Effect of Integrated Management of Phosphorus, Sulphur and Biofertilizers on Dry Matter Production, Yield and Nutrient Status of Pigeon pea

(C*ajanus cajan* (L.) Millspough)

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Abstract— The present experiment was conducted at the Agriculture Farm of Shri Durga Ji Post Graduate College Chandeshwar, Azamgarh, Uttar Pradesh during *Kharif* season 2020 and 2021 to find out the effect of integrated nutrient management on growth, yield and nutrient status of pigeon pea (*Cajanus cajan* (L.) Millsp.). The experiment was laid out in Randomized Block Design (RBD) with three replications. There were 13 treatments combinations, consisted of phosphorus, sulphur and biofertilizer. Combined application of phosphorus, sulphur and biofertilizers significantly increased dry matter production, yield and nutrient status of pigeonpea over the control during both the years. The result revealed that higher grain yield (16.68 q ha^{-1}) and stalk yield (53.22 q ha^{-1}) of pigeon pea was obtained in plants treated with treatment T_{10}(60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium + PSB) than that of control and other treatments.The results showed that the plots fertilized with a higher dose of phosphorus and a lower level of sulphur with biofertilizer under treatment T_{10} (60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium + PSB) had higher contents of N, P, and S (3.45, 0.449, and 0.204%, respectively) in grains and in stalks (1.59, 0.373, and 0.105%, respectively). Interaction effects (years ×treatments) were non-significant which implies interaction is absent indicated that treatments behave independently over years. The findings concludes that use of optimum fertilizer level along biofertilizers could able to enhance the performance of crop in terms of growth and yield.

Keywords: Pigeonpea, Phosphorus, Sulphur, Rhizobium, PSB

I. INTRODUCTION

Pulses are the main source of dietary protein for the majority of vegetarians in India, which is essential for the growth and development of both human and animal bodies (Anonymous, 2004)[4]. In addition to being a great source of nutrition and fodder for animals, pulses offer the unique ability to maintain and replenish soil fertility. Despite being the world's largest producer, consumer, processor, and importer of pulses, India's average productivity is extremely poor, and the country's production cannot fulfill its population's daily needs (Kumawat *et al*., 2012)[1]. Pigeonpea (*Cajanus cajan* (L.) Millsp), after chickpea, is the second most significant crop in India among pulses (Kumawat et al., 2013)[2]. It is mostly consumed as *dal,* or split pulse. In addition, pigeonpea is a widely used green vegetable in tribal areas across several states (Saxena et al., 2010)[3]. With a total yield of 3.65 MT and an average productivity of 398 kg ha^{-1}, it covers an area of roughly 4.92 m ha in India (Anonymous, 2021)[4a]. Together, Madhya Pradesh, Maharashtra, Rajasthan, Uttar Pradesh, Karnataka, and Andhra Pradesh are the major states that produce pulses.

At the national and international levels, attempts are being undertaken to raise the per hectare production in order to meet the g rowing population's nutritional needs.Although fertilisers are crucial agricultural inputs that increase productivity, their manufa cture and use have a significant detrimental impact on the environment and public health (Rather et al. 2010)[5]. Chemical fertilizers, yet increasingly expensive and scarce, are essential to the current agricultural system. Nevertheless, the lack of plant nutrients in the soil limits productivity because the majority of our farmers hardly ever apply manure or fertilizer to their legume crops (Singh *et al.* 2018)[6]. However, there is an opportunity to boost productivity through ideal fertilization and management because there is a sizable gap between the crop's average yield and yield potential.

Legumes can fix nitrogen through *Rhizobium* to meet their own needs. By supplying nitrogen to maintain soil health, legumes can benefit subsequent crops (Odame, 1997)[7]. The necessity of phosphorus for plant growth is one of the many factors contributing to low productivity. Due to its significance as an energy store and transfer component required for metabolic activities, phosphorus also has a positive effect on plant growth and biological yield (Singh *et al.* 2014)[8]. According to Rakshit *et al*. (2015)[9], phosphorus is essential for the plant system's functions of photosynthesis, respiration, energy storage, energy transfer, cell division, and elongation. Numerous researchers have reported on the response of phosphorus in pigeon pea (Kumar and Kushwaha, 2006; Singh and Yadav, 2008; Kumawat et al., 2015)[10,11,12]. Because it strengthens the symbiotic bond between nitrogen-fixing bacteria like *Rhizobium* sp., phosphorus has been proposed to have an indirect effect in the start of nodules in pigeon peas (Jacobsen, 1985)[13]. It has been observed that the phosphorus status of a number of leguminous plants increases the amount of nitrogen (N) in plant tissues and promotes host plant growth (Israel, 1987)[14]. However, because there is a finite supply of phosphate fertilizers, their price keeps rising. Investigating ways to preserve phosphate fertilizers without compromising economic yields is therefore necessary. By making phosphorus and other nutrients more available to the crops, biofertilizers may be extremely important in this area (Selvakumar *et al*., 2012)[15]. By increasing phosphorus availability, phosphorus-solubilizing microorganisms are one of the biofertilizers that significantly improves pigeonpea development, yield characteristics, and yield (Singh and Yadav, 2008)[11].

