Impact of Planting Geometry and Phosphorus Levels on Summer Moong Vigna Radiata L. Growth and Yield

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Abstract

Pulses are a "smart food" because they provide a substantial amount of plant protein and help combat obesity, diabetes, and associated illnesses. Greengram, sometimes called "Moongbean" or "moong," is an excellent source of phosphorus and iron and has 24.5% protein. It also contains 57%-58% carbohydrates, as well as trace levels of riboflavin and thiamine. Here, we examine how different angles of planting and different phosphorus concentrations affect the growth and yield of Vigna radiata L. var. summer moong.

Keywords: Pulses, Planting, Phosphorus, Growth, Agriculture, Geometry.

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1. Introduction

Growing pulses on a total of 28.83 mha results in an annual harvest of 25.72 million metric tonnes. The moongbean is the third most popular kind of pulse after the chickpea and the pigeonpea. It is harvested at a rate of 26.20 million metric tonnes from a total of 41.63 million acres of land. Rajasthan, Madhya Pradesh, Uttar Pradesh, Orissa, Maharashtra, Karnataka, and Bihar are among the top mungbean-producing states in India. Mung beans were grown on 4.5 million ha in 2020–21, producing 2.5 million tonnes at an average productivity of 5.48 qph. Summertime is peak Mung bean growing season in the state.[1-2]

Pulses are also low-maintenance, resistant to drought, and increase soil fertility by fixing nitrogen. Therefore, pulses may help the world's future food, protein, and sustainability needs. It is grown as a monocrop, in a rotation, or as an intercrop during the kharif and summer seasons when there is an abundance of water. Moongbean is a day-neutral warm season crop that thrives in the semiarid to subhumid tropical climates. This annual crop matures in 90-120 days and is often planted in a rotating system with cereals. Mungbean, like soybean, is a tropical rain-fed crop that can withstand dry conditions. [3-4]

In addition to mungbean, other legumes that fall under the umbrella name "pulse crops" include drybean (Phaseolus vulgaris L.), lima or butterbean (Phaseolus lunatus L.), broadbean (Vicia faba L.) and garden pea (Pisum sativum L.). The chickpea (Cicer arietinum L.), lentil (Lens culinaris Medik.), pigeonpea (Cajanus cajan (L.) Millsp.), cowpea (Vigna unguiculata (L.) Walp.), black gramme (Vigna mungo (L.) Hepper), and adzuki bean (Vigna angularis (Willd. Mungbean and other pulse crops are examples of grain legumes. The health of plant populations and summer moong go hand in hand. Both the distance between rows and the distance between plants inside a row impact the overall plant density in a given space. The best plant spacing simplifies field operations like fertiliser supply and weed control, while also promoting healthy competition for light, water, and nutrients. The low average yield of mungbean in farmer's fields in India is mostly caused by the adoption of a low seed rate and poor agronomic practises, such as inter-row spacing.[5-6]

Incorrect plant spacing may lead to inadequate light for photosynthesis and a high frequency of diseases, both of which are detrimental to a successful harvest. On the other hand, a low plant population density will also reduce output. Thus, a healthy population is crucial for productive levels. Due to light no longer being a limiting factor in arid circumstances, the advantages of regular spacing are nullified. It's the most crucial variable outside cash investment if you want to optimise output per unit area.[7-8]

Several plant molecules rely on phosphorus for their function, and this includes nucleoproteins, phospholipids, and enzymes. The cell's ability to store and release energy relies on phosphorus. It promotes plant growth, especially the roots, and helps plants fight disease-causing organisms. It also helps in the synthesis and transport of carbohydrates. It is mostly located in the rapidly replicating cells of the seed, called meristems. Stunted plants, due to a shortage of phosphorus, will have dark green leaves that fade, become blotchy, and lack protein. [9-10]

2. Material And Methods

Experimental site:

The study was carried out at the Acharya Narendra Deva University of Agriculture & Technology at Kumarganj, Ayodhya, (UP), during the Zaid season of 2020-21. The university's main campus serves as the experimental site, which is located 42 kilometres from the Ayodhya district headquarters on the Ayodhya-Raebareli road at 260.47 degrees north latitude, 82.12 degrees east longitude, and 113.3 metres above mean sea level.

