# RESPONSE OF SOYBEAN (*Glycine max L.)* TO POTASSIUM FERTILIZER UNDER DIFFERENT CROP GEOMETRY

ABSTRACT

An experiment entitled, "Response of soybean (*Glycine max* L.) to potassium fertilizer under different crop geometry" was carried out at experimental cum demonstration field, SVIAg, SVVV, Indore during *rabi* 2023-24. The soil of experimental field was medium black clay in texture. It was low in available nitrogen (209 kg $ha^{-1}$), medium in phosphorus (14.65 kg $ha^{-1}$) and high in potassium (453.12 kg $ha^{-1}$). The soil organic carbon content, pH, and EC was 0.52 %, 7.25 %, and 0.74 $dSm^{-1}$, respectively.

The experiment consists of twelve treatment combinations with three main plot treatment (crop geometry) *viz*. $C_1$: 30 cm x 20 cm, $C_2$: 40 cm x 15 cm, and $C_3$: 60 cm x 10 cm and $K_1$: 0 kg $K_2O$ $ha^{-1}$ , $K_2$: 20 kg $K_2O$ $ha^{-1}$, $K_3$: 40 kg $K_2O$ $ha^{-1}$, and $K_4$: 60 kg $K_2O$ $ha^{-1}$ as four sub-plot treatments (potassium levels). Each experimental unit was replicated thrice having the gross plot size of 4.0 x 3.0 $m^2$. Sowing of soybean at 30 cm x 20 cm spacing recorded maximum growth attributes, *viz*. plant height (40.92 cm) at harvest, number of branches $plant^{-1}$ (10.66) at harvest, number of functional leaves (27.18) $plant^{-1}$ at 60 DAS, dry matter accumulation $plant^{-1}$ ( 22.64 g) at harvest, leaf area $plant^{-1}$ (12.64 $dm^2$) at 60 DAS, number of root nodules $plant^{-1}$ (54.91) at 60 DAS and dry weight of root nodules (1.078 g) at 75 DAS, higher yield attributes such as number of pods (37.48) $plant^{-1}$, number of seeds $pods^{-1}$ (2.68), and number of seeds $plant^{-1}$ (100.88 g). The highest seed yield (15.67 q $ha^{-1}$), straw yield (24.01 q $ha^{-1}$), and biological yield (39.68 q $ha^{-1}$) was also observed under crop geometry of 30 cm x 20 cm. Sowing of soybean at 30 cm x 20 cm obtained higher gross monetary returns (₹ 78337.10 $ha^{-1}$), net monetary returns (₹ 33714.05 $ha^{-1}$) and B:C ratio (1.72). While in potassium levels, treatment application of 60 kg $K_2O$ $ha^{-1}$ was recorded significantly higher growth parameters of soybean such as., plant height (43.22 cm) at harvest, number of branches (11.30) $plant^{-1}$ at harvest, number of functional leaves (27.42) $plant^{-1}$ at 60 DAS, leaf area (12.82 $dm^2$) $plant^{-1}$ at 60 DAS, dry matter accumulation $plant^{-1}$ (23.13 g) at harvest, number of root nodules $plants^{-1}$ (56.10) at 60 DAS, and dry weight of root nodules (1.103 g) at 75 DAS, yield parameters viz., number of pods (36.88) $plant^{-1}$, number of seeds $pods^{-1}$ (2.69) and number of seeds $plants^{-1}$ (103.05), as compared to other potassium levels. Amongst the potassium levels 60 kg $K_2O$ $ha^{-1}$ recorded significantly higher seed yield (16.34 q $ha^{-1}$), straw yield (24.57 q $ha^{-1}$) and biological yield (40.91 q $ha^{-1}$) in contrast to the other potassium level. In potassium levels, higher gross monetary returns (₹ 81699.35 $ha^{-1}$) and net monetary returns (₹ 34450.64 $ha^{-1}$) were obtained under treatment 60 kg $K_2O$ $ha^{-1}$ than rest of treatments with higher B:C ratio (1.69).
Keywords : Soybean, Crop geometry, Potassium fertilization

