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Response of interaction of different phosphorus levels and plant geometry on crop growth and yield of green gram in Uttrakhand conditions

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Abstract
The present investigation was conducted to study the response of interaction of different phosphorus levels and plant geometry on crop growth and yield of Green gram (*Vigna radiata* L.) in Uttrakhand conditions and this experiment was carried out by using Randomized Block Design (Factorial) with twelve treatments and each treatment was replicated at three times in a plot size of 3 m × 3 m ($9m^2$) at Crop Research Farm, Maya College of Agriculture and Technology, Selaqui, Dehradun. The application of 60 kg phosphorus ha^{-1} along with row spacing of 30×15 cm were significantly increased maximum plant height (75.23 cm), no. of branches $plant^{-1}$ (2.67), no of nodules $plant^{-1}$ (24.80), dry weight (30.89 g) and grain yield (1.51 t ha^{-1}) except C.G.R. (15.27 g/m²/day) and R.G.R. (0.04 g/g/day) which was recorded non-significant during interaction of treatments. The highest plant height (54.08 cm), Dry weight (20.34 g $plant^{-1}$), no. of branches $plant^{-1}$ (1.78), CGR (10.45 g m^{-2} day^{-1}), RGR (0.03 g g^{-1} day^{-1}) and grain yield (1.06 t ha^{-1}) were recorded in treatment R_1 (30 x 15 cm) whereas maximum no of nodules $plant^{-1}$ (15.67) and were observed in R_2 (45 x 15 cm) which was statistically at par with treatment R_1. Similarly the maximum growth and yield were recorded in P_3 (60 kg P_2O_5 ha^{-1}).

Keywords: Greengram, phosphorus levels, row spacing, yield attributes

Introduction

Green gram locally called as moong or mung [*Vigna radiata* (L.) Wilczek] belongs to the family leguminaceae. It's one of the important pulse crops of India. India alone accounts for 65 percent of its world acreage and 54 percent of the total production. In India, green gram was planted on roughly 31 lakh hectares of land in 2019–20. According to the Directorate of Economics & Statistics (2019), the states of Rajasthan (18.3 lakh ha), Karnataka (2.7 lakh ha), Maharashtra (3.3 lakh ha), Madhya Pradesh (1.8 lakh ha) are the top producers of mung bean. Due to an increase in crop area of 7.41 percent to 34.5 lakh ha, mung bean output in 2018-19 climbed from 19.3 to 20.3 lakh tonnes (Anonymous, 2020) [5]. Which is one of the largest pulses producing countries in the world. But due to per capita requirement of pulses about 2-3 million tons are imported annually from other countries. Thus, there is need to increase production and productivity of pulses in the country by more intensive interventions. It is grown on about 3.50 mha in the country mainly in Rajasthan, Maharashtra, Andhra Pradesh, Karnataka, Orissa and Bihar. A phenomenal increase in area, production and productivity has occurred since 1964-65. The area has increased from 1.99 million ha in 1964-65 to 4.30 million ha in 2016-2017. The production has increased from 0.60 million tonnes to 2.07 million tonnes during the same period. Throughout the India, the mungbean is used for different purposes. Green gram is nutritious, containing 23-26 percent proteins, 57-58 percent carbohydrate, 1.1 percent fat, 9.7 percent water, 3.3 – 3.8 percent fibre and 4 - 4.8 percent ash. As a vegetable protein it is rich in vitamin B, also rich in phosphorus and iron (Ashour *et al.*, 1994) [7]. Mung bean flour is used for making bread and it is an important source of starch production (Ibrahim and Al- Bassyuni, 2012) [14].

Mungbean plays an important role in maintaining and improving the fertility status of the soil, as they have ability to fix atmospheric N (20-25 $kgha^{-1}$) symbiotically in soil through root nodules. Being a short duration and having wide adaptability, it generally grown as intercrop, mixed crop and sole crop in kharif as well as in summer season where adequate irrigation facilities are available (Patel *et al.*, 2013) [21]. It can be grown on a variety of soil and climatic conditions, as it is tolerant to drought. It is mostly grown under dry land farming system where erratic rains often fetch the crop under moisture stress (Malik *et al.*, 2006) [17].

The low productivity of mungbean may be due to nutritional deficiency in soil and imbalanced external fertilization (Awomi *et al.,* 2012) [8]. Due to Lack of flowering synchronisation, excessive flower and fruit drop (Kaul 1979) [15], poor pod setting and pod filling, and pod cracking are some serious issues in green gram production. These lead to a decreased transfer of dry matter to reproductive organs and which are linked to nutritional deficiencies and improper crop geometry (Prakash et al. 2003) [24] and ultimately the yield of green gram (*Vigna radiata*) is extremely low. Phosphorus plays a significant role in pulse crops to its energy transfer reactions, possible fibrous root ramification, nodule development, profuse blooming, pod setting, seed quality, and other physiological processes (Garai and Datta 2002; Tisdate et al.1995) [11, 30]. The availability of pulses is very negligible at present as against required 85 g day^{-1} capita^{-1} for balanced diet (Patel *et al.,* 2013) [14].

Phosphorus, the master key element is known to be involved in a plethora of functions in the plant growth and metabolism. Such key functions include cell division and development, photosynthesis, breakdown of sugars, energy transfer, nutrient transfer within the plant and expression. The phosphorus is present at levels of 400-1200mg kg-1 of soil (Begon *et al*., 1990) [10].

Phosphorus plays a vital role in the formation and translocation of carbohydrates, root development, crop maturation and resistance to disease pathogens. Thus increase the mung bean yield and improves its quality (Arya and Kalara, 1988) [6]. Growth and development of crops depend largely on the development of root system (Raboy, 2003). Phosphorus (P) is one of the three macronutrients that plants must obtain from the soil. Its availability is influenced by many factors of which pH are important. Phosphorus use efficiency in black cotton soils ranges from 18 to 20 percent. Therefore, to increase the phosphorus use efficiency, it is required to find out the optimum level of phosphorus for green gram (Patil *et al.,* 2011) [23]. The plant development is mainly affected by plant stand, planting geometry, soil fertility and soil-moisture availability. Among these factors, planting geometry is an important factors in which row spacing plays an important role in plant development (Rajput *et al.,* 1993) [26]. For commercial cultivation of row spacing of 30 cm with plant spacing of 10 cm is generally used to obtain 320,000 plants ha^{-1} (Bashir, 1994) [9].