Soil of experimental field:

The testing area was flat and had enough drainage. Before the soil fertility treatments were implemented, composite soil samples were taken from the top 30 centimetres of the ground for physico-chemical examination. In Table, we can see the specifics of the soil's qualities.The texture of the soil in the experimental field was determined to be silty loam by testing. The pH of the soil was only slightly alkaline, and it had a medium level of organic carbon and fertility.

Table 1: Soil physicochemical characteristics at the outset of the study:

S.N	Soil properties	Value obtained
A	**Physical properties**	
I	Sand (%)	27.11
II	Silt (%)	55.78
III	Clay (%)	17.62
IV	Textural classes	Silty loam
B	**Chemical properties**	
I	Soil pH & Soil water ratio (1:2.5)	8.3
II	EC (dS m-1) & soil water ratio (1:2.5)	0.25
III	Organic carbon (%)	0.38
IV	Available N (kg ha-1)	166.00
V	Available P (kg ha-1)	17.05
VI	Available K (kg ha-1)	279.80

Soil testing revealed that the soil in the experimental plot was a ''silty loam,'' with a medium phosphorus and potassium content and low levels of organic carbon and accessible nitrogen.

Description of varietyNDM-1

From Ayodhya's Acharya Narendra Deva University of Agriculture and Technology in Kumarganj, 1992 comes this publication. It can withstand the cold of winter and the heat of summer, making it ideal for the spring and Kharif seasons. The following is a list of highlighted details.

Duration	:	65-70 days
Test weight	:	34-36 (g)
Protein content (%)	:	25 %
Yield	:	10-12 q/ ha
Recommended for inter cropping	:	Pigeon pea and sugarcane

Parameters for development

- **Plant density at planting (m-2):**

At 20 days after sowing, the total number of plants in each treatment was counted from three predetermined sites within each plot, averaged, and then represented as a number of plants per square metre.

- **Plant heights (cm) :**

From the soil up to the very top of the plant, that's how high it was measured to be. Five randomly chosen plants were tagged from each plot and measured at the 25, 50, and harvest intervals. Inches were used to measure the height.

- **Leaf area index:**

The leaf area index (L.A.I.) was measured at 25 and 50 DAS of the crop. To calculate the leaf area index (L.A.I.), five leaves were selected randomly from the sample plants. The length and maximum width of each of the leaf was measured. The area covered by the leaf was worked out and the total surface area of leaves per plant was calculated by counting the leaves per plant and multiplying it by average leaf area (Watson, 1958). The leaf area index (L.A.I.) was calculated by following formula:

$$\text{L. A. I.} = \frac{\text{Leaf area}}{\text{Ground area}}$$

Importance of dry matter buildup (g m-2)

- **The average plot had a dry matter buildup of 25 grammes per metre of row length.**

50 DAS and at harvest, one metre of each row's worth of plants were removed at random. The samples were root-trimmed and then air-dried for 48 hours. The samples were then weighed before and after being baked in a hot air oven at 700C 10C for 72 hours. Treatment-specific dry matter yield was reported in kilogrammes per hectare.

Yield attributes

- **The Average Pod Production Per Plant:**

The average number of pods per plant was determined by tallying the total number of pods on the five plants used in the research.

- **Number of grains per pod:**

The average number of grains per pod was calculated from the counts of ten randomly chosen pods from each of five tagged plants.

- **Test weight (g)**

Each plot had random samples taken from the cleaned grains, and the weight of 1000 grains was recorded in grammes using an electronic scale.

Yield

- **Biological yield (q ha^{-1})**

We measured the biological yield in units of (q ha-1) by weighing the unharvested product from the net plot area after sun drying.

Biological yield = Grain yield + Straw yield

- **Grain yield (q ha^{-1})**

The gathered plants were left out in the sun to dry, and then they were threshed by hand. Using a moisture metre, we determined the moisture content of 100 g samples from each treatment, and then we normalised the measured yield to 14% moisture. In order to convert net plot yield into q ha-1, grains were winnowed, washed, and weighed.

- **Harvest index (%)**

Harvest index, measured in percentage, is the proportion of total harvest that consists of grain (economic yield). This formula was used to get the harvest index value. The harvest index is the economic yield expressed as a fraction of the biological output.

$$\text{Harvest index (\%)} = \frac{\text{Economic yield q ha}^{-1}}{\text{Biological yield q ha}^{-1}} \times 100$$

Quality

- **Protein in grain (%) :**

When calculating the protein content of grain, nitrogen is multiplied by a factor of 6.25.