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## INTRODUCTION

Soybean (*Glycine max* (L.) Merrill) belongs to family Fabaceae and has Eastern Asian origin. It is one of the most important pulse crops in the world which supplies most of the protein and oil requirements. It is known by various names in different regions such as soja bean, soya bean, Chinese pea and manchurian bean and considered as a ‘wonder crop’, ‘Golden bean’ and ‘Gold of soil’ of the 21$^{st}$ century due to its various quality such as ease in cultivation, less requirement of fertilizer and labour.

In recent years, soya foods have expanded to include fresh beans and sprouts, grain products soya bread, pasta and flour, dairy substitutes such as soymilk, cheese, meat substitutes, soya paneer, soya-yogurt, soya-ice cream, soya-flour, soya fortified food stuffs and biscuits that have good acceptability among the people, because of its cost specific and nutritional advantages (Rathwa *et al.,* 2023). Soybean oil is used as a raw material in manufacturing antibiotics, paints, lubricants varnishes and adhesives *etc*. Soya meal is an excellent feedstuff for livestock and poultry. Soya meal comprises 60 percent of the global oil production.

It is an excellent health food containing 40 to 44 % quality protein, 20 % cholesterol free oil, 20 % carbohydrate and 0.69 % phosphorous. Soybean protein has 5 % lysine, which is deficit in most of the cereals and enriching the cereal flour with soybean improves the nutritive quality. It’s a rich source of fats, amino acids, vitamins and minerals. Nutritionally, soybean oil is high in unsaturated fats, such as oleic acid (OA), linoleic acid (LA), and α-linolenic acid, and represents an important way for consumers to reduce the intake of SFAs, as recommended in the Dietary Guidelines for Americans. LA and ALA are essential fatty acids that must be obtained through dietary intake. Soybean oil is the most common source of LA and ALA, have been linked with a decreased risk of cardiovascular disease.

The efficient production of soybean crop is constraint, with several biotic, abiotic factors, and crop management practices. Fertilization is one of the cultivation technologies that can be done to increase the productivity of plants (Chakrabarty *et al.,* 2014). This is due to the availability of essential nutrients through improved soil capacity providing nutrients, as well as improved physical and biological properties of soil after fertilizer. Potassium (K) is one element in the fertilizer, as it plays an important role in regulating the availability of other nutrients, stimulating the process of photosynthesis and plant growth, assisting in the process of photosynthate distribution, becoming a catalyst in protein synthesis, and improving crop quality. Potassium fertilizer is easy to decompose and very mobile in the ground. Most bean

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crops, one of which is soybean, require high amounts of potassium, so it will be greatly affected if there is a deficiency of potassium. The deficiency of K element can cause a decrease in the number of leaves and leaf size. This may lead to a reduction in photosynthetic rate which affects the reduced amount of assimilate produced, which may interfere with plant growth (Pettigrew, 2008).

Spacing is also one of the important parameters, which ultimately affects the nutrients uptake, growth and yield of plant. Increase in spacing, the total population decrease, but with more nutrition the individual plant grows better and get more yield and vice-versa. The increase or decrease of row spacing's and plant population has definite pattern in relation to the yield. In these simultaneous opposing effects of the two components there should be a point where maximum yield is expected and that should be at the optimum spacing. Among various agronomic yield limiting factors, planting pattern is considered of great importance. (Keisham *et. al.,* 2021).

Application of fertilizers / nutrients specially potassium in proper amount can help to increase nutrient use efficiency and maintaining the optimum spacing in soybean can help to utilize the resources such as nutrient, water, sunlight, etc. Thus, increasing growth and yield of soybean. Keeping the above points in view, a research work entitled "Response of soybean (*Glycine max.* L.) to potassium fertilizer under different crop geometry." was conducted.