Materials and Methods

The experiment was conducted during the *kharif* season of 2016-17 at the plot no. 200 of the Crop Research Farm, Department of Agronomy, Maya College of Agriculture and Technology, Selaqui, Dehradun. The Crop Research Farm is situated at 31^0 N latitude, 87^0 19' E longitude and 450 m altitude from the sea level. Dehradun has humid-subtropical and semi-arid climate with the monsoon commencing from July and withdrawing by the end of September. The rainfall is unevenly distributed and most of it is received between July and September. The experiments were laid out in 4×3 factorial Randomized Block Design, having four levels of row spacing and three levels of phosphorous making 12 treatment combinations, each replicated three times. The data recorded during the course of investigation were subjected to statistical analysis as per method of analysis of variance (Skeleton). Initial soil samples were taken from a depth of 15 cm with the help of an auger and analysis revealed that the soil of the experimental field was with pH = 7.4, organic carbon 0.28 percent and sand 58.50 percent, silt 25.10 percent & clay 16.40 percent. The available N, P and K of the experiment soil were 225, 21.50 and 87 kg ha^{-1} respectively. Fertilizers were applied as side placement, for which 4-5 cm deep furrows were made along the seed rows with a *hand hoe*. The nutrient sources were urea, diammonium phosphate (DAP) and muriate of potash (MOP) to fulfill. The recommended dose was applied according to the treatment details through Urea and MOP. Whole of nitrogen, phosphorus and potash was applied as basal at the time of sowing.

The treatments are as follows

1. Row spacing

$S_{1=}$ (30 × 15 cm)
$S_{2=}$ (45 × 15 cm)
$S_{3=}$ (60 × 15 cm)
$S_{4=}$ (75 × 15 cm)

2. Levels of Phosphorus

P_1= (Phosphorus @ 40 Kg ha^{-1})
P_2= (Phosphorus @ 50 Kg ha^{-1})
P_3= (Phosphorus @ 60 Kg ha^{-1})

Treatments

T_1= S_1+P_1 S_1= 30 × 15 P_1=40
T_2= S_1+P_2 S_1= 30 × 15 P_2=50
T_3= S_1+P_3 S_1= 30 × 15 P_3=60
T_4= S_2+P_1 S_2= 45 × 15 P_1=40
T_5= S_2+P_2 S_2= 45 × 15 P_2=50
T_6= S_2+P_3 S_2= 45 × 15 P_3=60
T_7= S_3+P_1 S_3= 60 × 15 P_1=40
T_8= S_3+P_2 S_3= 60 × 15 P_2=50
T_9= S_3+P_3 S_3= 60 × 15 P_3=60
T_{10}=S_4+P_1 S_4= 75 × 15 P_1=40
T_{11}= S_4+P_2 S_4= 75 × 15 P_2=50
T_{12}= S_4+P_3 S_4= 75 × 15 P_3=60

Results and Discussion

Growth Parameters of Greengram

Plant height (cm): Observations on the plant height are given in tables 1 and figure 2

Performance under different row spacing

From perusal of data in table 1, at all growth stages plant height showed significant difference among themselves. The results showed that the highest plant heights (7.31, 14.92, 32.90, 52.27 and 54.08cm) were observed in R_1 (30 × 15 cm), while lowest plant heights (6.22, 13.37, 28.33, 48.64 and 51.52 cm) were observed in R_4 (75 × 15 cm) row spacing at 15, 30, 45, 60 and 75 DAS, respectively. Row spacing R_2 (45 x 15 cm) and R_3 (60 x 15 cm) were found statistically at par with R_1 at different interval of 15, 30 and 45 DAS.

Performance under different phosphorus levels

From perusal of data in table 1, it was observed that there was a steady increase in plant height from 15 DAS to 75DAS. Whereas 15, 30, 45, and 75 DAS, showed significant influence on plant height but 60 DAS interval showed non-significant. At 15, 30, 45, 60, and 75 DAS highest plant heights (9.61, 19.97,43.22,67.68 and 71.41 cm, respectively) were observed in phosphorus levels P_3 (60 kg ha^{-1}), while at 15, 30, 60 and 75 DAS lowest plant heights (8.48, 18.07, 65.72 and 69.02 cm, respectively) were observed in Phosphorus level (50 kg ha^{-1}) but at 45 DAS lowest plant height (38.22 cm) was observed in Phosphorus level (40 kg ha^{-1}).

Interaction effect of different row spacing and phosphorus levels

From perusal of data in figure 2, the interaction effect between different row spacing and phosphorus levels were significant at 75 DAS. While at 15, 30, 45 and 60 DAS plant height showed non-significant. The results showed that the maximum increased plant height (75.23 cm) was observed in treatment T_3 (30 × 15 cm +60 kg ha^{-1} phosphorus) while lowest plant height (68.13 cm) was observed in T_{11} ((75 cm × 15 cm) + 50 kg ha^{-1} Phosphorus at 75 DAS.

Different row spacing and phosphorus levels did not affect the plant height at early stages of growth. This may have been due to the slower rate of mineralization of nutrients, but in T_3 at later stages the growth increase was may be due to the more mineralization and availability of nutrients. The results are in agreement with those of Singh and Hiremath (1990) [29] who reported that the P fertilization @ 60 kg ha^{-1} was maximum plant height and dry weight plant^{-1}. Shabber (1982) [27] also reported that the application of 20 kg nitrogen and 60 kg ha^{-1} P_2O_5 was significantly increased the number of branches plant^{-1}, number of pod plant^{-1} and 1000 seed weight of gram.

