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Growth, yield and economics of soybean [*Glycine max* (L.) Merril] as influenced by phosphorus and potassium fertilization

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Abstract
A field experiment was conducted to determine the Growth, Yield and Economics of Soybean [*Glycine max* (L.) Merril] as influenced by Phosphorus and Potassium fertilization, at the Agriculture Farm of Suresh Gyan Vihar University [SGVU], Jaipur, Rajasthan, during 2022. The experiment was laid out in an FRBD (factorial randomized block design) consisting of fifteen treatments with three replications. Treatments included four levels of phosphorus (0, 30, 60, and 90 kg P ha^{-1}) and four levels of potassium (0, 20, 40, and 60 kg K ha^{-1}). The statistical analysis indicated that growth was significantly influenced by the application of phosphorus and potassium.
It is evident from the results with the application of phosphorus of the present findings that vegetative characteristics like (plant height, branch per plant, plant dry weight number of nodules per plant, Number of pods per plant, number of seeds per pod, seed index, Seed yield, stover yield, biological yield), were markedly improved by the application of 60 kg P_2O_5 ha^{-1} and 30 kg P_2O_5 ha^{-1} and also remained at par with application of 90 kg P_2O_5 ha^{-1}. However, the highest B: C ratio was obtained with the application of 60 kg P_2O_5 ha^{-1} which was significantly higher over control only. By and large, varying doses of phosphorus increased the nitrogen content in straw and grain, phosphorus content in straw and grain and potassium content in straw and grain up to 60 kg P_2O_5 ha^{-1}. Application of phosphorus failed to cause significant variation in (plant stand, harvest index and protein content). Results further showed that application of 40 kg K_2O ha^{-1} significantly increased the (plant height, branch per plant, plant dry weight number of nodules per plant, Number of pods per plant, number of seeds per pod, seed index, Seed yield, stover yield, biological yield) were markedly improved by the application of 40 kg K_2O ha^{-1} and 20 kg K_2O ha^{-1} and also remained at par with application of 60 kg K_2O ha^{-1}. However, the highest B: C ratio was obtained with the application of 40 kg K_2O ha^{-1} which was significantly higher over control only. By and large, varying doses of phosphorus increased the nitrogen content in straw and grain, phosphorus content in straw and grain and potassium content in straw and grain up to 40 kg K_2O ha^{-1}. Application of potassium failed to cause significant variation in (plant stand, harvest index and protein content).

Keywords: Potassium, phosphorus, growth, yield attributes

Introduction

Soybean [*Glycine max* (L.) Merrill] is considered one of the vital legume crops for food and feed worldwide. It contains about 20–22% vegetable oil, 42–45% protein, 30–35% carbohydrates, and 10–12% total sugar, as well as a high amount of amino acids, thiamin, vitamins, niacin, riboflavin, phosphorus, calcium, and iron. In addition, soybean seed oil is free of cholesterol and rich in essential and unsaturated fatty acids. Moreover, the oil of soybeans is important for dieting and diabetics and protects against some types of cancer diseases. Besides the importance of soybeans as an important oil crop (20– 30% of the world's processed vegetable oil) (Graham and Vance, 2003) [4], There is a big gap between consumption and production of oil. For this reason, the cultivated area of soybean plants has increased to minimize the deficit in oil crop production. According to FAO (2022-23), with a total seed production of about 21.22 million tons and a yield of 1130 kg/hectare; on the other hand, in Rajasthan, the area was 18.81 million hectares. On the other hand, the worldwide cultivation of soybeans reached about 121.5 million ha, with an approximate productivity of about 334.9 million tons. Soybeans (*Glycine max*) are the most important crop from the Fabaceae family in the world today.