**MATERIAL AND METHODS**

The field experiment was conducted at experimental cum demonstration field, SVIAG, SVVV Indore during 2023. The experimental plot had a plain topography. In view to know the initial fertility status of the soil, representative and composite soil samples were collected from experimental site from 0-30 cm depth randomly from five different locations. The soil samples were analysed in departmental laboratory by using standard analytical methods for determination of soil physical and chemical properties of soil. The soil was medium black clay in texture with low in available nitrogen (209 kg $ha^{-1}$), medium in phosphorus (14.65 kg $ha^{-1}$) and high in potassium (453.12 kg $ha^{-1}$). The soil organic carbon content, pH, and EC was 0.52 %, 7.25 %, and 0.74 $dSm^{-1}$, respectively.

The experiment consists of twelve treatment combinations with three main plot treatment (crop geometry) and four sub-plot treatments (potassium levels). The treatments were replicated three times in split plot design. The field was divided into 36 plots with gross plot

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size of 4.0 m x 3.0 m. The details of the treatment and symbols used during research work are presented in Table 1.

**Table 1. Details of treatment and symbols used**

| Sr. No. | Treatments | Symbol |
|---|---|---|
| **A.** | **Main plot treatment (crop geometry)** | |
| 1. | 30 cm x 20 cm | $C_1$ |
| 2. | 40 cm x 15 cm | $C_2$ |
| 3. | 60 cm x 10 cm | $C_3$ |
| **B.** | **Sub plot treatment (Potassium levels)** | |
| 1. | 0 kg $K_2O$ $ha^{-1}$ | $K_1$ |
| 2. | 20 kg $K_2O$ $ha^{-1}$ | $K_2$ |
| 3. | 40 kg $K_2O$ $ha^{-1}$ | $K_3$ |
| 4. | 60 kg $K_2O$ $ha^{-1}$ | $K_4$ |

Recommended dose of fertilizer 20:40 kg N: $P_2O_5$ $ha^{-1}$ and doses of $K_2O$ as per the treatment was applied at the time of sowing to soybean. The truthful seed of soybean (Cv. JS-9560) was obtained from seed sale unit, Jawaharlal Neharu Krishi Vishwavidyalaya, Jabalpur and treated with *Rhizobium japonicum* before sowing. The line sowing was done under different crop geometry.

The various biometric observations were recorded on five randomly selected plants from each net plot. The selected plants were tied with tags for their easy identification. All the biometric observations were recorded at 15 days interval commencing from 30 after sowing up to harvest. The same plants were harvested separately for generating data on yield attributes. At physiological maturity stage, initially all border rows from each gross plot were harvested separately and thereafter the remaining plots were harvested as net plot produce. Harvesting of soybean was done manually by cutting plants at their base with sickle and harvested produce was kept for drying for 2 days. The sundried soybean plants were threshed by beating the pods. Then seed and straw yield were separated by winnowing and weighed separately. Thus, plot-wise yields obtained were tabulated, analyzed, and interpreted in experimental result.

The standard method of analysis of variance was used for analyzing the data for Randomized Block Design (Panse and Sukhatme,1985). The f test of significance was used for testing the null hypothesis and appropriate standard error of mean (SE$\pm$) for each treatment

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effect and where the treatment effect was significant, critical difference (C.D.) at 5 per cent probability level was worked out for testing the significance of treatment differences.