Table 1: Effect of different row spacing and phosphorus levels on dry weight and plant height of Greengram (*Vigna radiata*)

Treatments	Dry weight (g plant^{-1})					Plant height (cm)				
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
Row spacing										
R_1	0.23	1.31	6.82	12.27	20.34	7.31	14.92	32.90	52.27	54.08
R_2	0.22	1.16	6.65	11.60	19.16	7.20	14.52	30.31	49.89	52.42
R_3	0.22	1.15	6.18	11.18	19.19	6.53	13.63	29.77	48.92	51.97
R_4	0.23	1.11	6.37	11.47	18.01	6.22	13.37	28.33	48.64	51.52
F test	NS	S	S	S	S	S	S	S	S	S
SEd (±)	0.02	0.06	0.26	0.47	0.49	0.53	0.67	1.58	1.04	0.69
CD (P= 0.05)	-	0.13	0.53	0.97	0.99	1.09	1.36	3.24	2.12	1.42
Phosphorus level										
P_1	0.29	1.50	8.53	15.26	24.51	9.18	18.39	38.22	66.34	69.57
P_2	0.33	1.62	8.33	15.15	24.76	8.48	18.07	39.88	65.72	69.02
P_3	0.30	1.63	9.15	16.11	27.44	9.61	19.97	43.22	67.68	71.41
F test	S	S	S	S	S	S	S	S	NS	S
SEd (±)	0.01	0.05	0.22	0.41	0.42	0.46	0.58	1.37	0.90	0.60
CD (P= 0.05)	0.02	0.11	0.46	0.84	0.86	0.95	1.18	2.80	1.84	1.23

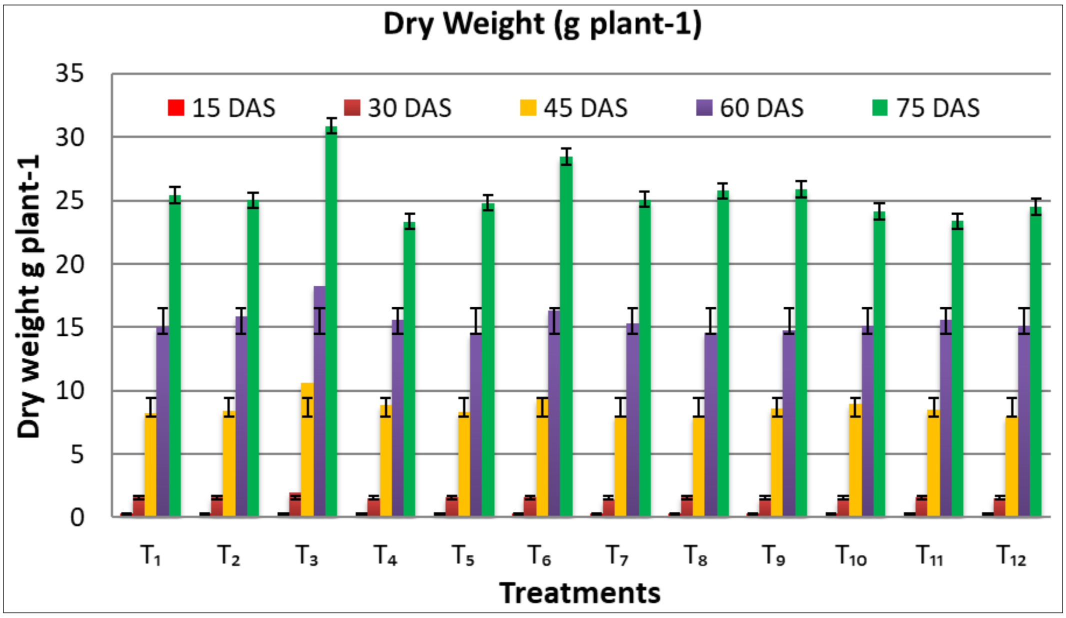

Fig 1: Interaction effect of different row spacing and phosphorus levels on dry weight (g plant^{-1}) of Greengram (*Vigna radiata*)

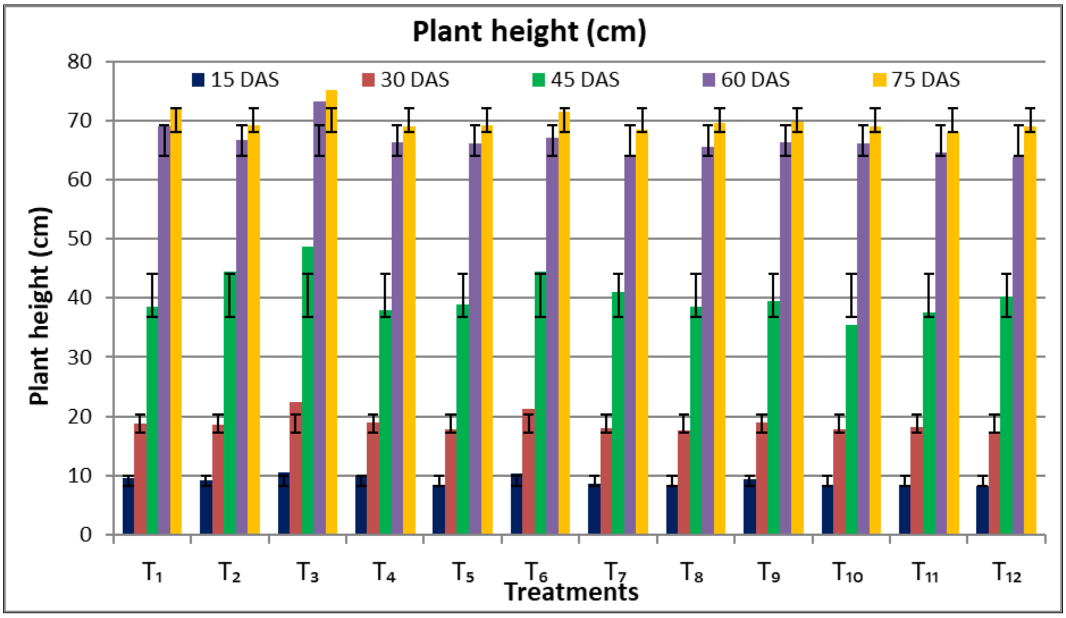

Fig 2: Interaction effect of different row spacing and phosphorus levels on plant height of Greengram (*Vigna radiata*)

Plant dry weight (g)

Performance under different row spacing

From perusal of data in table 2a, it was observed that there was a steady increase in plant dry weight from 15 DAS to 75 DAS. At 30, 45, 60 and 75 DAS were significant influence in plant dry weight, while 15 DAS was non-significant. At 30 and 75 DAS maximum plant dry weight (1.31, 20.34 g) was observed in R_1 (30 x 15 cm) while lowest plant dry weight (1.11, 18.01 g) was observed in R_4 (75 x 15 cm), respectively.