They can be used as food, livestock feed, oil, and fuel sources. Soybeans have a complete protein composition similar to that of meats, milk products, and eggs. (Masuda & Goldsmith, 2009) [5]. The increasing population simultaneously enhances the demand for this crop. Soybeans have some beneficial effects on human health. Replacement of cattle's protein with soybeans could increase the intake of folate and vitamin K, calcium, magnesium, iron, and fibre per day. At the same time, this replacement would lower the saturated fat intake. However, soybean has an equal protein rating to egg or cow's milk. It was because of a small and unique protein called "peptides." They are defensins, glycine, conglycinins, and lunatic. All of these peptides have a beneficial effect on human health, including enhanced blood pressure regulation, improved blood sugar control levels, and better immune function. Soy also has antioxidant properties, such as genistein and phenolic acid, which improve the body's immunity from cancer risk. Another study was done to determine the effect of soy consumption on the cardiovascular system. It was found that using about 30 grams of soybeans each day could decrease coronary heart disease because of the lowering of LDL cholesterol. This finding concluded that soybeans seem to have a beneficial role in supporting cardiovascular health. In addition, soy bars made from 100% soy powder had a better effect on diabetes mellitus patient consumption than cookies made from wheat grain ("Soybeans," 2017; Urita *et al*., 2012) [10, 11].

Phosphorous (P) plays a pivotal role in improving growth, development, and reproduction; flowering; pod setting; seed formation; protein synthesis; sugar translocation; plant resistance to several diseases; and seed quality (Brady, 2002) [1]. Phosphorus is considered a major and essential macronutrient required by all plants because it contributes to many metabolic processes, i.e., cell division, building new tissues, photosynthesis, respiration, nucleic acids, glucose synthesis, N fixation, and the synthesis of phospholipids. In addition, during the process of symbiotic N2 fixation, the rhizobium bacteria need a high quantity of phosphorous as a source of energy for bacterial growth, increasing root growth and the density of rhizobia bacteria in the soil, and transforming atmospheric N2 into the ammonium (NH4) form available for plant nutrition and the energy transfer adenosine triphosphate (ATP) metabolism, mainly depending on the availability of P in soils (Plaxton, 2004) [8].

Potassium (K) also plays an important role in regulating the water loss of plants, thus helping to prevent plant necrosis. It serves as an activator of enzymes used in photosynthesis and respiration, helps to build cellulose, aids in photosynthesis by the formation of a chlorophyll precursor, and finally results in quality fruits. The relatively large amounts of K are required for high-yielding soybeans. The deficiency of K at any time during the growing season of soybeans reduced its pod yields, whereas the application of K fertilizers increased the number of nodules, weight of nodules, and number of pods per plant. Therefore, the present research work will be carried out to find suitable fertilizer treatments.

Materials and Methods

The experiment was conducted to determine the effect of different doses of phosphorus and potassium on the growth and economics of soybean [*Glycine max* (L.) Merrill] cv. JS-9305, was carried out at the Agriculture Farm of Suresh Gyan Vihar University [SGVU], Jaipur, Rajasthan, in 2022. The average RH range was 48.69–81.87%, and soil physical properties were sand (69.0), silt (22.4), clay (14.0), and soil type (sandy loam) with a soil pH of 6.25. Available nutrients include nitrogen (154.80), phosphorus (20.70), and potassium (126.60).

The total rainfall received during the cropping period was 47.50 mm. The experiment was laid out in an FRBD (factorial randomized block design) consisting four levels each of P_2O_5 (0, 30, 60, 90 kg/ha) and K_2O (0, 20, 40, 60 kg/ha) with a total number of sixteen treatments with three replications.

Results and Discussion: Parameters

Effect of Phosphorus

Data presented in Table 1. indicated that the maximum plant height of Soyabean was recorded at 90 kg P_2O_5 ha^{-1} at all the growth stages. The above treatment proved significantly superior over control and 30 kg P_2O_5 ha^{-1} increasing plant height by 25.85 and 9.26 % at 30 DAS, 13.34 and 5.66 % at 60 DAS and 9.33 & 4.20 % at harvest respectively. The minimum plant height was recorded under control treatment. It is evident from data (Table 1) that the application of phosphorus at 60 and 90 kg ha^{-1} remaining at par with each other significantly increased the number of branches per plant over the lower levels (0 & 30 kg P_2O_5 ha^{-1}) at 60 DAS. However, at harvest, increasing level of phosphorus up to 90 kg ha^{-1} significantly increased the number of branches per plant over its preceding level by 12.33, 34.21 & 58.88 % over 60, 30