## RESULT AND DISCUSSION

### Effect of crop geometry

### Growth studies

As per the data presented in table 2, the crop geometry of 30 cm x 20 cm has shown noticeably greater growth characters such as., plant height (40.92 cm), number of branches plant$^{-1}$ (10.66), number of functional leaves (27.18) plant$^{-1}$, leaf area plant$^{-1}$ (12.64 dm$^{2}$) at 60 DAS, number of root nodules plant$^{-1}$ (54.91) at flowering whereas, dry matter accumulation plant$^{-1}$ (22.64 g) at harvest. The lowest growth characters viz. plant height (36.00 cm), number of branches plant$^{-1}$ (7.94), number of functional leaves (22.74) plant$^{-1}$, leaf area plant$^{-1}$ (9.60 dm$^{2}$) at 60 DAS, number of root nodules plant$^{-1}$ (51.53) at flowering and dry matter accumulation plant$^{-1}$ (18.14 g) at harvest was recorded under treatment 60 cm x 10 cm.

The increased plant height may be due to factors explaining increased plant height in higher plant densities due to reduced inter-row spacing influenced light quantity and quality. The higher plant density can lead to increased competition for sunlight, water, and nutrients. As a response to this competition, soybean plants may produce more branches to increase their leaf area and maximize light capture. Higher density can also lead to change in the levels of hormones such as auxins and cytokinin, which regulate leaf growth and development. These hormonal changes can promote the formation of more leaves in densely planted condition. These results are close conformity with the findings of Khan *et al.,* (2015), Rahman *et al.,* (2013), Singh (2011), Mondal *et al*., (2014), Anusha *et al.,* (2021) and Durga *et al.,* (2018).

The increase in total dry matter plant$^{-1}$ could be due to a balance between plant density, air circulation and resources competition resulting in higher total dry matter production. Similar results were recorded by Sharma 2011 and Mondal *et al*., (2014).

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**Table 2. Growth attributes of soybean as influenced by different treatments.**

| Treatment | Growth attributes | | | | | |
|---|---|---|---|---|---|---|
| | **Plant height (cm)** | **Number of branches plant$^{-1}$** | **Number of functional leaves plant$^{-1}$** | **Leaf area ($dm^2$) plant$^{-1}$** | **Number of root nodules plant$^{-1}$** | **Dry matter (gm) plant$^{-1}$** |
| **A) Crop geometry** | | | | | | |
| $C_1$: 30 x 20 cm | 40.92 | 10.66 | 27.18 | 12.64 | 54.91 | 22.64 |
| $C_2$: 40 x 15 cm | 38.92 | 9.80 | 25.21 | 11.85 | 53.48 | 20.81 |
| $C_3$: 60 x 10 cm | 36.00 | 7.94 | 22.74 | 9.60 | 51.53 | 18.14 |
| S. Em. ± | 0.72 | 0.38 | 0.68 | 0.59 | 0.53 | 0.76 |
| CD at 5% | 2.11 | 1.11 | 1.98 | 1.71 | 1.56 | 2.22 |
| **B) Potassium level** | | | | | | |
| $K_1$: 00 kg ha$^{-1}$ | 33.78 | 8.10 | 22.84 | 9.74 | 50.32 | 17.69 |
| $K_2$: 20 kg ha$^{-1}$ | 37.22 | 8.61 | 23.87 | 10.49 | 52.91 | 19.52 |
| $K_3$: 40 kg ha$^{-1}$ | 40.22 | 9.86 | 26.04 | 12.41 | 53.90 | 21.79 |
| $K_4$: 60 kg ha$^{-1}$ | 43.22 | 11.30 | 27.42 | 12.82 | 56.10 | 23.13 |
| S. Em. ± | 1.13 | 0.54 | 0.74 | 0.75 | 0.78 | 0.87 |
| CD at 5% | 3.28 | 1.58 | 2.17 | 2.19 | 2.28 | 2.54 |
| **C) Interaction effect** | | | | | | |
| **C x K** | NS | NS | NS | NS | NS | NS |
| **General mean** | **38.61** | **9.47** | **25.04** | **11.36** | **53.31** | **20.53** |

**Yield studies**

The data related to yield attributes and yield is presented in table 3. In a similar vein of growth parameters, noticeably higher yield contributing character such as number of pods (37.48) plant$^{-1}$, number of seeds pods$^{-1}$ (2.68), and number of seeds plant$^{-1}$ (100.88), was recorded in treatment 30 cm x 20 cm. Whereas, the minimum number of pods (29.35) plant$^{-1}$, number of seeds pods$^{-1}$ (2.55), and number of seeds plant$^{-1}$ (90.15), was recorded under treatment 60 cm x 10 cm.

