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Impact of spacings on growth, seed yield and economics of rajma (*Phaseolus vulgaris* L.) varieties in *rabi* season

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ABSTRACT

This study investigates the impact of plant spacing on the growth and yield of different French bean (Phaseolus vulgaris L.) varieties, addressing the need to understand the behavior of new genotypes under varying spacing conditions. Conducted during the rabi season of 2022-2023 at the Experimental Farm, Agronomy Section, College of Agricultural Biotechnology, Latur, the research aimed to find an optimal balance between vegetative and reproductive growth to enhance yield. The experimental design was a Factorial Randomized Block Design, examining nine treatments across two factors: spacing and variety. Among the varieties tested, Phule Rajma (V_1) showed superior growth and yield, followed by Arka Komal (V_3). A spacing of 45 cm × 30 cm was found to be most effective with Phule Rajma (V_1) achieving significantly highest seed yield (1905 kg ha^{-1}), gross monetary returns (₹. 1,23,839 ha^{-1}), net monetary returns (₹. 69,993 ha^{-1}) and a benefit-cost ratio of 2.30. Furthermore, wider spacing resulted in even greater seed yield (2148 kg ha^{-1}), gross returns (₹. 1,38,263 ha^{-1}), net returns (₹. 84,167 ha^{-1}) and a benefit-cost ratio of 2.56, compared to closer spacing. The genotype performance varies with location, season and management practices. The major constraint in the popularity of French bean in Maharashtra and Marathwada region is the lack of production technology for the cultivation of French bean. These findings highlight the significance of selecting appropriate spacing for optimizing French bean cultivation.

Keywords: *French bean, Phaseolus vulgaris, Plant spacing, Yield optimization, Vegetative growth, Reproductive growth, Varieties performance Rabi Season, Genotypes, Seed yield).*

Introduction

Pulses constitute an integral part of Indian vegetarian diet. The credit of green revolution recorded in sixties has been very much shared by cereals while the productivity of pulses remains unchanged. Besides with increase in population, there has been growing demand of pulses, however, the pulse production almost remained stagnant, thereby limiting protein availability to majority of vegetarian population. Pulses contribute about 14 per cent of the proteins of the Indian diet.

Atmospheric N fixation is a unique feature of leguminous crops, but French bean is an exception with a little or no N fixation. This is because of the absence of NOD gene regulator [1]. Being shy nodulation legume, it requires fairly large quantity of nitrogenous fertilizer [2] [3]. It is almost unable to fix atmospheric nitrogen symbiotically, hence responds well to N application [4]. French bean is a temperate region crop. French bean (*Phaseolus vulgaris* L.) (2n = 22) belongs to family Fabaceae, a non-traditional grain legume, has shown tremendous production potential during winter (*rabi*) season under North Indian conditions [5].

Timely sowing, high-yielding varieties, proper plant spacings, recommended fertilizer doses, irrigation, optimum seed rate and need based plant protection are the key factors in getting better yields. The work on varietal improvement is going on very fast in India.

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Therefore, every year or in alternate years new genotypes are being recommended. The performance of these new genotypes is necessary to be assessed in comparison with presently recommended varieties.

The genotype performance varies with location, season and management practices. The major constraint in the popularity of French bean in Maharashtra and Marathwada region is the lack of production technology for the cultivation of French bean. The production of French bean can be improved by growing high yielding and most adaptable varieties and intensive cultivation practices like use of suitable varieties, plant spacings, use of fertilizers etc. Among these, plant spacing and varieties are the most critical factors for getting higher productivity. During the last decade, suitable varieties for winter (*rabi*) season have been developed. The varieties show differential performance with the location and agronomic management. The varieties differ in plant type, due to this variation it is necessary to study the behaviour of these new genotypes under various plant spacings. Whether they perform better under lower, medium or higher spacing.