At 15, 45 and 60 DAS highest plant dry weight (0.23, 6.82, 12.27 g) was observed in R_1 (30 x 15 cm) while lowest plant dry weight (0.22, 6.18, 11.18 g) was observed in R_3 (60 x 15 cm), respectively. Row spacing of R_2 (45 x 15 cm) and R_4 (75 x 15 cm) were found statistically at par with R_1 at different intervals of 45 and 60 DAS.

Performance under different phosphorus levels

From perusal of data in table 2a, it was observed that there was a steady increase in plant dry weight from 15 DAS to 75 DAS. At interval 15, 30, 45, 60 and 75 DAS plant dry weight was showed statistically significant difference in plant dry weight. At 15 DAS highest plant dry weight (0.33 g) was observed in treatment P_2 (50 kg ha^{-1}) while lowest plant dry weight (0.29 g) was observed in treatment P_1 (40 kg ha^{-1}) phosphorus level.

At 30, 45, 60 and 75 DAS highest plant dry weight (1.63, 9.15, 16.11, 27.44 g, respectively) was observed in treatment P_3 (60 kg ha^{-1}) phosphorus level. Whereas, lowest plant dry weight was observed in treatment P_1 at 30 and 75 DAS (1.50, 24.51 g), while 45 and 60 DAS were recorded minimum plant dry weight in treatment P_2 (50 kg phosphorus ha^{-1}) phosphorus level. However, phosphorus level of P_2 was found statistically at par with P_3 in 30 DAS.

Interaction effect between different row spacing and phosphorus levels

The interaction effect between different row spacing and phosphorus levels at 15 and 30 DAS were statistically non-significant while 45, 60 and 75 DAS were significant effect in plant dry weight (Table 2b). At 45, 60 and 75 DAS were recorded maximum plant dry weight in treatment T_3 -30 × 15 cm+60 kg ha^{-1} phosphorus (10.45, 18.22 and 30.89 g, respectively). However, minimum plant dry weight was recorded in treatment T_{12} -75× 15 cm+60 kg ha^{-1} phosphorus (7.99 g) at 45 DAS, while 60 and 75 DAS were minimum plant dry weight in treatment T_5- 45× 15 cm+50 kg ha^{-1} phosphorus (14.51 g) and T_4- 45×15 cm+40 kg ha^{-1} phosphorus (23.35 g).

It was observed that dry shoot weight increased with the increasing levels of phosphorus, which further enhanced when these treatments were applied along with proper row spacing. The results are in agreement with Kumar *et al.* (2012) [16] found that the increasing levels of Phosphorus and Sulphur enhanced the growth, Plant height, yield attributes like number of nodules plant^{-1}, dry weight of nodules, number of pods plant^{-1}, number of grains pods^{-1}, 1000 weight, grain yield and straw yield showed maximum increase at 45 kg ha^{-1} P_2O_5 and 30 kg ha^{-1} S, respectively. Nemat *et al.* (2000) [18] reported by results might be due to increment in dry weight of plant, stems, pods, L A I, CGR and AGR by increasing levels of phosphorus. Singh and Hiremath (1990) [28] recorded the P fertilization @ 60 kg ha^{-1} was maximum plant height and dry weight plant^{-1}.

Number of branch plant^{-1}

Performance under different row spacing

The data are presented in table 2, it was observed that there was a steady increase in number of branch plant^{-1} from 45 DAS to 75 DAS. At 45 DAS was recorded non-significant effect but 60 and 75 DAS were significant influence in number of branch plant^{-1}. At 15 DAS maximum number of branch plant^{-1} (0.68) was observed in R_1 (30 x 15 cm), while lowest number of branch plant^{-1} (0.60) in R_3 (60 x 15 cm). However, at 60 and 75 DAS maximum number of branch plant^{-1} (1.5 and 1.78) were observed in R_1 (30 x 15 cm) while lowest number of branch plant^{-1} (1.2 and 1.63) in R_4 (75 x 15 cm), respectively.

Performance under different phosphorus levels

From perusal of data in table 2, it was observed that there was a steady increase in number of branch plant^{-1} from 45 DAS to 75 DAS. At interval 45, 60 and 75 DAS were showed statistically significant difference in number of branch plant^{-1}. At 45, 60 and 75 DAS maximum number of branch plant^{-1} (0.93, 1.90 and 2.32) were observed in treatment P_3 (60 kg ha^{-1} Phosphorus) while lowest number of branch plant^{-1} (0.78, 1.72 and 2.13 respectively) in treatment P_2 (50 kg ha^{-1} Phosphorus) but phosphorus level of P_1 (40 kg ha^{-1}) was found statistically at par with P_3 in 75 DAS.

Interaction effect between different row spacing and phosphorus levels

The interaction effect between different row spacing and phosphorus levels at 45, 60 and 75 DAS were statistically significant difference in number of branch plant^{-1} (figure 3). At 45, 60 and 75 DAS were recorded maximum number of branch plant^{-1} in treatment T_3 -30×15 cm+60 kg ha^{-1} Phosphorus (1.20, 2.40 and2.67). However, minimum number of branch plant^{-1} was recorded in treatment T_9 -60×15 cm+60 kg ha^{-1} Phosphorus (0.73) at 45 DAS, but 60 and 75 DAS were minimum number of branch plant^{-1} in treatment T_5 -45× 15 cm+50 kg ha^{-1} Phosphorus (1.60 and 2.00).

Branching is basically a genetic character but environmental conditions and proper row spacing may also influence the number of branches per plant and play an important role in enhancing seed yield. Similar results have been studied by Shabber (1982) [27], who reported that the application of 20 kg nitrogen and 60 kg ha^{-1} P_2O_5 was significantly increased the number of branches plant^{-1}, number of pod plant^{-1} and 1000 seed weight of gram.