The highest seed yield (15.67 q ha$^{-1}$), straw yield (24.01 q ha$^{-1}$), and biological yield (39.68 q ha$^{-1}$) at harvest was observed under crop geometry of 30 cm x 20 cm as compared to rest of the crop geometries.

The increase in yield attributes could be due to more favourable growing environment for soybean plants, allowing for reduced competition, better light interception, improved

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nutrient and water uptake, enhanced air circulation, and healthier root development. The plant geometry of 30 x 20 cm spacing result in reduced plant stress. Lower stress allows the plants to allocate more resources to seed production rather than survival. Similar results were reported by Durga *et al.,* (2018).

Test weight was not influenced significantly due to different crop geometry treatment at harvest.

The seed yield is the chain reaction of growth parameter and yield attributing characters. During the experiment 30 x 20 cm spacing recorded higher values of reproductive parameter of individual plants over other spacing resulting in higher values for seed yield. Increase in dry matter accumulation might result in increase in straw yield. The increase in biological yield could be attributed due to better plant development in more uniform distribution of plants. Similar results were reported by Durga *et al.,* (2018).

**Table 3. Yield attributes and yield of soybean as influenced by different treatments.**

| **Treatment** | **Yield attributes and yield.** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Number of pods plant$^{-1}$** | **No. of seeds pod$^{-1}$** | **No. of seeds plant$^{-1}$** | **Test weight** | **Seed yield q ha$^{-1}$** | **Straw yield q ha$^{-1}$** | **Biological yield q ha$^{-1}$** |
| **A) Crop geometry** | | | | | | | |
| $C_1$: 30 x 20 cm | 37.48 | 2.68 | 100.88 | 107.95 | 15.67 | 24.01 | 39.68 |
| $C_2$: 40 x 15 cm | 35.92 | 2.64 | 98.53 | 106.67 | 14.07 | 22.79 | 36.87 |
| $C_3$: 60 x 10 cm | 29.35 | 2.55 | 90.15 | 105.73 | 11.33 | 19.06 | 30.39 |
| S. Em. $\pm$ | 0.69 | 0.05 | 0.84 | 0.63 | 0.61 | 0.46 | 0.98 |
| CD at 5% | 2.03 | NS | 2.46 | NS | 1.79 | 1.34 | 2.87 |
| **B) Potassium level** | | | | | | | |
| $K_1$: 00 kg ha$^{-1}$ | 31.86 | 2.52 | 90.23 | 105.17 | 10.94 | 18.85 | 29.79 |
| $K_2$: 20 kg ha$^{-1}$ | 33.20 | 2.61 | 93.81 | 106.10 | 12.47 | 21.46 | 33.92 |
| $K_3$: 40 kg ha$^{-1}$ | 35.06 | 2.66 | 98.99 | 107.41 | 15.02 | 22.94 | 37.96 |
| $K_4$: 60 kg ha$^{-1}$ | 36.88 | 2.69 | 103.05 | 108.46 | 16.34 | 24.57 | 40.91 |
| S. Em. $\pm$ | 0.83 | 0.06 | 1.91 | 1.07 | 0.72 | 0.87 | 1.52 |
| CD at 5% | 2.44 | NS | 5.58 | NS | 2.09 | 2.54 | 4.45 |
| **C) Interaction effect** | | | | | | | |
| **C x K** | NS | NS | NS | NS | Sig. | Sig. | Sig. |
| **General mean** | 34.25 | **2.62** | **96.52** | **106.78** | **13.69** | **21.96** | **35.65** |