Material and Method

A field experiment was conducted at Research Farm, Department of Agronomy, College of Agriculture, Latur under Vasantrao Naik Marathwada Krishi Vidyapeeth Parbhani during *rabi* season of 2022-23. The experiment was laid out in a factorial randomized block design with three replications. It consists of nine treatment combinations comprising three varieties (V_1: Phule Rajma, V_2: Phule Varun, V_3: Arka Komal) and three spacings (S_1: 45 cm × 10 cm, S_2: 45 cm × 20 cm, S_3: 45 cm × 30 cm) The recommended dose of fertilizer was 120:60:60 NPK kg/ha applied during year of study.

The soil of the experimental plot was black clayey in texture, slightly alkaline in reaction having pH 7.59 with chemical composition such as very low in available nitrogen (112.90 kg ha^{-1}), very low in available phosphorous (14.69 kg ha^{-1}) and very high in available potassium (306.29 kg ha^{-1}). It was well drained and favorable for optimum crop growth. During this study various aspects of vegetative growth and seed yield of French bean were studied. Observations in respect growth and growth attributes like plant height, plant spread, number of branches $plant^{-1}$, number of leaves $plant^{-1}$, leaf area $plant^{-1}$ and in respect to yield and yield attributes like number of pod $plant^{-1}$, dry matter $plant^{-1}$ no of seeds pod^{-1}, seed yield $plant^{-1}$, dry weight of pod $plant^{-1}$, seed index, seed yield (kg ha^{-1}), straw yield (kg/ha), biological yield (kg/ha), harvest yield (%) were recorded from whole plot. All other recommended production and protection measures were uniformly adopted. The analysis was made from research data obtained on various variables were analyzed by the "Analysis of Variance Method" [6].

Result and Discussion

1. Effect of varieties

1.1 Growth attributes

The plant height was increased very fast up to 60 DAS and there after plant height was increased slowly up to harvest of crop. While dry matter accumulation increased at every stage of crop growth till maturity. The number of functional leaves and leaf area was increased up to 60 DAS and decreased towards maturity due to the senescence of leaves.

Phule Rajma higher was with number of branches $plant^{-1}$ (8.56), number of leaves $plant^{-1}$ (49.20) and leaf area $plant^{-1}$ (26.40 dm^2). The LAI was low in beginning (30 DAS) and reached to peak at 60 DAS followed with a declining trend towards harvest. The higher LAI values of these varieties might be due to optimum temperature and bright sunshine hours resulting in higher photosynthetic surface area [7].

Plant spread (39.00 cm) and dry matter accumulation $plant^{-1}$ (23.72 g) over variety Phule Varun where as it recorded comparable plant height (36.87 cm), number of branches $plant^{-1}$ (8.12), number of leaves $plant^{-1}$ (45.65), leaf area $plant^{-1}$ (24.64 dm^2), plant spread (36.67 cm) and dry matter accumulation $plant^{-1}$ (22.39 g) with Arka Komal (Table 1).

1.2 Yield and yield parameter

The effect of different varieties on yield and yield attributing character *viz.,* No. of pods $plant^{-1}$ dry wt. of pod $plant^{-1}$, seed index, seed yield (kg ha^{-1}) and harvest index (%) were considerably higher with variety Phule Rajma (V_1). Whereas number of seed pod^{-1}, seed yield $plant^{-1}$, straw yield (kg ha^{-1}) and biological (kg ha^{-1}) were recorded in variety Arka Komal (V_3). The lowest values of the all above-mentioned parameters were recorded with variety Phule Varun (Table 2).

On the basis of contribution to the yield of a varieties; the number of pods per plant having an important role so more number of pods per plant responsible for high yield and vice-versa [8][9].

The above discussion showed that the quantitative characters are controlled by the genetic makeup of the crop plant. The variation in the expression of the characters in comparison to its original description is mainly due to environmental factors. Therefore, during the selection of a variety/genotype for the recommendation of commercial cultivation, it is very necessary to take into consideration the environmental condition to the particular area/region.