Moreover, it has been found that sulfur, which is essential for many physiological processes in plants and is mostly provided to oilseeds and pulses as the fourth major nutrient S (Singh *et al*., 2005)[16]. Growing more severe every year is the sulfur deficit, which has a severe negative impact on millions of farmers' financial returns, crop yield, quality, and efficiency in using nutrients. It is a vital part of higher pulse production and is required for the synthesis of proteins, vitamins, and enzymes. It also helps with the biological fixing of nitrogen. Because of all of these reasons, scientists are currently investigating biological fertilizers, or "bio-fertilizers," as a sustainable substitute for supplying nutrients to crops (Nyekha *et al*., 2015)[17]. All biofertilizers are low-cost, safe, and easy to apply. Legume crops treated with biofertilizer have shown encouraging results; pulses have produced especially notable results. The essential role that phosphate solubilizing bacteria and nitrogen fixers play in giving the plant extra nitrogen and phosphorus allows for a sustainable usage of nitrogen and phosphate fertilizers (Tambekar *et al.,* 2009)[18]. Biofertilizers can be made from algae, fungi, and bacteria like *Rhizobium*, *Azospirillium*, *Azotobacter*, *P*-solubilizers, etc (Boraste, 2009)[19].

To maintain soil fertility and plant nutrient availability for maximum crop output, Integrated Nutrient Management, or INM, is a comprehensive strategy. It entails combining nutrients from both organic and inorganic sources, such as chemicals, biofertilizers, and organic manures. Integrated nutrient management is the practice of providing the required plant nutrients to sustain the desired crop productivity with little to no adverse effects on the environment and soil health (Verma *et al.,* 2022)[20]. Therefore, using phosphorus, sulfur, and biofertilizers together may be able to boost production while preserving the soil ecosystem. People would also be freed from the health hazards that come with applying fertilizers on their own. The current study was carried out to assess the impact of integrated management of phosphorus, sulfur, and biofertilizers on dry matter production, yield, and nutrient status in plant sections of pigeon pea (*Cajanus cajan* (L.) Millsp.). This was done in light of the previously indicated facts.

II. MATERIALS AND METHODS

The present experiment was conducted during the *Kharif* season 2020 and 2021 at the Agriculture Farm of Shri Durga Ji Post Graduate College Chandeshwar, Azamgarh, U.P. (26° 0.5824'N, 83° 11.4212'E and at altitude of 276 ft. above mean sea-level). The soil was sandy clay loam with pH 7.52, organic carbon 0.55 per cent, available N 238.28 kg/ha, available P 17.21 kg /ha and available k 246.56 kg/ha. The soil of the experimental field had pH 7.3, EC = 0.52 mmhos/cm, organic carbon 0.45%, available N360 kg/ha (medium), available P 14.65 kg/ha (low) and available K 194 kg/ha (medium).The average rainfall of the district is 1031 mm which is suitable for growing rainfed crop. The experiment was laid out in randomized block design with 3 replications. The crop variety Bahar was sown at the seed rate of 20 kg ha^{-1} in rows distance between 60 cm apart. The light hoeings with *khurp*i were done at 15 and 30 DAS to remove weeds along with thinning operations maintaining plant to plant spacing at 20 cm. There were three levels of phosphorus and sulphur. Thirteen treatments were applied in experiment which in combination of 2 levels of phosphorus and sulphur, and bio-fertilizers *viz.*, *Rhizobium*, and PSB applied singly as well as in co-inoculation including control. Bio-fertilizers were applied through seed inoculation. For each kg of seed slurry was preparedby mixing and warming 200g of bio-fertilizer culture in200ml water containing 50g Jaggery. The seeds were then put in the slurry and removed after 15-20 minutes and spread in shade for 20-30 minutes and then sown in theprepared field. Observations were recorded from five representative sample plants on dry matter production atgrowth stages, yield and nutrients statusin plant parts of pigeon pea. Finally the data were subjected to statistical analysis and pooled mean of years interpreted in findings.