- **Protein in straw (%)**

To calculate the protein composition of straw, we multiply its nitrogen content by a factor of 6.25.

- **Protein yield (kg ha^{-1}):**

The percentage of protein yield is the result of dividing the total protein content by the total grain yield.

Statistical analysis:

The statistical tabulation and analysis of the experimental data acquired over the course of the inquiry allowed for the formation of a reliable conclusion. Standard "Analysis of Variance" (ANOVA) methodology, as outlined by Gomez and Gomez (1984), was used to analyse the data. The 'F' test (Variance ratio) was used to examine the statistical significance of treatments. The mean and the standard deviation were also calculated. Significant difference (sd) was used at the 5% probability level when the 'F' test indicated a statistically significant difference between groups' means, as calculated as follows:

$$\mathbf{sd} = \sqrt{\frac{2\times\text{error mean sum of square}}{N}} \times t\ (\text{error d.f. } 5\%)$$

3. Results

Growth Characters

- **Initial Plant Population:**

Table show the recorded statistics for the initial plant population of summer moong. According to the data, the initial plant population was highest in the 30 cm 10 cm planting geometry, followed by the 30 cm 15 cm and 30 cm 20 cm planting geometries.

Since a higher plant population per unit area is the result of a closer planting geometry, the competition among plants for nutrients, space, and light was found to be greater in the 30 cm 10 cm planting geometry compared to the wider 30 cm 15 cm and 30 cm 20 cm planting geometries. The 30 cm 10 cm planting geometry was documented by Singh and Singh (2021).

Up to 40 kg/ha, the current research found no statistically significant effect of phosphorus on population growth from the first count. Up to 40 kg/ha of phosphorus, the effect on summer moong's initial plant population did not grow noticeably. Application of 60 kg/ha of phosphorus was found to be distinct from the other treatments, to the benefit of green gramme production, by Singh and Singh (2021).

There was no statistically significant interaction impact seen on the number of seedlings planted. However, a 40 Kg/ha phosphorus dose and a 30 cm 10 cm planting geometry produced the highest initial plant population. Initial plant density was lowest at 30 cm 20 cm planting geometry with no phosphorus added.

- **Plant Height:**

Table show the results of several treatments in terms of plant height at 25, 50 DAS and harvesting stage. Data analysis revealed that planting at geometry of 30 cm 10 cm resulted in considerably taller plants at 25, 50 DAS, and the harvesting stage compared to planting at a geometry of 30 cm 15 cm and 30 cm 20 cm.

There was a lot of competition for nutrients, solar energy, light, and space, thus the plants in the 30 cm 10 cm planting geometry grew substantially taller than those in the 30 cm 15 cm and 30 cm 20 cm planting geometries. Similar findings on the impact of planting geometry were reported by Hangsing et al. (2020). However, at 25 DAS, both the 30 cm 15 cm and 30 cm 20 cm planting geometries were found to be equivalent, as were the 30 cm 10 cm and 30 cm 15 cm harvesting geometries. At 50 DAS, when the crop was ready for harvest, the smallest plants measured only 30 by 20 centimetres.

There was a noticeable difference in plant height between the 25, 50, and harvest stages when phosphorus levels rose from 0 to 60 kg/ha. At 60 kg P2O5/ha, maximum plant height was observed, which was much better than the remainder of the treatment throughout crop development, while at harvest, it was determined to be on par with 40 kg P2O5/ha. The control treatment resulted in the shortest plants (36.10 cm) compared to the other treatments.

Although the effect of phosphorus levels on the initial plant height of summer moong increased significantly up to 40 kg/ha, applying 60 kg/ha is optimal because greengram is a heavy feeder of phosphorus, which promotes growth, governs physiochemical processes, and enhances the availability of nutrients.

In the current field research, an interaction impact on plant height was not detected. However, 30 cm 10 cm planting geometry and 60 Kg/ha quantity of phosphorus were similarly detected to produce the tallest plants at 25, 50 DAS, and the harvesting stage. When using a 30 cm 20 cm planting geometry and a control amount of applied phosphorus, the smallest plant heights were seen across the board.