& control treatments, respectively. It is apparent from the data presented in Table 1 that dry matter accumulation per plant increased significantly with the application of phosphorus over control. Each increasing dose of phosphorus up to 60 kg P_2O_5 brought significant improvement in plant dry weight at 30 DAS after sowing. However, at successive stages that is 60 DAS and at harvest each incremental dose of phosphorus increased the dry weight linearly but significant improvement was observed only up to 30 kg P_2O_5 thereafter the increase was almost the same. Hence 60 kg P_2O_5 was found to be the most suitable dose concerning dry matter accumulation which enhanced the quantum of dry matter by 13.55 and 7.64% respectively over control at 60DAS and at harvest. The lowest value of plant dry weight (9.58 g, 30.93 g, 59.46 g) was recorded in the plots devoid of any application of phosphorus (P0) at all stages. It is evident from data (Table 1) that the number of pods per plant was influenced by various levels of phosphorus application, wherein each increasing dose of phosphorus increased the number of pods per plant but a perceptible increase was not recorded beyond 60 kg P_2O_5 ha^{-1}. Phosphorus application at 30 and 60 kg ha^{-1} enhanced the number of pods per plant as compared to control by 9.16 and 14.53 % respectively. An appraisal of data (Table 1) revealed that a number of seeds per pod was strongly influenced by the phosphorus wherein the increasing level of phosphorus significantly increased the seeds per pod up to 60 kg P_2O_5 ha^{-1} thereafter, the increase was not significant. Hence, 60 kg P_2O_5 was observed to be the most effective dose which enhanced the number of seeds per pod by 20.81 and 44.24 % over 30 and 0 kg P_2O_5 ha^{-1} respectively. The lowest value of number of seeds per pod (1.65) was recorded in the plots devoid of any application of phosphorus (P0). Data clearly showed that seed, straw and biological yield of soybean was significantly increased by the application of phosphorus levels. The significantly higher yields in terms of seed, straw and biological yield were recorded with the application of phosphorus @ 60 kg P_2O_5 ha^{-1} over control and 30 kg and also proved as effective as 90 kg P_2O_5 ha^{-1}. However, the harvest index of soybeans was not influenced by different levels of phosphorus.

Effect of Potassium

Data (Table 1) further indicated that increasing levels of potassium brought the increasing trend in the plant height of soybean with the maximum value at 60 kg K_2O ha^{-1}. However, the treatments 20, 40 & 60 kg K_2O ha^{-1} being at par with each other produced a significant increase in plant height by 10.24, 11.51 & 13.17 % respectively at 30 DAS. The corresponding increase brought about by the above treatments was with magnitude of 4.89, 6.42 & 8.69 % at harvest. It was further observed that by and large increasing levels of potassium failed to bring significant variation in plant height at 60 DAS. It is further evident from data (Table 1) that graded levels of potassium from 20 to 60 kg K_2O ha^{-1} were found to increase the number of branches of soybean significantly over control. The application of 20, 40 & 60 kg K_2O ha^{-1} enhanced the number of branches by the tune of 27.00, 29.62 & 30.77 % respectively over control. However, the above three treatments were at par with each other. Data further revealed that the application of potassium at varying levels exerted a significant influence on dry matter accumulation of soybean over control (Table 1). However, every implemental dose of potassium could not bring significant variation except 20 kg K_2O ha^{-1}, thereafter at least a linear increase was observed at all the stages of observation. Here, 40 kg K_2O was found to be the most suitable dose, since the increase was meagre with the next higher dose. In terms of percentage, 40 kg K_2O ha^{-1} enhanced the dry matter accumulation over no potash, at 30, 60 DAS and at harvest respectively by 17.50, 7.42 & 7.02. The lowest dry matter accumulation was obtained in the plots devoid of potash application at all stages. It is further evident from data (Table 1) that the number of pods per plant was influenced by various levels of potassium application, wherein each graded level of potassium increased the number of pods per plant but a remarkable increase was observed only up to 40 kg K_2O ha^{-1}. Hence, potassium application at 20 and 40 kg K_2O ha^{-1} was in the order of 11.45 and 18.16% respectively over no potassium (K0). A critical examination of data (Table 1) indicated that increasing levels of potassium up to 60 kg K_2O ha^{-1} increased the number of seeds per pod but no appreciable increase was recorded beyond 40 kg K_2O, hence this dose may be considered appropriate in this regard. Per cent increase brought about by 40 kg K_2O ha^{-1} over 0 kg K_2O was 19.34. The corresponding increase due to 20 kg K_2O over control was observed to be 17.13%. The lowest value of number of seeds per pod (1.81) was recorded in the plots devoid of any application of potassium (K0). With regard to seed, straw and biological yield of soybean, various doses of potassium also exhibited a similar trend as observed in yield attributes where 40 kg K_2O ha^{-1} proved significantly superior over 0 and 20 kg K_2O ha^{-1} and was found equally good as 60 kg K_2O ha^{-1}. However, the harvest index of soybeans was not affected significantly due to potassium treatments.