III. RESULTS AND DISCUSSION

The results under the following subheadings are explained in this part using previous study findings from other researchers.

III.I. DRY MATTER PRODUCTION

The findings showed that as growth phases advanced, there was a consistent increase in the amount of dry matter produced per plant (Table 1 & Figure 1). Similar to treatments, there were notable variations in the amount of dry matter produced in the two experimental years. Higher dry matter/plant (18.25, 42.08, 83.05, 140.5 and 157.22 g plant^{-1} at 40, 80, 120, 160 DAS and at harvest, respectively) was produced with the treatment T_{10} (60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + *Rhizobium* + PSB) whereas the lower dry matter/plant (10.37, 25.75, 56.42, 90.52 and 111.9 g plant^{-1} at 40, 80, 120, 160 DAS and at harvest, respectively) was obtained from the control treatment T_1. The results obtained from the present study were similar with the findings of Idapuganti *et al. (*2011)[21], and Singh and Singh (2012)[22].

III.II. GRAIN YIELD

The yield of pigeon pea (*Cajanus cajan* (L.) Millsp.) is significant due to their high protein, carbohydrate, mineral, and vitamin content. *Dal* is one way to use this as human nourishment. The findings in Tables 2 and illustrated in Figure 2 & 3 showed that, independent of interventions, there was a substantial variation in the pigeon pea grain production between years. The rates of phosphorus, and sulfur together with biofertilizers have a major impact on grain yield. Maximum grain yield (16.68 q ha^{-1}) was recorded in plants treated with $T_{10,}$which was significantly superior to others. Minimum grain yield (11.17 q ha^{-1}) was recorded in plants under control treatment. Since the interaction effect is not statistically significant, it can be concluded that there is no interaction and that treatments behave independently over time. The favorable increase in yield characteristics and yield may be due to a sustained increase in the number of pods and grain weight per plant, as well as an improved rate of carbohydrate synthesis in the reproductive organs of the plant. According to Hussain *et al*. (2021)[23], phosphorus greatly increased the production of pulse crops when phosphatic and biofertilizer applications were increased. The current findings were corroborated by Sahu *et al.* (2021)[24], who found an increase in grain production of up to 60 kg ha^{-1} with the application of P_2O_5.

III.III. STALK YIELD

Pigeon pea stems have a high potential yield because they can be used to make biochar, which has numerous advantages including the ability to lower carbon dioxide emissions. Irrespective of treatments, the results (Table 2) revealed that there was a significant difference in stalk yield of pigeon pea due to years. The rates of phosphorus, and sulphur together with biofertilizers had markedly influenced the stalk yield of pigeon pea. Maximum stalk yield (53.22 q ha^{-1}) was recorded in plants treated with T_{10},which was far better than others. Minimum stalk yield (33.15 q ha^{-1}) was recorded in plants under control treatment. Interaction effect is non-significant which implies interaction is absent indicated that treatments behave independently over years. The enhanced rate of photosynthesis combined with efficient metabolic activities may be the cause of the improvements in stalk production, as this improves the translocation of nutrients in the sink. Similarly, Pramod Kumar *et al.* (2012)[25] reported decline in stalk yield of pigeon pea over 60 kg P_2O_5 ha^{-1}. They also observed beneficial effect of biofertilizer in addition with phosphorus. Later on, significant effects of Sulphur on stalk yield were reported by Umesh and Shankar (2013)[26] and Yadav et al. (2021)[27].