1.3 Economics

The significantly higher gross monetary returns (₹. 1,23,839 ha^{-1}) and net monetary returns (₹. 69,993 ha^{-1}) were obtained by Phule Rajma with Arka Komal (₹. 1,12,859 ha^{-1} and ₹. 58,263 ha^{-1}) and Phule Varun (₹. 95,615 ha^{-1} and ₹. 41,769 ha^{-1}) respectively. The highest B:C ratio (2.30) was obtained with (V_1) Phule Rajma, whereas lowest B:C ratio (1.78) was obtained with Phule Varun (V_2) (Table 3).

2 Effect of spacing

2.1 Growth parameter

Considerable differences in growth attributes viz., plant height (cm), number of branches, number of leaves, leaf area (dm^2), dry matter (g), and plant spread (cm) were observed due to the different treatments.

The number of branches increased up to 60 DAS and were constant at harvest while plant height and dry matter accumulation increased at every stage of crop growth till maturity. The number functional leaves and leaf area increased up to 60 DAS and decreased towards maturity due to the senescence of leaves.

Adoption of spacing 45 cm × 30 cm recorded significantly higher plant height (38.26 cm) and number of branches $plant^{-1}$ (9.11). The lesser number of branches were recorded in S_1 (45 cm × 10 cm). This might be due to more space, nutrients, moisture and light available in wider spacing [10][11]. The spacing S_3 (45 cm × 30 cm) recorded a higher number of leaves $plant^{-1}$ (49.46) with the closer spacing.

Wider spacing has higher leaf area due to better aeration and optimum moisture conditions than closer spacing (45 cm × 10 cm). Similar result was observed by [12] Plant spread (39.67 cm) was higher in S_3. The plant geometry played a conspicuous role in dry matter production. Closer spacing S_1 (45 cm × 10 cm) produced the lowest total dry matter (g) per plant due to increase in crop competition for production resources [13]. The wider spacing has higher dry matter accumulation $plant^{-1}$ (25.03 g) than the 45 cm × 20 cm and 45 cm × 10 cm spacings (Table 1).

2.2 Yield and yield parameter

The effect of different spacing was found significant on yield and yield attributing character viz., No. of seeds pod^{-1}, No. of pod $plant^{-1}$, dry wt. of pod $plant^{-1}$, seed yield $plant^{-1}$, seed yield (kg ha^{-1}), straw yield (kg ha^{-1}) and biological yield (kg ha^{-1}) were significantly higher with the adoption of 45 cm× 30 cm wider spacing. Wider spacing has more no. of pod $plant^{-1}$ This might be because of more space available between the plants and less competition area in line.[14][15]. The lowest values of the above-mentioned parameters were recorded with a narrow spacing of 45 cm × 10 cm (Table 2).

2.3 Economics

The significantly higher gross monetary returns (₹. 1,38,263 ha^{-1}) and net monetary returns (₹. 84,167 ha^{-1}) were obtained by sowing of rajma at a spacing of 45 cm × 30 cm over 45 cm × 10 cm or 45 cm × 20 cm. The higher B: C ratio (2.56) was obtained with the adoption of 45 cm × 30 cm. Lowest gross monetary returns (₹. 86,741 ha^{-1}), net monetary return (₹. 32,645 ha^{-1}) and B: C ratio (1.60) was obtained with the narrow spacing of 45 cm × 10 cm. (Table 3)

Among the different varieties of rajma, Phule Rajma (V_1) recorded higher growth and yield attributes followed by (V_3) Arka Komal. Sowing of rajma at a spacing of 45 cm × 30 cm recorded higher growth and yield attributes of rajma.