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**Table 3.a. Interaction effect between crop geometry and potassium levels on seed yield of soybean**

| Crop geometry (C) / Potassium levels (k) | Seed yield ($q\ ha^{-1}$) | | | |
|---|---|---|---|---|
| | $C_1$: 30 x 20 $cm^2$ | $C_2$: 40 x 15 $cm^2$ | $C_3$: 60 x 10 $cm^2$ | Mean |
| $K_1$: OO kg per ha | 12.07 | 11.69 | 9.05 | 10.94 |
| $K_2$: 2O kg per ha | 12.82 | 14.40 | 10.18 | 12.47 |
| $K_3$: 4O kg per ha | 13.27 | 18.14 | 13.65 | 15.02 |
| $K_4$: 6O kg per ha | 24.51 | 12.07 | 12.44 | 16.34 |
| Mean | 15.67 | 14.07 | 11.33 | |
| **Source** | | **S. Em (±)** | **CD at 5%** | |
| Between two sub plots means at the same level of main plot means | | 1.24 | 3.62 | |
| Between two main plots means at the same level of sub plot means | | 1.16 | 3.38 | |

**Table 3.b. Interaction effect between crop geometry and potassium levels on straw yield of soybean**

| Crop geometry (C) / Potassium levels (k) | Straw yield ($q\ ha^{-1}$) | | | |
|---|---|---|---|---|
| | $C_1$: 30 x 20 $cm^2$ | $C_2$: 40 x 15 $cm^2$ | $C_3$: 60 x 10 $cm^2$ | Mean |
| $K_1$: OO kg per ha | 19.98 | 20.36 | 16.21 | 18.85 |
| $K_2$: 2O kg per ha | 21.49 | 24.77 | 18.10 | 21.46 |
| $K_3$: 4O kg per ha | 21.19 | 26.06 | 21.57 | 22.94 |
| $K_4$: 6O kg per ha | 33.37 | 19.98 | 20.36 | 24.57 |
| Mean | 24.01 | 22.79 | 19.06 | |
| **Source** | | **S. Em (±)** | **CD at 5%** | |
| Between two sub plots means at the same level of main plot means | | 1.50 | 4.39 | |
| Between two main plots means at the same level of sub plot means | | 1.02 | 2.98 | |

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**Table 3.c. Interaction effect between crop geometry and potassium levels on biological yield of soybean**

| Crop geometry (C) / Potassium levels (k) | Biological yield (q ha$^{-1}$) | | | |
|---|---|---|---|---|
| | $C_1$: 30 x 20 cm$^2$ | $C_2$: 40 x 15 cm$^2$ | $C_3$: 60 x 10 cm$^2$ | Mean |
| $K_1$: OO kg per ha | 32.05 | 32.05 | 25.26 | 29.79 |
| $K_2$: 2O kg per ha | 34.31 | 39.18 | 28.28 | 33.92 |
| $K_3$: 4O kg per ha | 34.46 | 44.19 | 35.22 | 37.96 |
| $K_4$: 6O kg per ha | 57.88 | 32.05 | 32.81 | 40.19 |
| Mean | 39.68 | 36.87 | 30.39 | |
| **Source** | | **S. Em (±)** | **CD at 5%** | |
| Between two sub plots means at the same level of main plot means | | 2.64 | 7.71 | |
| Between two main plots means at the same level of sub plot means | | 1.44 | 4.22 | |

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**Economic studies**

Significantly higher gross monetary returns (₹ 78337.10 ha$^{-1}$) and net monetary returns (₹ 33714.05 ha$^{-1}$) of soybean were obtained under crop geometry 30 cm x 20 cm than rest of treatments with higher B:C ratio (1.72), while lowest gross monetary returns (₹ 56655.35 ha$^{-1}$) and net monetary returns (₹ 15180.72 ha$^{-1}$) of soybean were obtained under crop geometry 60 cm x 10 cm with B:C ratio of (1.36).