Table 2: Initial plant population (m-2) and plant height at various phases of summer moong development as a function of planting geometry and phosphorus levels

Treatments	Initial plant population (m^{-2}) (20 DAS)	Plant height(cm)		
Planting geometry		25 DAS	50 DAS	Harvesting stage
30 cm × 10 cm	31.00	23.60	39.65	43.05
30 cm × 15 cm	20.50	22.25	37.10	41.7
30 cm × 20 cm	15.75	21.95	35.05	38.25

SEm±	**0.554**	**0.435**	**0.435**	**0.919**
CD at 5%	**1.626**	**1.276**	**1.276**	**2.694**
Phosphorus Levels (kg/ha.)				
0	21.67	16.03	28.87	36.10
20	22.33	21.50	35.53	39.10
40	23.00	25.83	41.03	44.10
60	22.67	27.43	43.63	44.70
SEm±	**0.64**	**0.502**	**0.706**	**1.061**
CD at 5%	**N.S.**	**1.473**	**2.070**	**3.111**

Dry matter accumulation (g/m^{-2}):

The data on dry matter accumulation (g/m^{-2}) as influenced by planting geometry and phosphorus levels have been presented in Table and the data on drymatter accumulation (g/m^{-2}) showed significant variation due to planting geometry at 25, 50 DAS and at harvesting stage whereas, planting geometry of 30 cm × 15 cm caused significant enhanced meant over other planting geometry, respectively.

The dry matter accumulation at all stages were also increased significantly under of 30 cm × 15 cm planting geometry due to the competition of plants for solar and soil energy was probably the minimum due to which individual plants were benefitted for the growth and development processes. **Kadam and Khanvilkar (2015)** also reported that higher dry matter accumulation at planting geometry of 30 cm × 15 cm over other treatments at different stages of crop growth.

However, the minimum dry matter accumulation was found under the plant geometry 30 cm × 20 cm over other at 25 DAS, 50 DAS and at harvest and found at parwith 30 cm × 10 cm.

The dry matter accumulation (g/m^{-2}) was significantly more with 60 Kg/ha levelof phosphorus at 25, 50 DAS and at harvesting stage, the application of 60 Kg/ha level of phosphorus increased significantly the dry matter over lower level of treatments.

By using different levels of phosphorus at 25 DAS, 50 DAS and at harvest the phosphorus level 60 kg/ha phosphorus level found at par with 40 kg/ha phosphoruslevel at 50 DAS and at harvest.

Dry matter accumulation at 25 DAS was found non–significant (not any significant effect was found). However, minimum dry matter accumulation at 25 DAS, 50 DAS and at harvest was recorded with treatment control. The effect of phosphorus level on dry matter accumulation increased significantly at all stages except 25 DAS in present trial because phosphorus controls physiochemical processes and aids in root growth to improve nutrition and moisture availability, which ultimately led to a higher number of branches.

Interaction effect of planting geometry and phosphorus levels was not found significant at any of the stages in the study year. However, the trend showed phosphorus response in 30 cm × 15 cm planting geometry more than other gThe effects of planting geometry and phosphorus levels on dry matter accumulation (g/m-2) are shown in Table. The data on dry matter accumulation (g/m-2) showed significant variation due to planting geometry at 25, 50 DAS, and at the harvesting stage, with a significantly enhanced mean for the 30 cm 15 cm planting geometry compared to the other planting geometries.

Even though the rivalry between plants for sun and soil energy was probably at its lowest under the 30 cm 15 cm planting geometry, the dry matter accumulation at all stages was greatly boosted. However, at 25 DAS, 50 DAS, and harvest, dry matter accumulation was lowest under the 30 cm 20 cm plant geometry compared to any other.

At both the 25-day after seeding (DAS) and 50-day after seeding (DAS) stages, as well as during harvest, dry matter accumulation (g/m-2) was considerably greater with the 60 Kg/ha level of phosphorus than with lower level treatments. Using phosphorus applications at 25, 50, and harvest, we observed that a 60 kg/ha phosphorus application at 25 DAS was equivalent to a 40 kg/ha phosphorus application at both 50 DAS and harvest.