III.IV. NUTRIENT STATUS IN PIGEON PEA

The combined effect of phosphorus and sulphur with bio-fertilizer treatment was shown to have a substantial influence on the nutritious content of elements, specifically N, P, and S, which were found to be higher in grains than in the stalks of the pigeon pea, regardless of treatments (Table 2). Unlike N and P, variations S content were found be significant in grains and stalk, respectively between years of study. Interaction effect is non-significant which implies interaction is absent indicated that treatments behave independently over years. The results showed that the plots fertilized with a higher dose of phosphorus and a lower level of sulphur with biofertilizer under treatment T_{10} (60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + *Rhizobium* + PSB) had higher contents of N, P, and S (3.45, 0.449, and 0.204%, respectively) in grains and in stalks (1.59, 0.373, and 0.105%, respectively). Sulphur content in grains of plants treated with $T_{10}$was found to be on same bar with T_8, T_9, T_{11}, T_{12} and T_{13}. The lowest nutrient content was obtained under control. According to the results, treatment T_{10} (60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + *Rhizobium* + PSB) produced grains and stalks with the highest amount of nutrients, specifically N, P, and S,which may have been caused by higher nutrient uptake. After reaching a critical level, at par results with this treatment showed that S application greater than 15 kg S ha^{-1} could not improve the nutritional status of pigeon pea. The present study were similar with the findings of Singh and Singh (2012)[22], Singh et al. (2014)[8], and Singh *et al.* (2022)[28] in pulse crops.

Table 1: Effect of combined dose of phosphorus, sulphur and biofertilizers on dry matter production (g $plant^{-1}$) in pigeon pea.

Treatment	**Treatment detail**	**Pooled Mean**				
		40 DAS	**80 DAS**	**120 DAS**	**160 DAS**	**at harvest**
T 1	Control	10.37	25.75	56.42	90.52	111.90
T 2	30 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium	12.22	30.80	76.45	117.90	146.90
T 3	30 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + PSB	12.02	27.02	72.37	106.65	135.52
T 4	30 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium + PSB	14.60	39.93	86.52	125.18	156.07
T 5	30 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium	11.85	26.07	59.40	99.48	124.02
T 6	30 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + PSB	12.00	27.95	73.75	115.45	144.03
T 7	30 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium + PSB	12.45	34.75	80.63	118.98	148.85
T 8	60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium	18.25	42.08	94.75	137.28	155.77
T 9	60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + PSB	13.02	36.08	83.05	122.65	150.62
T 10	60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium + PSB	18.33	43.63	99.95	140.50	157.22
T 11	60 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium	14.53	39.53	85.62	127.20	143.47
T 12	60 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + PSB	13.28	36.20	82.28	121.68	140.02
T 13	60 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium + PSB	15.83	40.08	94.07	133.52	148.98
CD for Years		0.49	0.90	1.03	3.42	1.62
CD for Treatments		0.18	0.55	2.17	3.38	4.64
CD for Years X Treatments		N.S.	N.S.	N.S.	N.S.	N.S.

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Fig. 1: Pooled data of combined effect phosphorus, sulphur and biofertilizers on dry matter production (g plant^{-1}) in pigeon pea.