Higher gross monetary returns might have resulted in maximum net monetary returns for soybean crop for the treatment of 30 cm x 20 cm. Also, the higher yield per unit area is directly contributed to increase in net monetary return. These result are in confirmity with finding of Rajeshkumar *et al.,* (2017) and Karwal *et al.,* (2023). Higher gross monetary returns and net monetary returns for soybean crop might have resulted in maximum B: C ratio.

**Table 4. Economics of soybean as influenced by different treatments**

| Treatments | Gross | Cost of cultivation | Net monetary returns | B:C ratio |
|---|---|---|---|---|

| | monetary returns (₹ ha$^{-1}$) | (₹ ha$^{-1}$) | (₹ ha$^{-1}$) | |
|---|---|---|---|---|
| **A) Crop geometry** | | | | |
| $C_1$: 30 x 20 cm | 78337.10 | 44623.05 | 33714.05 | 1.72 |
| $C_2$: 40 x 15 cm | 70371.42 | 43760.64 | 26610.77 | 1.60 |
| $C_3$: 60 x 10 cm | 56655.35 | 41474.63 | 15180.72 | 1.36 |
| S. Em. ± | 3067.47 | -- | 3067.47 | -- |
| CD at 5% | 8953.75 | -- | 8953.75 | -- |
| **B) Potassium level** | | | | |
| $K_1$: 00 kg per ha | 54675.72 | 38924.50 | 15751.22 | 1.40 |
| $K_2$: 20 kg per ha | 62342.89 | 41889.19 | 20453.69 | 1.48 |
| $K_3$: 40 kg per ha | 75100.55 | 45082.03 | 30018.52 | 1.66 |
| $K_4$: 60 kg per ha | 81699.35 | 47248.71 | 34450.64 | 1.69 |
| S. Em. ± | 3584.59 | -- | 3584.59 | -- |
| CD at 5% | 10463.192 | -- | 10463.19 | -- |
| **C) Interaction effect** | | | | |
| **C x K** | NS | NS | NS | NS |
| **General mean** | 68454.63 | 43286.11 | 25168.52 | 1.56 |

**Effect of potassium levels**

**Growth studies**

Application of 60 kg $K_2O$ ha$^{-1}$ was recorded significantly higher growth parameters of soybean such as, plant height (43.22 cm) at harvest, number of branches (11.30) plant$^{-1}$, number of functional leaves (27.42) plant$^{-1}$, leaf area (12.82 dm$^2$) plant$^{-1}$ at 60 DAS, number of root nodules plants$^{-1}$ (56.10) at flowering, dry matter accumulation plant$^{-1}$ (23.13 g) at harvest. The lowest growth characters *viz*. plant height (33.78 cm) at harvest, number of branches (8.10) plant$^{-1}$ at harvest, number of functional leaves (22.84) plant$^{-1}$, leaf area (9.74 dm$^2$) plant$^{-1}$ at 60 DAS, number of root nodules plants$^{-1}$ (50.32) at flowering, and , dry matter accumulation plant$^{-1}$ (17.69 g), dry weight of root nodules (0.972 g) at 75 DAS was recorded under treatment 0 kg $K_2O$ ha$^{-1}$.

The use of larger dose of potash in these treatments may be the cause of the rise in soybean height. The higher potassium level likely provides Potash is known to augment cell division and cell expansion by providing more favourable environment for the plants physiological processes, leading to increased growth attributes of soybean. The growth in total

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dry matter accumulation can be partially ascribed to the beneficial effect of potash fertilization. The phenomenon could be attributed to increased photosynthetic activity, which is subsequently followed by the effective transfer of metabolites and their accumulation. These results are close conformity with Thesiya *et al.,* (2012), Dixit *et al.* (2011) and Sherawat and Singh (2009).