Table 2: Effect of different row spacing and phosphorus levels on number of branches plant^{-1} of Greengram (*Vigna radiata*)

Treatments	No. of branches plant^{-1}		
	45 DAS	60 DAS	75 DAS
Row spacing			
R_1	0.68	1.5	1.78
R_2	0.61	1.31	1.67
R_3	0.60	1.28	1.67
R_4	0.61	1.26	1.63
F test	NS	S	S
SEd (±)	0.06	0.07	0.07
CD (P= 0.05)	-	0.15	0.14
Phosphorus level			
P_1	0.80	1.75	2.30
P_2	0.78	1.72	2.13
P_3	0.93	1.90	2.32
F test	S	S	S
SEd (±)	0.05	0.06	0.06
CD (P= 0.05)	0.12	0.13	0.12

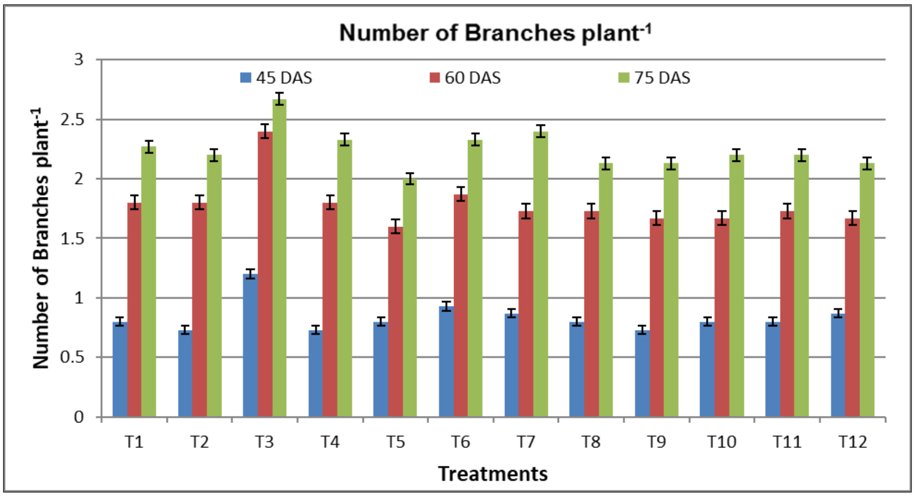

Fig 3: Interaction effect of different row spacing and phosphorus levels on number of branches plant^{-1} of Greengram (*Vigna radiata*)

Number of nodules plant^{-1}

Performance under different row spacing

The table 3, showed that in number of nodules plant^{-1} was increased from 15 to 75 DAS. At 15, 45 and 60 DAS were recorded non-significant but 30 and 75 DAS were significant influence in number of nodules plant^{-1}. At 15 DAS maximum number of nodules plant^{-1} (4.75) were observed in R_1 (30 x 15 cm), while lowest number of nodules plant^{-1} (4.40) in R_3 (60 x 15 cm).

At 45 and 60 DAS maximum number of nodules plant-^{1} (41.83 and 40.01) were observed in R_1 (30 x 15 cm), while lowest number of nodules plant^{-1} (39.40 and 38.13) in R_4 (75 x 15 cm), respectively. At 30 and 75 DAS maximum number of nodules plant^{-1} (25.83 and 15.67) were observed in R_1 (30 x 15 cm) and R_2 (45 × 15 cm), while lowest number of nodules plant^{-1} (22.12 and 14.28) in R_3 (60 x 15 cm), respectively. Row spacing of R_2 and R_4 were found statistically at par with R_1 at 30 DAS but R_2, R_4 and R_3 were found statistically at par with R_1 at 75 DAS.

Performance under different phosphorus levels

The data are presented in table 3, results revealed that there was a steady increase in number of nodules plant^{-1} from 15 DAS to 75 DAS. At interval 15 DAS was statistically non-significant but 30, 45, 60 and 75 DAS were showed statistically significant difference in number of nodules plant^{-1}.

At 30, 45, 60 and 75 DAS maximum number of nodules plant^{-1} (33.52, 57.16, 54.12 and 21.03) were observed in treatment P_3 (60 kg ha^{-1} Phosphorus) while lowest number of nodules plant^{-1} (30.43 and 19.37), (52.18 and 50.60) in treatment P_2 (50 kg ha^{-1} Phosphorus) and P_1 (40 kg ha^{-1} Phosphorus) at (30, 75) and (45, 60) DAS, respectively. At 30 and 75 DAS, phosphorus level of P_1 (40 kg ha^{-1}) was found statistically at par with P_3.

Interaction effect between different row spacing and phosphorus levels

From perusal of data in figure 4, the interaction effect between different row spacing and phosphorus levels at 45, 60 and 75 DAS were statistically significant difference in number of nodules plant^{-1} while 15 and 30 DAS were non-significant. At 45, 60 and 75 DAS were recorded maximum number of nodules plant^{-1} in treatment T_3 -30×15 cm+60 kg ha^{-1} Phosphorus (64.73, 61.67 and 24.80, respectively). However, minimum number of nodules plant^{-1} was recorded in treatment T_2 -30×15 cm+50 kg ha^{-1} Phosphorus (51.13) at 45 DAS, but 60 and 75 DAS were minimum number of nodules plant^{-1} in treatment T_4 -45× 15 cm+40 kg ha^{-1} Phosphorus (48.00) and T_9 -60× 15 cm+60 kg ha^{-1} Phosphorus (18.27), respectively. At 45 DAS, treatment T_6 (45 x 15 cm) + 60 kg ha^{-1} phosphorus was found statistically at par with T_3.

Phosphorus is key element in process of photosynthesis, root formation and development, growth and yield and enhancement of maturity of the crop. Similar reports have been reported by Patil and Jadav (1994) [22] showed supply of phosphorus to legume increase the number and size of root nodules and nitrogen fixing potentiality of *Rhizobium*, so it essential for obtaining the higher yield of crop. Ahmad *et al.* (1986) also reported that the phosphorus application upto 60 kg ha^{-1} progressively and significantly enhanced the growth and yield parameters.