Discussions

The beneficial effect of applied nutrients, as revealed by the better performance of the plants about various growth and development characteristics, including the length and breadth of the fruits, certainly positively influenced this character. The important role of both nutrients concerning the growth and development of roots and aerial parts might have accentuated the synthesis of chlorophyll, photosynthetic area, and the production of carbohydrates for accumulation in the fruits. This conformed with the findings of Singh *et al*. (2008a). The use of phosphorous and potassium in this investigation favoured vegetative growth, and the number of flowers borne was proportionally high. A relatively large number of auxins and various other substances regulating bud initiation are produced by the foliage, and hence, applied nitrogen seems to have a positive correlation with the number of flowers borne. The result is in line with the previous findings obtained by Moniruzzaman and Quamruzzaman (2009) [6], Firoz (2009) [2], and Osmond and Kang (2008) [7], who also reported higher growth parameters and yields with higher doses of phosphorous and potassium in soybeans. The above results indicated that the number of days until first fruit picking decreased with increasing nitrogen, phosphorous, and their combinations. It might be because high levels of nitrogen, phosphorous, and their combinations reduce the growing period, resulting in early maturity.

Table 1: Effect of phosphorus and potassium on growth and yield of soybean.

Treatments P_2O_5 (Kg/ha)	Plant height	Number of branches	Plant dry weight	Pods per plant	Grains per pod	Seed index (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Biological yield (kg/ha)
0	65.14	3.21	59.46	34.06	1.65	7.88	1424.09	2351.27	3783.70
30	68.35	3.80	62.48	37.18	1.97	8.82	1724.27	2766.37	4281.46
60	69.38	4.54	64.00	39.01	2.38	9.99	1936.50	3046.10	4738.83
90	71.22	5.10	65.04	39.64	2.42	10.27	2009.55	3241.47	5003.52
SE.m (±)	1.40	0.09	1.27	1.02	0.06	0.22	50.84	78.96	123.31
CD at 5 %	4.04	0.26	3.67	2.95	0.17	0.60	146.85	228.07	356.15
K_2O (Kg/ha)									
0	65.26	3.91	59.24	33.09	1.81	7.20	1478.52	2582.41	3763.48
20	68.45	4.17	63.19	36.88	2.12	8.98	1713.49	2762.04	4355.23
40	69.45	4.25	63.40	39.10	2.16	9.95	1929.91	3010.93	4772.44
60	70.93	4.33	65.15	40.45	2.17	10.35	1972.48	3049.83	4916.36
SE.m (±)	1.40	0.09	1.27	1.02	0.05	0.22	50.84	78.96	123.31
CD at 5 %	4.04	0.26	3.67	2.95	0.18	0.65	146.85	228.07	356.15
CV (%)	7.08	7.49	7.02	9.49	10.74	7.44	9.93	9.59	9.60

Conclusion

Based on the results of one year of experimentation, it may be concluded that independent application of 60 kg P_2O_5 and 40 kg K_2O ha^{-1}, significantly increased the Grain yield (1937 & 1930 kg/ha), over their corresponding lower levels. However, these results are only indicative and require further experimentation to arrive at a more consistent and final conclusion to be passed on to the farmers.

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