There was no statistically significant increase in dry matter buildup by 25 DAS. However, treatment control showed the lowest dry matter accumulation at 25 DAS, 50 DAS, and harvest. Phosphorus controls physiochemical processes and aids in root growth to improve nutrition and moisture availability, leading to a higher number of branches and, thus, a greater effect of phosphorus level on dry matter accumulation at all stages except 25 DAS in the present trial.

At no point throughout the research year was there a statistically significant interaction impact between planting geometry and phosphorus levels. However, the trend revealed that 30 cm 15 cm planting geometry elicited a greater phosphorus response than any other geometry.

Table 3: Dry matter accumulation (g m-2) at various phases of development in summer moong as influenced by planting geometry and phosphorus levels

Treatments	**Dry matter accumulation**		
Planting geometry	**25 DAS**	**50 DAS**	**Harvesting stage**

30 cm × 10 cm	110.50	324.70	405.88
30 cm × 15 cm	115.50	350.80	438.50
30 cm × 20 cm	104.25	307.40	384.25
SEm±	**2.451**	**6.27**	**6.52**
CD at 5%	**7.189**	**18.389**	**19.123**
Phosphorus Levels (kg/ha.)			
0	108.27	270.67	338.33
20	109.67	306.67	383.33
40	110.67	364.53	455.67
60	111.73	368.67	460.83
SEm±	**2.830**	**7.240**	**7.529**
CD at 5%	**N.S.**	**21.233**	**22.081**

- **Leaf area index:**

The leaf area index at 25 and 50 DAS for each treatment is shown in Table. Upon closer inspection, it became evident that the leaf area index rose dramatically when planting geometry changed from 30 cm 10 cm to 30 cm 15 cm. At 25 and 50 days after sowing, substantial variations in summer moong crops were not established beyond a planting geometry of 30 cm 15 cm.

Significant increases in leaf area at 25 and 50 days after sowing were observed in the 30 cm 15 cm treatment, suggesting that this planting geometry was the minimum at which individual plants benefited from competition for solar and soil energy. Significantly 30 cm 10 cm gap was measured by Singh and Singh (2021). During 50 DAS of crop development, field experiments showed that applying 60 kg/ha of phosphorus considerably increased the leaf area index compared to other phosphorus levels and found at par with 40 kg/ha phosphorus level.

Phosphorus controls physiochemical reactions and aids in root growth to improve nutrition and moisture availability, ultimately leading to a higher leaf area index, but its effect is not noticeable until 50 days after sowing (DAS) in summer moong. The application of 60 kg/ha of phosphorus resulted in a considerable increase in Singh and Singh (2021) as compared to the other treatments. At 25 and 50 DAS, there were no significant variations in leaf area index between planting geometries and phosphorus levels.

Table 4: Changes in leaf area index during the summer moong crop as a function of planting orientation and phosphorus levels.

Treatments	Leaf area index	
Planting geometry	25 DAS	50 DAS
30 cm × 10 cm	1.10	2.70
30 cm × 15 cm	1.19	3.05
30 cm × 20 cm	1.16	2.93
SEm±	0.022	0.048
CD at 5%	0.065	0.141
Phosphorus Levels (kg/ha.)		
0	1.10	2.47
20	1.13	2.83
40	1.17	3.07
60	1.20	3.20
SEm±	0.026	0.056
CD at 5%	N.S	0.163

YIELD CHARACTERS

- **Number of pods/plant:**

Number of pods per plant data presented in Table showed that planting geometry significantly impacted pod yield. When field-testing several planting geometries, we found that a 30 cm 20 cm spacing between plants resulted in a much better pod yield per plant than a 30 cm 10 cm spacing between plants. Maximum pod yield (31.45) was observed at a planting geometry of 30 cm 20 cm, which was comparable to that of 30 cm 15 cm.

Further shown by the preceding chapter's findings is that a planting geometry of 30 cm 20 cm yielded a much higher total number of pods per plant than any other geometry tested. This was attributable to an increase in the number of pods per plant brought about by the increased interception of sunlight.

The highest pod yield per plant was achieved with a phosphorus application rate of 60 kg/ha, which was also shown to be comparable to rates of 40 kg/ha.

In contrast, the lowest pod yield (26.13) was found in the treatment with 0 kg/ha phosphorus level, followed by the treatment with 20 kg/ha phosphorus level in the field.