Conclusion

On the basis data of field experiment performed during *rabi* 2022-23, it could be concluded that the, application of varieties and spacings on growth and growth as well as yield and yield attributes of French beans influenced significantly. Both factors affected seed yield and growth of French beans significantly. Among the different varieties Phule Rajma (V_1) (Higher plant height, plant spread, no of branches plant^{-1}, no of functional leaves, leaf area, dry matter plant^{-1}, no of pods plant^{-1}, dry weight of pod plant^{-1}, seed index, seed yield (kg/ha), harvest index %, gross monetary returns (GMR), net monetary returns (NMR), and B:C ratio) recorded higher growth and yield attributes followed by (V_3) Arka Komal (Higher no. of seeds pod^{-1}, seed yield plant^{-1}, straw yield plant^{-1}, biological yield). Sowing of rajma at a spacing of 45 cm × 30 cm recorded higher growth and yield attributes of rajma (Higher plant height no. of branches, no. of leaves plant^{-1}, plant spread, dry matter plant^{-1}, no, pods plant^{-1}, dry weight of plant^{-1}, dry wt. of pod plant^{-1}, seed yield plant^{-1}, seed yield (kg ha^{-1}), straw yield, biological yield, harvest index, gross monetary returns, net monetary returns, and B:C ratio). Among the treatment combination, it is advisable to sow the Phule Rajma variety at a spacing of 45 cm × 30 cm during *rabi* season for better yield and net profit per unit area. (Table 4)

Future scope of the study

Further investigation needs to conduct for the field trial in the research farm in the different region of the country as the French bean genotypes / varieties / germplasm and spacings used in this study which is widely recommended in the different states in India to increase the production potential of farmers. The genotype performance varies with location, season and management practices. The full yield potential of individual variety is achieved when sown at wider spacing. Yield per plant is decreases gradually as the plant population per unit area is increased. Plant height increases within increase in plant population due to competition for light. An increase in plant height is responsible for better interception of light due to exposure of individual leaves at wider vertical interval. Leaf thickness and leaf orientation is also changed.

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Conflict of Interest

The authors declare that there is no conflict of interest.

Table 1: Growth and growth attributes of French bean

Treatment	Plant height (cm)	Plant spread (cm)	No of branches plant^{-1}	number of functional leaves plant^{-1}	leaf area plant^{-1} (dm^2)	Total dry matter plant^{-1}
Varieties (V)						
V_1: Phule Rajma	38.74	39.00	8.56	49.20	26.40	23.72
V_2: Phule Varun	32.48	32.11	6.55	42.35	22.73	16.82
V_3: Arka Komal	36.87	36.67	8.12	45.65	24.64	22.39
SEm±	0.85	0.84	0.22	1.23	0.61	0.73
CD at 5%	2.56	2.53	0.67	3.71	1.85	2.19
Spacing (S)						
S_1: 45 cm × 10 cm	35.18	33.78	7.01	43.65	23.26	18.09
S_2: 45 cm × 20 cm	34.64	34.33	7.11	44.08	25.02	19.81
S_3: 45 cm × 30 cm	38.26	39.67	9.11	49.46	25.48	25.03
SEm±	0.85	0.84	0.22	1.23	0.61	0.73
CD at 5%	2.56	2.53	0.67	3.71	1.85	2.19
Interaction (V×S)						
SEm±	1.48	1.47	0.39	2.14	1.07	1.27
CD at 5%	NS	NS	NS	NS	NS	NS
General Mean	36.03	35.93	7.74	45.73	24.59	20.98