Table 3: Effect of different row spacing and phosphorus levels on number of nodules plant^{-1} of Greengram (*Vigna radiata*)

	Treatments	No of nodules plant^{-1}				
		15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
	Row spacing					
R_1	30 cm × 15 cm	4.75	25.83	41.83	40.01	15.65
R_2	45 cm × 15 cm	4.68	23.2	40.25	38.25	15.67
R_3	60 cm × 15 cm	4.40	22.12	40.20	39.15	14.28
R_4	75 cm × 15 cm	4.61	23.95	39.80	38.13	14.58
	F test	NS	S	NS	NS	S
	SEd (±)	0.37	1.44	1.72	1.64	0.78
	CD (P= 0.05)	-	2.94	-	-	1.59
	Phosphorus level					
P_1	40 kg Phosphorus ha^{-1}	5.90	31.15	52.18	50.60	19.77
P_2	50 kg Phosphorus ha^{-1}	6.22	30.43	52.75	50.83	19.37
P_3	60 kg Phosphorus ha^{-1}	6.33	33.52	57.16	54.12	21.03
	F test	NS	S	S	S	S
	SEd (±)	0.31	1.24	1.49	1.42	0.67
	CD (P= 0.05)	-	2.54	3.05	2.90	1.38

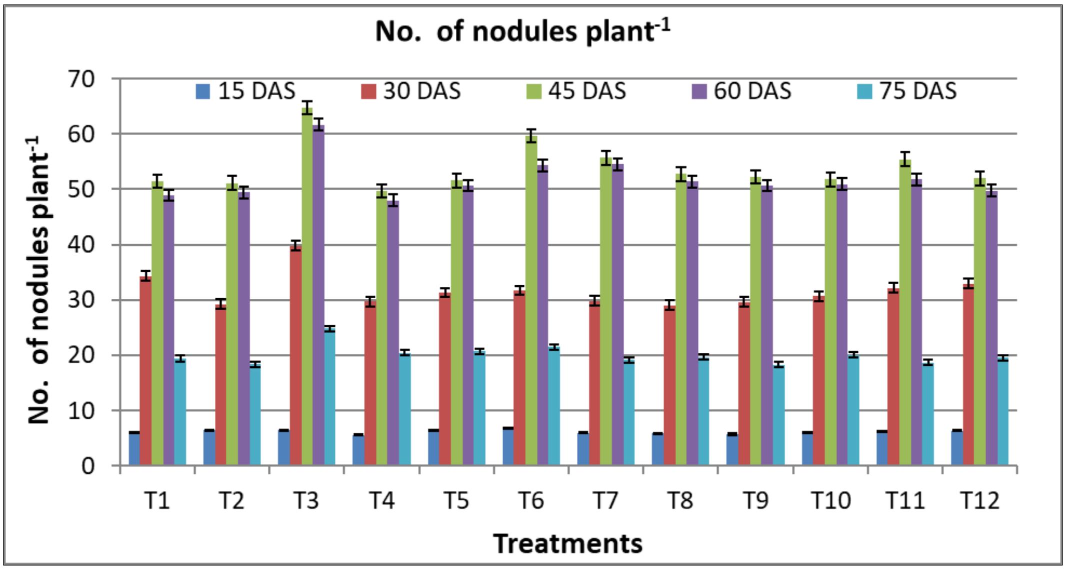

Fig 4: Interaction effect of different row spacing and phosphorus levels on number of nodules plant^{-1} of Greengram (*Vigna radiata*)

Crop growth rate (g m^{-2} day^{-1})

Performance under different row spacing

Data are presented in table 4, results revealed that there was a steady increase in CGR from 0-15 DAS to 60-75 DAS, which are significant among themselves. Between 0-15, 15-30, 30-45, 45-60 and 60-75 DAS were increased CGR (0.33, 1.62, 7.94, 8.11 and 10.45 g m^{-2}day^{-1}, respectively) was observed in R_1 (30×15 cm) while lowest CGR (0.14, 0.53, 3.14, 3.06 and 4.26 g m^{-2} day^{-1}) was observed in R_4 (75×15 cm) row spacing.

Performance under different phosphorus levels

From perusal of data in table 4, it was observed that there was a steady increase in CGR from 0-15 DAS to 60-75 DAS, later at interval 45-60 and 60-75 DAS were showed non-significant influence on CGR but 0-15, 15-30 and 30-45 DAS showed significant result. Between 0 -15 DAS, highest CGR (0.31 g m^{-2} day^{-1}) was observed in treatment P_2 (50 kg ha^{-1} Phosphorus), while lowest CGR (0.27 g m^{-2} day^{-1}) was observed in treatment P_1 (40 kg ha^{-1} Phosphorus). Between 15 -30 DAS, highest CGR (1.33 g m^{-2} day^{-1}) was observed in treatment P_3 (60 kg ha^{-1} Phosphorus), while lowest CGR (1.18 g m^{-2} day^{-1}) was observed in treatment P_1 (40 kg ha^{-1} Phosphorus) but P_2 (50 kg ha-1 phosphorus) was found statistically at par with P_3.

Between 30-45 DAS and 60-75 DAS, highest CGR (7.44 g m^{-2} day^{-1}) and (10.06 g m^{-2} day^{-1}) was observed in treatment P_3 (60 kg ha^{-1} Phosphorus), respectively. While lowest CGR (6.26 g m^{-2} day^{-1}) and (9.01 g m^{-2} day^{-1}) was observed in both cases treatment P_2 (50 kg ha^{-1} Phosphorus) and P_1 (40 kg ha^{-1} Phosphorus) respectively.

Interaction effect between different row spacing and phosphorus levels

In figure 5, the interaction effect between different row spacing and phosphorus levels between 0-15, 45-60 and 60-75 DAS, CGR showed non-significant difference, but 15-30 and 30-45 DAS showed significant difference. At 15-30 and 30-45 DAS were recorded maximum CGR in treatment T_3 -30 × 15 cm+60 kg ha^{-1} Phosphorus (2.58 and 12.74), while minimum CGR was recorded in treatment T_{12} -75×15 cm+60 kg ha^{-1} Phosphorus (0.69 and3.90).

Different planting methods and nutrient levels did not affect the CGR at early stages of growth. This may have been due to the slower rate of mineralization of nutrients, but in T_5 at later stages the growth increase was may be due to the more mineralization and availability of nutrients. Similar reports have been reported by Nemat *et al*. (2000) [18] reported by results might be due to increment in dry weight of plant, stems, pods, LAI, CGR and AGR by increasing levels of phosphorus.