This beneficial effect of applied phosphorus could be attributed to the important role played by this element in promoting the plant's reproductive process, as both Yadav et al. (2017) and the present study found that the number of pods per plant increased after 60 kg/ha of phosphorus was applied instead of the control levels of 0 and 20 kg/ha.

There was no discernible change in total pod production as a result of the interaction impact of planting geometry and phosphorus levels. In this study, the number of pods per plant was lowest with a planting geometry of 30 cm 10 cm and 0 Kg/ha phosphorus, and it was greatest with a geometry of 30 cm 20 cm and 60 Kg/ha phosphorus.

- **Number of Grains/pod:**

From 30 cm 10 cm to 30 cm 20 cm, the number of seeds per pod grew steadily, and the largest number of seeds per pod was seen with 30 cm 15 cm planting geometry in the research year. In field experiments, the 30 cm 20 cm treatment yielded the same number of grains as the 30 cm 15 cm treatment. Better interception of sunlight also improves the quantity of grains per pod, and this is what we see in this experiment, where the effect is most pronounced at the 30 cm 15 cm planting geometry. The increased amount of grains per pod was reported by Singh and Singh (2021), who also noted the need of adequate spacing.

while compared to dosages of 0 and 20 kg/ha phosphorus, the number of grains per pod observed while using 40 kg/ha phosphorus was considerably higher; nevertheless, above the 60 Kg/ha level of phosphorus, statistically more seeds/pod were recorded. In the current experimental field, the number of pods per plant increased dramatically after the application of 40 kg/ha of phosphorus over 0 and 20 kg/ha levels, but this increase was not statistically significant at a higher dose of 60 kg/ha. Phosphorus plays an important role in the reproductive phase of plant growth.

Table 5: Summer moong yield characteristics as influenced by planting geometry and phosphorus levels

Treatments	No. of pods/plant	No. of Grains/pod
Planting geometry		
30 cm × 10 cm	28.45	6.33

30 cm × 15 cm	30.65	6.80
30 cm × 20 cm	31.45	6.98
SEm±	**0.646**	**0.112**
CD at 5%	**1.895**	**0.328**
Phosphorus Levels (kg/ha.)		
0	26.13	5.8
20	30.20	6.7
40	31.80	7.07
60	32.60	7.23
SEm±	**0.746**	**0.129**
CD at 5%	**2.189**	**0.378**

- **Grains/plant:**

Table provide data on the total number of seeds per plant and how they are affected by the planting geometry and phosphorus levels, respectively. The findings showed that in summer moong, the greater row spacing of 30 cm 20 cm yielded more grains per plant while not being statistically significant compared to the lower row spacing of 30 cm 10 cm.

Better interception of sunlight aids in increasing the quantity of grains per plant in the present experiment, which is why we chose a planting geometry of 30 cm 20 cm.

There was a considerable increase in summer moong yield in response to phosphorus treatment, but only up to a level of 40 kilogrammes per hectare. Application of 40 kg/ha of phosphorus resulted in a statistically significant increase in grain yield compared to application of 0 and 20 kg/ha, but the effect was not seen at the higher dosage of 60 kg/ha.

Variation in seed yield was shown to be significantly affected by the interplay between plant geometry and phosphorus levels.

- **Test weight (g):**

Data analysis showed that the weight of 1000 seeds rose similarly among treatments. It was determined statistically that a 30 cm 20 cm planting geometry yielded the best results. The results showed that wider planting geometries were statistically superior to narrow planting geometries in terms of test weight, likely because individual plants benefited the most from the test weight at this geometry when there was less competition for solar and soil energy. Phosphorus applications as high as 60 kilogrammes per hectare did not noticeably increase the weight of a thousand seedlings. There was no statistically significant change in test weight between any of the phosphorus concentrations. There was no statistically significant effect of phosphorus levels over 40 kg/ha on the test weight of summer moong.

Table 6: Summer moong yield characteristics as influenced by planting geometry and phosphorus levels.