Table 2: Yield and yield attributes of French bean

Treatment	No. of pods plant^{-1} (g)	No. of seeds pod^{-1}	Dry. wt. of pod plant^{-1} (g)	Seed yield plant^{-1} (g)	Seed index (g)	Seed yield (kg ha^{-1})	Starw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)
A: Varieties (V)									
V_1: Phule Rajma	28.00	5.31	20.38	14.44	34.81	1905	2124	4029	47.29
V_2: Phule Varun	21.27	5.23	19.19	14.27	33.06	1471	2363	3834	38.37
V_3: Arka Komal	25.67	5.53	20.28	14.64	31.99	1810	2428	4239	42.71
SEm±	0.85	0.16	0.506	0.37	0.91	49.35	77.91	64.43	-
CD at 5%	2.56	NS	NS	NS	NS	147.95	233.55	193.14	-
B: Spacing (S)									
S_1: 45 cm × 10 cm	22.78	5.50	19.81	13.80	33.11	1370	2163	3533	38.77
S_2: 45 cm × 20 cm	23.33	5.33	19.91	14.56	32.38	1669	2291	3959	42.14
S_3: 45 cm × 30 cm	28.82	5.24	20.14	14.99	34.37	2148	2461	4609	46.61
SEm±	0.85	0.16	0.506	0.37	0.91	49.35	77.91	64.43	-
CD at 5%	2.56	NS	NS	1.11	NS	147.95	233.55	193.14	-
C: Interaction (V×S)									
SEm±	1.48	0.28	0.88	0.64	1.59	85.49	134.95	111.60	-
CD at 5%	NS	NS	NS	NS	NS	NS	NS	NS	-
General Mean	24.98	5.36	19.95	14.45	33.29	1729	2305	4034	43.00

Table 3: Economics of French bean

Treatment	Seed yield (kg ha^{-1})	Gross Monetary Returns (₹ ha^{-1})	Cost of cultivation (₹ ha^{-1})	Net monetary returns (₹ ha^{-1})	B:C ratio
A: Varieties (V)					
V_1: Phule Rajma	1905	123839	53846	69993	2.30
V_2: Phule Varun	1471	95615	53846	41769	1.78
V_3: Arka Komal	1810	112859	54596	58263	2.07
SEm±	49.35	3088.75	-	3088.75	-
CD at 5%	147.95	9259.10	-	9259.10	-
B: Spacing (S)					
S_1: 45 cm × 10 cm	1370	86741	54096	32645	1.60
S_2: 45 cm × 20 cm	1669	107309	54096	53213	1.98
S_3: 45 cm × 30 cm	2148	138263	54096	84167	2.56
SEm±	49.35	3088.75	-	3088.75	-
CD at 5%	147.95	9259.10	-	9259.10	-
C: Interaction (V×S)					
SEm±	85.49	5349	-	5349	-
CD at 5%	NS	NS	-	NS	-
General Mean	1729	110771	56675	57675	2.04

Table 4: An extract of relevant information showing effect of different treatments on growth and yield attributes of french bean

Sr. No.	Particulars	Treatments					
		Varieties			Spacing		
		V_1	V_2	V_3	S_1	S_2	S_3
01.	Mean plant height at harvest (cm)	38.74	32.48	36.52	35.18	34.64	37.92
02.	Mean plant spread at 60 DAS	39	32.11	36.67	33.78	34.33	39.67
03.	Mean number of branches plant^{-1} at 60 DAS	8.56	6.55	8.12	7.01	7.11	9.11
04.	Mean number of functional leaves plant^{-1} at 60 DAS	49.2	42.35	45.65	43.65	44.08	49.46
05.	Mean leaf area plant^{-1} at 60 DAS (dm^2)	26.4	22.73	24.64	23.26	25.02	25.48
06.	Mean total dry matter plant^{-1} at harvest (g)	23.72	16.82	22.39	18.09	19.81	25.03
07.	Mean number of pod plant^{-1}	38	31.27	35.67	32.78	33.33	38.82
08.	Mean number of seed pod^{-1}	5.31	5.23	5.53	5.5	5.33	5.24
09.	Mean pod yield plant^{-1}	18.38	17.19	18.28	17.81	17.91	18.14
10.	Mean seed yield plant^{-1} (g)	14.44	14.27	14.64	13.8	14.56	14.99
11.	Mean seed index weight (g)	34.81	33.06	31.99	33.11	32.38	34.37
12.	Mean seed yield (kg ha^{-1})	1905	1471	1810	1370	1669	2148
13.	Mean straw yield (kg ha^{-1})	2169	2351	2409	2184	2310	2435
14.	Mean biological yield (kg ha^{-1})	4074	3822	4220	3554	3879	4583
15.	Mean harvest index (%)	46.76	38.49	42.9	38.54	41.94	46.87

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