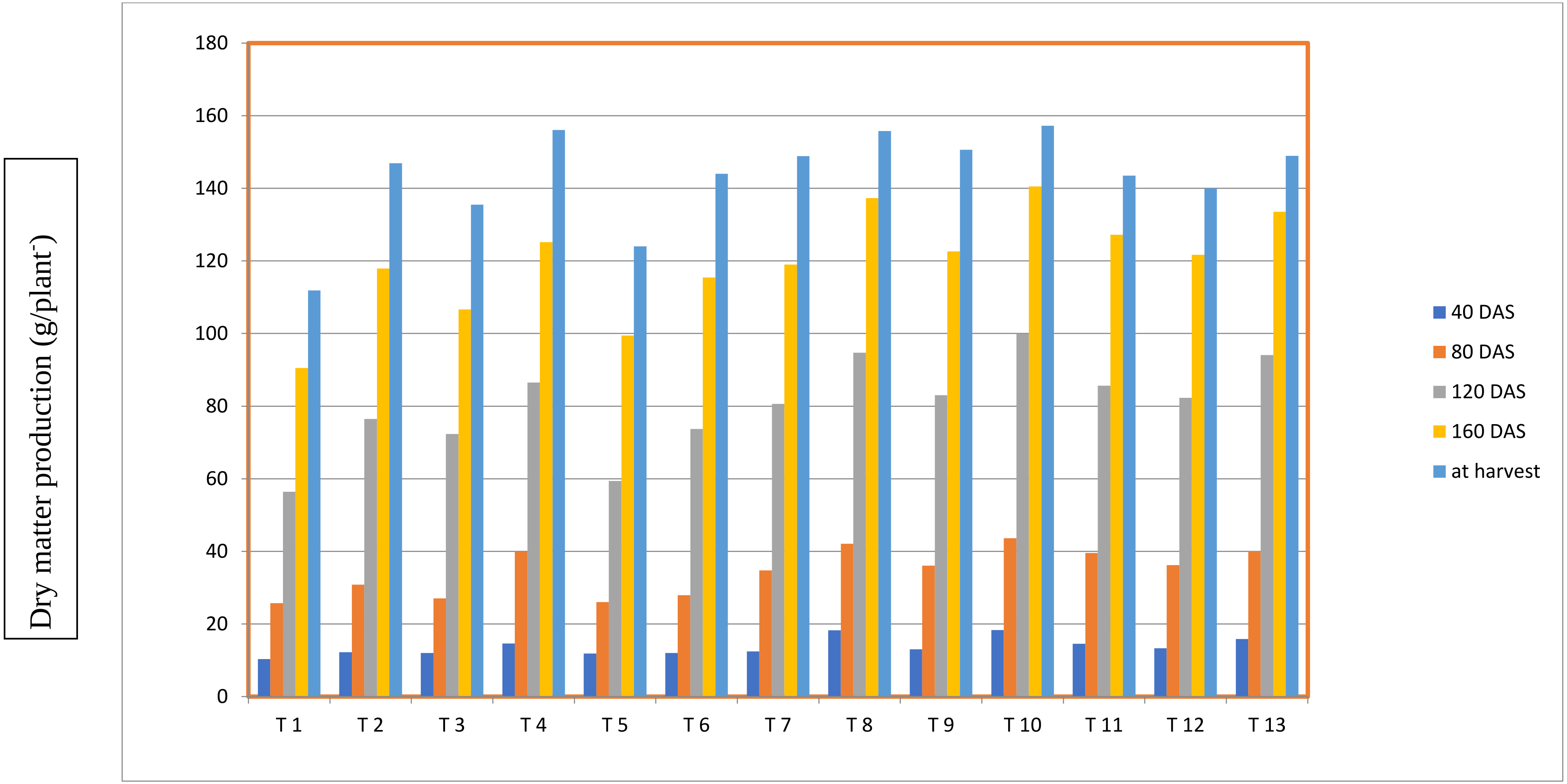


Table 2: Effect of combined dose of phosphorus, sulphur and biofertilizers on yield and nutrient status of plant parts in pigeon pea.

Treatment	Treatment detail	Pooled Mean							
		Grain yield (q ha^{-1})	Stalk yield (q ha^{-1})	N content (%)		P content (%)		S content (%)	
				Grains	Stalk	Grains	Stalk	Grains	Stalk
T 1	Control	11.17	33.15	2.29	1.18	0.270	0.247	0.151	0.071
T 2	30 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium	12.92	38.03	2.56	1.33	0.279	0.266	0.170	0.077
T 3	30 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + PSB	11.90	36.37	2.39	1.37	0.338	0.286	0.167	0.083
T 4	30 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium + PSB	15.13	42.98	2.95	1.49	0.412	0.332	0.175	0.086
T 5	30 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium	11.80	35.08	2.43	1.41	0.298	0.281	0.175	0.087
T 6	30 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + PSB	12.42	36.85	2.48	1.29	0.421	0.303	0.171	0.089
T 7	30 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium + PSB	13.42	39.65	2.60	1.43	0.430	0.319	0.181	0.091
T 8	60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium	16.25	44.42	3.28	1.53	0.390	0.317	0.186	0.090
T 9	60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + PSB	13.58	40.27	2.62	1.45	0.416	0.365	0.184	0.093
T 10	60 kg P_2O_5 ha^{-1} + 15 kg S ha^{-1} + Rhizobium + PSB	16.68	53.22	3.45	1.59	0.449	0.373	0.204	0.105
T 11	60 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium	15.08	42.88	2.99	1.53	0.315	0.300	0.191	0.086
T 12	60 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + PSB	14.47	42.57	2.90	1.46	0.398	0.303	0.185	0.088
T 13	60 kg P_2O_5 ha^{-1} + 30 kg S ha^{-1} + Rhizobium + PSB	15.67	43.85	3.08	1.53	0.352	0.341	0.197	0.096
CD for Years		0.84	2.61	N.S.	N.S.	N.S.	N.S.	0.013	0.003

CD for Treatments	0.39	0.87	0.34	0.05	0.072	0.031	0.021	0.008
CD for Years X Treatments	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Fig. 2: Effect of combined dose of phosphorus, sulphur and biofertilizers on yield and nutrient status of plant parts in pigeon pea.