Treatments		
Planting geometry	**No. of grains/plant**	**Test weight (g)**
30 cm × 10 cm	180.75	39.13
30 cm × 15 cm	210.05	39.80
30 cm × 20 cm	220.80	40.18
SEm±	**4.234**	**0.756**
CD at 5%	**12.418**	**N.S.**
Phosphorus Levels (kg/ha.)		
0	151.67	38.27
20	202.67	39.67
40	225.13	40.40
60	236.00	40.47
SEm±	**4.889**	**0.873**
CD at 5%	**14.339**	**N.S.**

YIELD

- **Biological yield (q/ha):**

Table provide information on biological yield affected by planting geometry and phosphorus levels, respectively. When comparing the biological yield of the 30 cm 10 cm and 30 cm 20 cm planting geometries for the summer moong crop, the 30 cm 15 cm planting geometry emerged as the clear winner. In the current field experiment, the percentage increases in yield from using the optimal planting geometry of 30 cm 15 cm compared to the 30 cm 10 cm and 30 cm 20 cm planting geometries were 6.15 q/ha (21.14%) and 1.57 q/ha (4.66%), respectively.

There was a statistically significant increase in biological yield under the influence of the 30 cm 15 cm planting geometry and the biological yield of summer moon compared to the other planting geometries in the present study. This may be attributed to the higher number of branches per plant, increased production of dry matter, and larger test weights observed under the 30 cm 15 cm planting geometry. Ibrahimi et al. also found that applying 60 kg of phosphorus per hectare had a similar impact on increasing biological production. In terms of biological output, a substantial response to phosphorus consumption was shown only up to the 40 kg/ha level. Summer moong's biological yield was observed to decline at phosphorus doses over 60 kg/ha. The biological yield increased by 5.43 q/ha (18.11%) as compared to the yield with no phosphorus when 40 kg/ha P2O5 was applied in the current field experiment.

The crop showed a significant increase in biological output only at a dosage of 40 kg/ha phosphorus. Phosphorus increases photosynthesis and enhances the plant's capacity to create carbohydrates, sugar, starch, and the generation of amino acids and proteins, all of which aid in fruiting and seed development.

- **Grain yield (q/ha):**

Table provide information on grain yield that was affected by different planting configurations and phosphorus applications. The current field experiments showed that a planting geometry of 30 cm 15 cm resulted in a much higher grain production than either 30 cm 10 cm or 30 cm 20 cm. Grain yield increased by 0.99 q/ha (10.15 %) and 0.64 q/ha (6.3 %), respectively, when the optimal planting geometry was 30 cm 15 cm, as opposed to 30 cm 10 cm and 30 cm 20 cm.

Grain yields were found to be considerably higher for the 30 cm 15 cm planting geometry compared to the 30 cm 10 cm and comparable to the 30 cm 20 cm planting geometry. Grain yield was greatly boosted with the 30 cm 15 cm planting geometry compared to the other planting geometries. The 30 cm 15 cm planting geometry seems to boost biological production by encouraging the development of more branches per plant, leading to an increase in dry accumulation. Prakash and Pandey (2016) showed that a considerable increase in seed production was achieved in summer moong by using a planting geometry of 25 cm 10 cm.

Grain yield was positively affected by phosphorus treatments, although this impact was only statistically significant up to 40 kg/ha. Results also showed that increasing the dosage of phosphorus to 60 kg/ha or higher had no discernible influence on summer moong output. In the current field study, adding 40 kg/ha P2O5 increased grain production by 3.11 q/ha (37.15%) compared to adding no phosphorus at all.When the crop reacted up to a dosage of 40 kg/ha of phosphorus, the yield of the grain was considerably greater in the study year. Increases in yield characteristics due to the impact of phosphorus treatment are responsible for the observed increases in grain yield in the ongoing field experiments. Kumawat et al. (2014) observed that applying 60 kg/ha of phosphorus to summer moong greatly enhanced seed output. Planting geometry and phosphorus levels were shown to have no significant relationship.

- **Harvest index (%):**

In Table, we can see how planting geometry and phosphorus levels affect the harvest index (percent). Here, substantial differences were found between the effects of various planting geometries, with the 30 cm 10 cm planting geometry yielding the highest harvest index (%). The results demonstrated that the 30 cm 10 cm planting geometry greatly enhanced the presence of phosphorus administration and had a much larger effect on harvest index than the broader 30 cm 15 cm and 30 cm 20 cm planting geometries. At 30 cm 10 cm, the harvest index dramatically rose, as reported by Yadav et al. (2014). With regard to harvest index (%) in summer moong, the reaction to applied phosphorus was limited to a dosage of 60 kg/ha, which was substantially higher than other doses of phosphorus like 0 and 20 kg/ha.