Table 4: Effect of different row spacing and phosphorus levels on CGR (g m^{-2} day^{-1}) of Greengram (*Vigna radiata*)

	Treatments	CGR (g m^{-2} day^{-1})				
		0-15 DAS	15-30 DAS	30-45 DAS	45-60 DAS	60-75 DAS
	Row spacing					
R_1	30 cm × 15 cm	0.33	1.62	7.94	8.11	10.45
R_2	45 cm × 15 cm	0.22	0.94	5.48	4.95	7.74
R_3	60 cm × 15 cm	0.16	0.65	3.71	3.66	5.72
R_4	75 cm × 15 cm	0.14	0.53	3.14	3.06	4.26
	F test	S	S	S	S	S
	SEd (±)	0.02	0.07	0.27	0.63	1.29
	CD (P= 0.05)	0.03	0.15	0.55	1.28	2.64
	Phosphorus level					
P_1	40 kg Phosphorus ha^{-1}	0.27	1.18	6.60	6.43	9.01
P_2	50 kg Phosphorus ha^{-1}	0.31	1.23	6.26	6.65	9.12
P_3	60 kg Phosphorus ha^{-1}	0.27	1.33	7.44	6.72	10.06
	F test	S	S	S	NS	NS
	SEd (±)	0.01	0.06	0.23	0.54	1.11
	CD (P= 0.05)	0.03	0.13	0.48	-	-

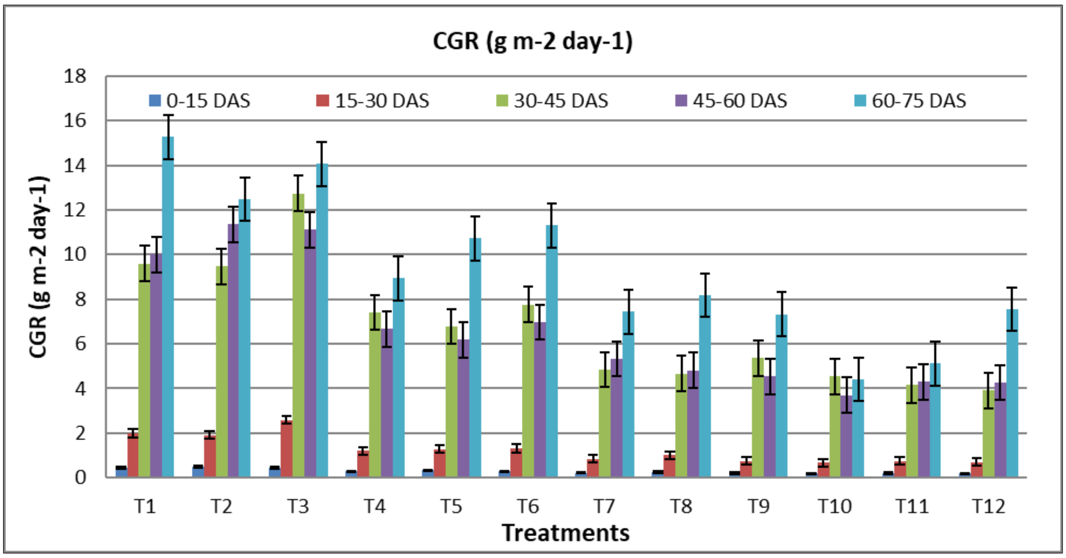

Fig 5: Interaction effect of different row spacing and phosphorus levels CGR (g m^{-2} day^{-1}) of Greengram (*Vigna radiata*)

Relative growth rate (g g^{-1} day^{-1})

Performance under different row spacing

From perusal of data in table 5, it was observed that there was a similar result in RGR from 15-30 DAS to 30-45 DAS, later at interval 45-60 DAS to 60-75 DAS, RGR decreased. At 15-30, 30-45, 45-60 and 60-75 DAS, interval RGR showed non-significant difference. Between 15-30 DAS, highest RGR (0.09 g g^{-1} day^{-1}) was observed in R_1 (30×15 cm), while lowest RGR (0.07 g g^{-1} day^{-1}) was observed in R_4 (75×15 cm) row spacing. The RGR was statistically at par with each other.

Performance under different phosphorus levels

From perusal of data in table 5, it was observed that there was a steady increase in RGR from 15-30 DAS to 30-45 DAS, later at interval 45-60 DAS to 60-75 DAS, RGR decreased. At 15-30, 45-60 and 60-75 DAS, interval RGR showed non-significant difference, but 30-45 DAS showed significant result.

Interaction effect between different row spacing and phosphorus levels

From perusal of data in figure 6, the interaction effect between different row spacing and phosphorus levels between 15-30, 30-45, 45-60 and 60-75 DAS, RGR showed non-significant difference.

Table 5: Effect of different row spacing and phosphorus levels on RGR (g g^{-1} day^{-1}) of Greengram (*Vigna radiata*)

	Treatments	RGR (g g^{-1} day^{-1})			
		30 DAS	45 DAS	60 DAS	75 DAS
	Row spacing				
R_1	30 cm × 15 cm	0.09	0.08	0.03	0.03
R_2	45 cm × 15 cm	0.08	0.09	0.03	0.02
R_3	60 cm × 15 cm	0.08	0.09	0.03	0.03
R_4	75 cm × 15 cm	0.07	0.09	0.03	0.02
	F test	NS	NS	NS	NS
	SEd (±)	0.005	0.004	0.63	0.003
	CD (P= 0.05)	-	-	-	-
	Phosphorus level				
P_1	40 kg Phosphorus ha^{-1}	0.11	0.12	0.04	0.03
P_2	50 kg Phosphorus ha^{-1}	0.11	0.11	0.04	0.03
P_3	60 kg Phosphorus ha^{-1}	0.11	0.12	0.04	0.04
	F test	NS	S	NS	NS
	SEd (±)	0.004	0.003	0.002	0.002
	CD (P= 0.05)	-	0.007	-	-