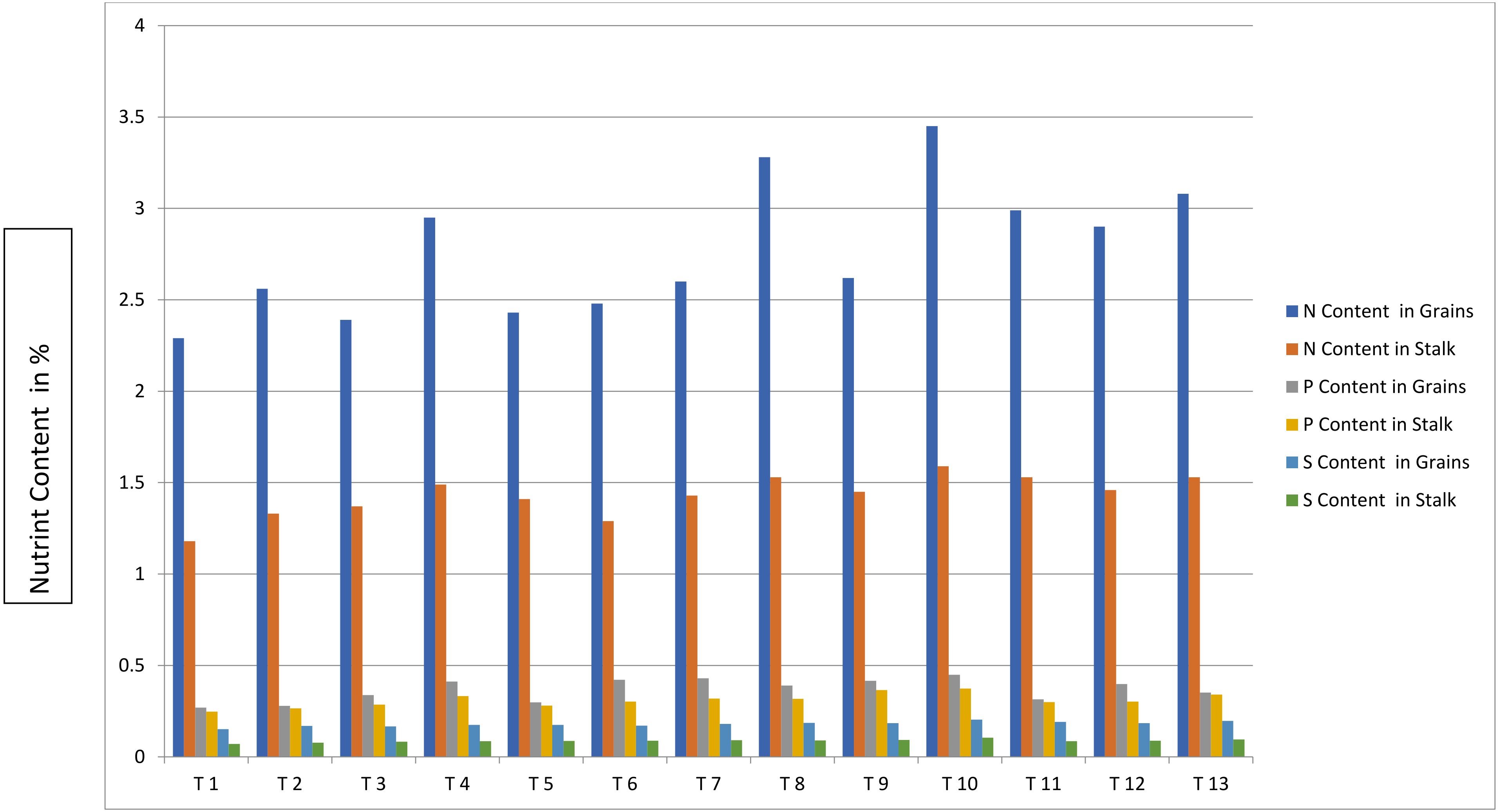
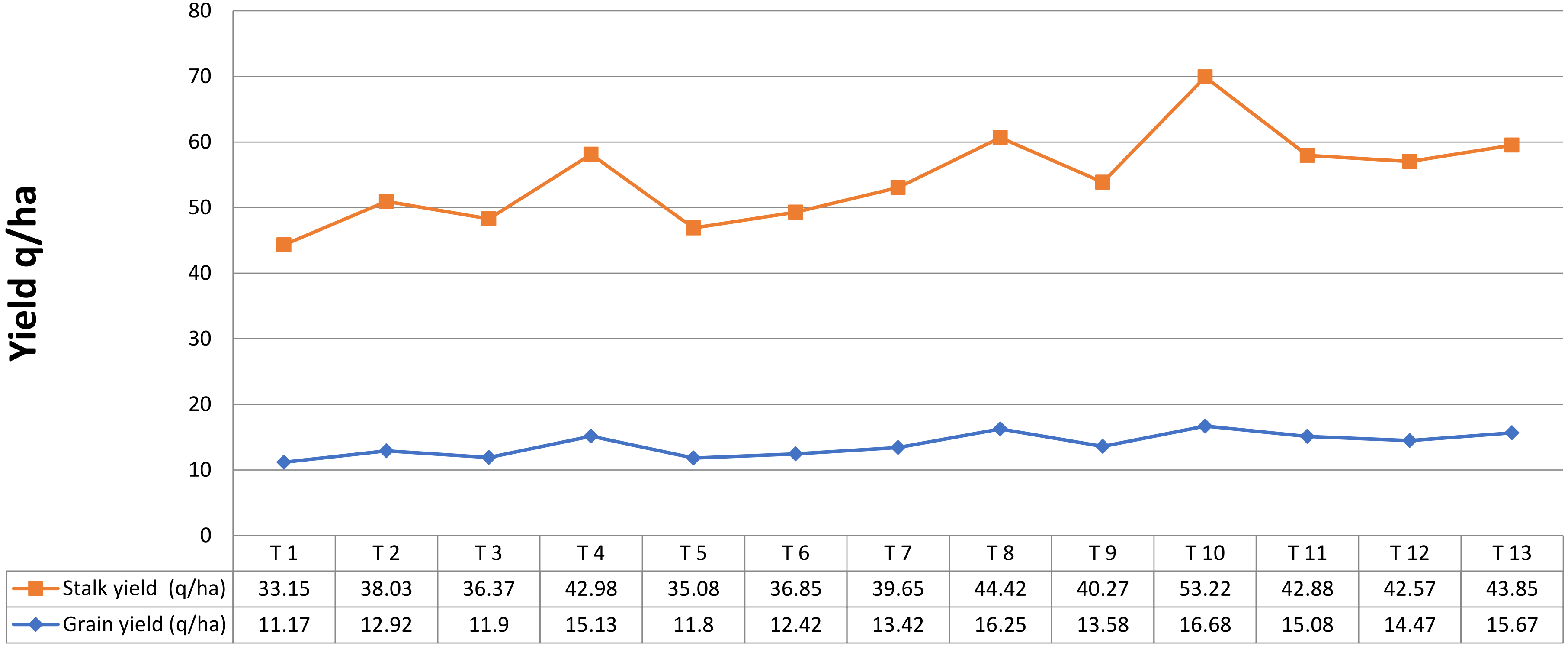

Nutrint Content in %
4
3.5
3
2.5
2
1.5
1
0.5
0
T 1
T 2
T 3
T 4
T 5
T 6
T 7
T 8
T 9
T 10
T 11
T 12
T 13
N Content in Grains
N Content in Stalk
P Content in Grains
P Content in Stalk
S Content in Grains
S Content in Stalk

Fig. 3: Effect of combined dose of phosphorus, sulphur and biofertilizers on grain and stalk yield of pigeon pea



	T 1	T 2	T 3	T 4	T 5	T 6	T 7	T 8	T 9	T 10	T 11	T 12	T 13
Stalk yield (q/ha)	33.15	38.03	36.37	42.98	35.08	36.85	39.65	44.42	40.27	53.22	42.88	42.57	43.85
Grain yield (q/ha)	11.17	12.92	11.9	15.13	11.8	12.42	13.42	16.25	13.58	16.68	15.08	14.47	15.67

IV. CONCLUSION

On the basis of finding of two consecutive years of experiments, it can be concluded that application of 60 kg P_2O_5 with 15 kg S ha^{-1} and dual inoculation of *Rhizobium* and PSB is most beneficial for sustainable production forthe farmers of eastern districts of Uttar Pradesh.

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