Due to low soil phosphorus and continuing mining of soil phosphorus in extensive cycles followed previously to the current experiment, the crop reacted considerably upto 60 kg/ha phosphorus level.

Table 7: Yield and harvest index of summer moong as affected by planting geometry and phosphorus levels

Treatments	Biological yield (q/ha)	Grain yield (q/ha)	Harvest index(%)
Planting geometry			
30 cm × 10 cm	29.09	9.75	33.44
30 cm × 15 cm	35.21	10.74	30.45
30 cm × 20 cm	33.64	10.10	29.94
SEm±	**0.394**	**0.238**	**0.662**
CD at 5%	**1.155**	**0.698**	**1.942**
Phosphorus Levels (kg/ha.)			
0	29.98	8.37	27.97
20	31.46	9.51	30.58
40	35.41	11.48	32.53
60	33.67	11.43	34.03

SEm±	0.455	0.275	0.765
CD at 5%	1.334	0.806	2.242

QUALITY

- **Protein content in grain (%):**

Table show how the planting geometry and phosphorus levels affected the collected data on protein (%) in grain. No major variations between geometry types were found. In general, nevertheless, the trend indicated that the protein content rose in tandem with the complexity of the planting pattern.

Maximum protein content in grain (21.88%) was recorded for a plant geometry of 30 cm x 20 cm, indicating that increased shape, size, taste, and quality resulted from the increased photosynthetic activity afforded by more light, space, and nutrients.

The protein content of grain rose considerably with increasing phosphorus levels up to the 40 kg/ha phosphorus level, but the differences were not found to be statistically significant in summer moong beyond that.

In the current investigation, a phosphorus treatment of 60 kg/ha considerably boosted the grain's protein content. This might be because phosphorus is essential for cell growth and the synthesis of nucleoproteins, amino acids, DNA, and other components of cells.

- **Protein yield (kg/ha):**

Table provide information on protein yield (kg/ha) as a function of planting geometry and phosphorus levels, respectively. Protein yield was shown to be insignificant across planting geometry types. Protein production (measured in kilogrammes per hour) has been rising as planting densities have increased in recent field trials.

Maximum protein yield (179.79 kg/ha) was achieved with a planting geometry of 30 cm 20 cm, as opposed to the lower geometry of 30 cm 10 cm, because of increased photosynthetic activity and greater light, space, and nutrient availability, which also improved plant growth, shape, flavour, and quality.

Protein yield (kg/ha) rose considerably with increasing amounts of phosphorus up to the 60 kg/ha phosphorus level, but this effect was not seen at the 0 kg/ha, 20 kg/ha, or 40 kg/ha phosphorus levels during the field experiments.

The present investigation found that adding 60 kg/ha of phosphorus significantly boosted the protein output. This may be due to the fact that phosphorus is required in the production of almost all building blocks of cells, including nucleic acids, amino acids, and RNA/DNA. Tomar et al. (2004) found that straw's protein content may be increased with the addition of phosphorus.

Protein yield (kg/ha) did not show a statistically significant interaction impact between planting geometry and phosphorus content.

Table :8 Total protein yield, grain protein yield, and straw protein yield in summer moong as affected by planting geometry and phosphorus levels.

Treatments	Protein content in grain (%)	Total protein yield(kg ha^{-1})
Planting geometry		
30 cm × 10 cm	20.94	171.78
30 cm × 15 cm	21.48	176.66
30 cm × 20 cm	21.88	179.79
SEm±	**0.467**	**3.138**
CD at 5%	**N.S.**	**9.204**
Phosphorus Levels (kg/ha.)		
0	19.38	161.46
20	21.04	173.05
40	22.19	180.99
60	23.13	188.80
SEm±	**0.540**	**3.624**
CD at 5%	**1.583**	**10.628**

4. Conclusion

Even though most Indians don't eat meat, the nation is the global leader in producing grain legumes. Pulse crops account for around 13% of India's acreage, making the country the world's sixth most productive. Based on these findings, it seems that a planting geometry of 30 cm 15 cm is optimal for a high summer moong harvest. Summer moong grew best and produced the most when treated with 40 kilogrammes of phosphorus per hectare.

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