**Yield studies**

The potassium level 60 kg $ha^{-1}$ recorded significantly highest number of pods (36.88) $plant^{-1}$, number of seeds $pods^{-1}$ (2.69) and number of seeds $plants^{-1}$ (103.05), as compared to other potassium levels. Whereas, minimum number of pods (31.86) $plant^{-1}$, number of seeds $pods^{-1}$ (2.52) and number of seeds $plants^{-1}$ (90.23) was recorded in treatment 0 kg $K_2O$ $ha^{-1}$.

Amongst the potassium levels 60 kg $K_2O$ $ha^{-1}$ recorded significantly higher seed yield (16.34 q $ha^{-1}$), straw yield (24.57 q $ha^{-1}$) and biological yield (40.91 q $ha^{-1}$) in contrast to the other potassium level. While lowest seed yield (10.94 q $ha^{-1}$), straw yield (18.85 q $ha^{-1}$) and biological yield (29.79 q $ha^{-1}$) was noticed under treatment 0 kg $K_2O$ $ha^{-1}$.

Test weight of soybean was not influenced significantly due to different potassium levels at harvest.

Increase in number of pods could be attributed to the fact that potassium plays a significant role in photosynthesis by regulating the opening and closing of stomata, the pores on leaves that control gas exchange. Adequate potassium ensures better carbon dioxide uptake thus more efficient photosynthesis, providing more energy for pod formation. Potassium enhances various physiological processes in plants, including photosynthesis, nutrient transport, and stress resistance. These improvements contribute to better pod and seed development, ultimately leading to an increased number of seeds $pod^{-1}$. Similar results were reported by kjam *et al.,* (2023) and Thesia *et al.,* (2013).

By providing 60 kg of potassium, plants receive a more optimal nutrient balance, which can result in improved growth conditions and higher seed yield. Similar results were described by Mali *et.al.,* (2017) and Farhad *et al.,* (2010) with the increase in potassium level yield of crop also increase.

The increase in biological yield with the increase in potassium level may be due to the positive effect of K on crop yield might also be requirement in carbohydrate synthesis and

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translocation of photosynthesis and may be due to improved yield attributing characters, shoot growth and nodulation. Similar results were reported by Chaudhari *et al.,* (2018).

**Economic studies**

Significantly higher gross monetary returns (₹ 81699.35 $ha^{-1}$) and net monetary returns (₹ 34450.64 $ha^{-1}$) of soybean were obtained under in treatment 60 kg $K_2O$ $ha^{-1}$ than rest of treatments with higher B:C ratio (1.69), while lowest gross monetary returns (₹ 54675.32 $ha^{-1}$) and net monetary returns (₹ 15751.22 $ha^{-1}$) of soybean were obtained under 60 kg $K_2O$ $ha^{-1}$ with B:C ratio of (1.40).

Higher gross monetary returns and net monetary returns for soybean crop might have resulted in maximum B: C ratio. These result are in confirmity with finding of Karwal *et al.,*(2023).

**Interaction effects of crop geometry and potassium levels**

The interaction effects between crop geometry and potassium levels in relation to growth attributes, yield attributes and economics was found to be non-significant. The interaction effects between crop geometry and potassium levels on seed yield, straw yield and biological yield was found to be significant. Sowing of soybean at 30 cm x 20 cm along with 60 kg K2O $ha^{-1}$ recorded highest seed yield, straw yield and biological yield as compared to rest of the treatment combination.

**CONCLUSION**

Based on experimentation, it could be concluded that sowing at 30 cm x 20 cm along with application of 60 kg potassium $ha^{-1}$ registered maximum growth, yield attributes, yield and quality parameters of soybean. The spacing 30 cm x 20 cm proved to be the most effective among the different spacing for obtaining higher net monetary returns, gross monetary returns and B:C ratio. On the other hand, it was discovered that application of 60 kg $K_2O$ $ha^{-1}$ was more remunerative.

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