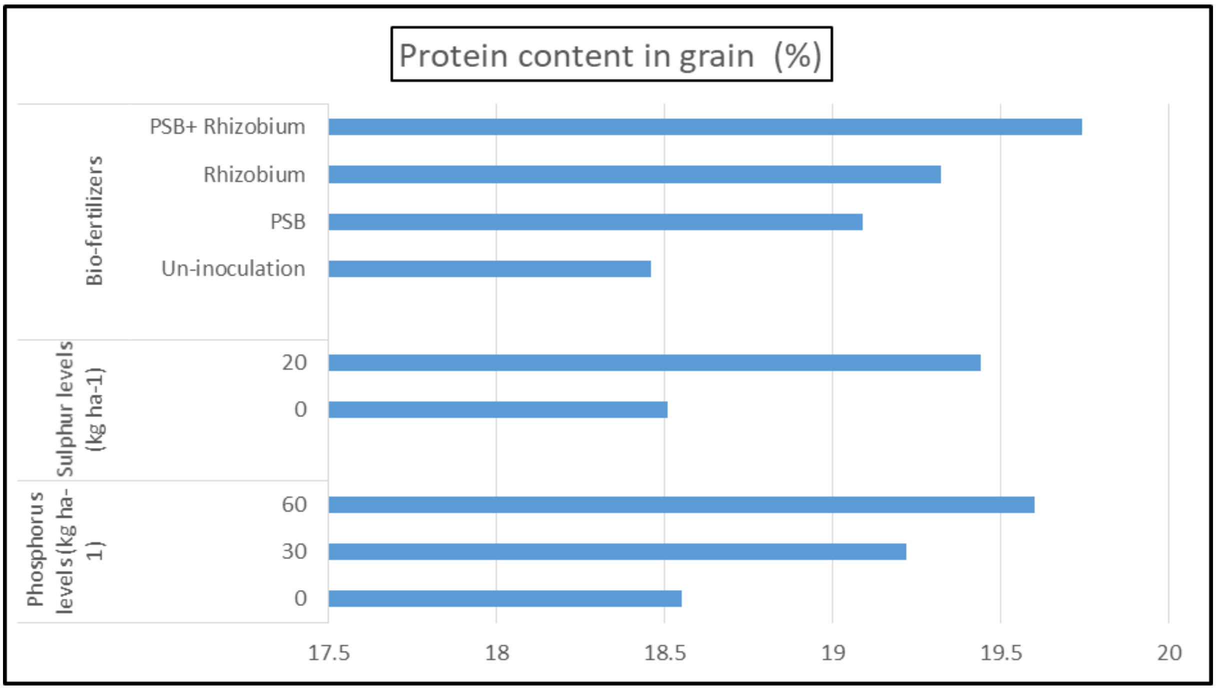

Fig 4: Protein content of chickpea grain as influenced by different levels of phosphorus & sulphur and inoculation of biofertilizers (pooled data of 2 years)

Conclusion

Pulses are play an important role in soil health improvement by nutrient fixation in its root and increment of microbial activity but cultivation and production of pulses are decreasing day by day because of various factors in which balance nutrition of plants is most important. On the basis of present investigation, it may conclude that with the application of adequate and balance fertilizers along with suitable biofertilizers can enhance the nutrient content, uptake and yield of crop. *Rhizobium* fix the atmospheric nitrogen in to the soil and PSB solubilize the unavailable P and make it available for plants. Now days nutrient rich food is requiring to fulfill the nutritional security. So, use of biofertilizers with optimum fertilizers may provide the nutrient rich and healthy food for current and future generation.

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