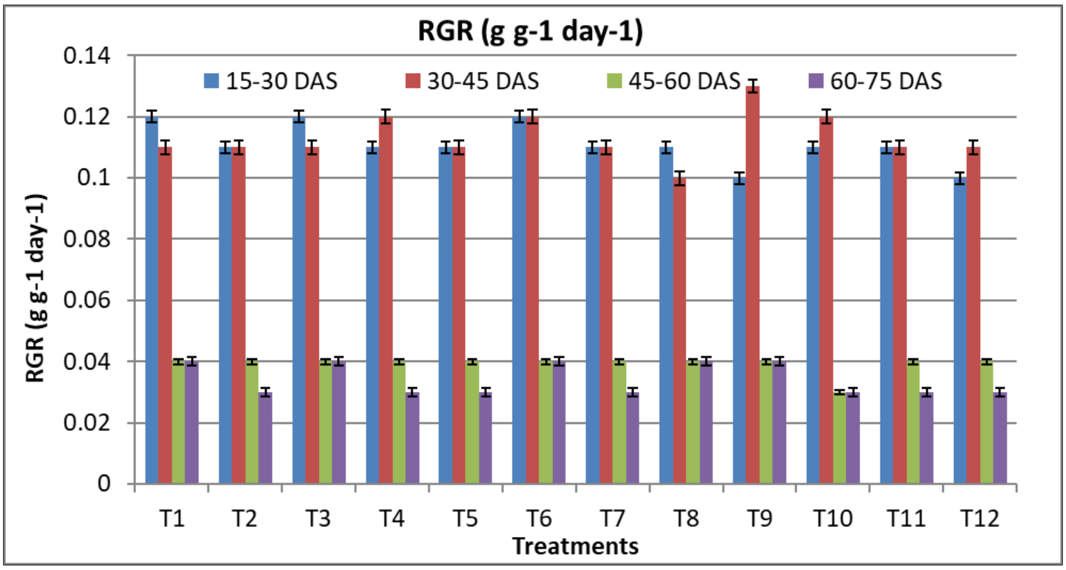

Fig 6: Interaction effect of different row spacing and phosphorus levels on RGR (g g^{-1} day^{-1}) of Greengram (*Vigna radiata*)

Grain yield (t ha^{-1})

Observations on the grain yield are given in tables 6 and figure 7.

Performance under different row spacing

Data are presented in table 6, results revealed that grain yield showed statistically significant effect between row spacing. The lowest grain yield (0.95 t ha^{-1}) was observed in R_4 (30×15 cm) row spacing but R_2 (45 x 15 cm) and R_3 (60 x 15 cm) were found statistically at par with R_1.

Performance under different phosphorus levels:

From perusal of data results presented in table 6, revealed that grain yield showed statistically significant among themselves. Highest grain yield (1.40 t ha^{-1}) was observed in treatment P_1 (40 kg ha^{-1} Phosphorus), while lowest grain yield (1.31 t ha^{-1}) was observed in treatment P_2 (50 kg ha^{-1} Phosphorus) but P_3 (60 kg ha^{-1} phosphorus) was found statistically at par with P_1.

Interaction effect between different row spacing and phosphorus levels

Data are presented in figure 7, revealed that the interaction effect between different row spacing and phosphorus levels was observed that grain yield showed non-significant difference. Dry matter production and its transformation into economic yield is the ultimate outcome of various physiological, biochemicals, phonological and morphological events occurring in the plant system. Seed yield of a variety is the result of interplay of its genetic makeup and environmental factors in which plant grow. These results are in line with the findings of Agarcio [1] (1985) Panwar and Sirohi (1987) [19], Ali *et al.* (2010) [4]. Gupta *et al.* (2006) [12] also showed phosphorus fertilization was significant up to 60 kg ha^{-1} P_2O_5 for seed yields. Ahmad *et al.* (1986) [2] reported that the phosphorus application upto 60 kg ha^{-1} progressively and significantly enhanced the growth and yield parameters. Ali *et al.* (2001) reported that seed yield and yield parameters of mungbean were affected significantly by different planting patterns and maximum seed yield was obtained in 30 cm apart rows. Sarkar *et al.* (2004) [26] reported that greengram planted at a spacing of 30 x 10 cm significantly produced the highest seed yield. Hussain (1983) [13] concluded that application of phosphorus to legumes improves seed yield considerably.

Table 6: Effect of different row spacing and phosphorus levels on yield attributes of Greengram (*Vigna radiata*)

Treatments		Grain yield (t/h)
	Row spacing	
R_1	30 cm × 15 cm	1.06
R_2	45 cm × 15 cm	1.03
R_3	60 cm × 15 cm	1.04
R_4	75 cm × 15 cm	0.95.83
	F test	S
	SEd (±)	0.03
	CD (P= 0.05)	0.07
	Phosphorus level	
P_1	40 kg Phosphorus ha^{-1}	1.40
P_2	50 kg Phosphorus ha^{-1}	1.31
P_3	60 kg Phosphorus ha^{-1}	1.38
	F test	S
	SEd (±)	0.03
	CD (P= 0.05)	0.06

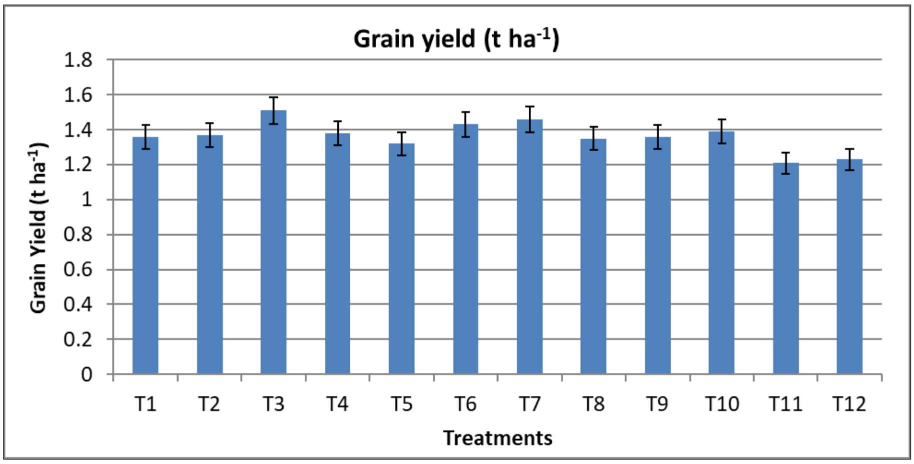

Fig 7: Interaction effect of different row spacing and phosphorus levels on yield attributes of Greengram (*Vigna radiata*)

Conclusion

The experiment was analyzed by using Randomized Block Design (Factorial) with twelve treatments and each treatment was replicated at three times in a plot size of 3×3 m^2 (9m^2). Phosphorus application of 60 kg ha^{-1} along with row spacing of 30×15 cm were significantly increase plant height, plant dry weight, number of branches per plant, number of nodules per plant, cumulative growth rate, relative growth rate and yield of green gram plant. It is concluded that green gram crop should preferably be grown with 60 kg of phosphorus along with 30×15 cm row spacing under agro-ecological conditions of Uttrakhand.

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