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Effect of different spacings on growth and yield of lima bean (*Phaseolus lunatus* L.)

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Abstract
A field experiment was conducted at Main Garden, Department of Horticulture, Dr. P.D.K.V. Akola during 2015-2016 to study the influence of seven different spacing i.e. 0.75m x 0.75m.1.0m x 0.5m, 1.0m x 0.75m, 1.0m x 1.0m, 1.5m x 0.5m, 1.5m x 0.75m and 1.5m x 1.0m on growth and yield of lima bean. The results revealed that all the growth and yield parameters were significantly influenced by various spacing. The growth parameters like plant height, length of primary branch, length of secondary branch was found to be maximum in spacing 0.75m x 0.75m whereas trifoliate leaves per plant, primary branches per plant, secondary branches per plant and leaf area was obtained maximum in the spacing 1.5mx 1.0m. As regards the yield and yield contributing parameters number of pods per cluster, length of pod, width of pod, seeds per pod, weight of fresh pod, weight of fresh seed, weight of dry seed, weight of dry seed per pod, weight of 100 dry seeds, seed yield per plant and seed yield per hectare were found to be significantly maximum in the plant spacing of 1.0m x 0.75m.

Keywords: Growth, yield, spacing, seed yield

Introduction
Lima bean (*Phaseolus lunatus* L) is an interesting crop belonging to the family Leguminaceae that grows in warm season. It is originated in or near Guatemala (Choudhary, 2006) [3]. This is the native of Central America, now widely naturalized in the tropics and it is also known by the names of butter bean or double bean.

It is found in humid, sub -humid and semi arid tropical climate as well as warm temperate climate. There are wild and cultivated types of *Phaseolus lunatus*, generally reffered to as *Phaseolus lunatus* var. silvester Baudet and *P.lunatus* var. lunatus respectively. Lima beans sprouts, leaves, young pods and green seeds are edible and eaten as vegetables. The dry seeds are eaten boiled, fried, ground into powder and baked and used in soups and stews.

Lima beans are tender annuals grown for their flat, crescent oval shaped seeds. There are two types of lima beans; bush and pole or vine varieties. Bush types grow to about 2 feet tall and tend to have smaller seeds; they bear more quickly than pole lima bean varieties. Lima beans are sometimes called potato limas. Large-seeded limas are often sold as dry beans. Lima beans have pale green pods that vary from 3-4 inches long to 5-8 inches long depending upon variety.

Lima bean seeds are eaten and not the pods. Leaves are commonly composed of three leaflets and flowers are white. Bush lima bean varieties are ready for harvest from 60 to 80 days from sowing while pole lima bean varieties are ready for harvest in 85 to 90 days.

Lima beans are very nutritious beans, high in protein, thiamine, riboflavin and iron. They contain about 25% protein in the dry matter, a value comparable to that of peas and cowpeas.

Good agronomic practices such as spacing, time of sowing and fertilizer application have been associated to high biological and economic yield (Onwueme, 1990) [13].

Spacing is required to ensure proper utilization of inputs like nutrients, moisture and light resulting in better production performance of the plant. Also maximum yield could be obtained mainly by providing the most optimum plant population per unit area (Shrikanth *et al*, 2008) [17]. Hence the present study was undertaken find out the suitable plant spacing for optimum growth and yield of lima bean.

Materials and Methods

The present study entitled "Effect of different spacings on growth and yield of lima bean (*Phaseolus lunatus* L.)" was carried out at Main Garden, University Department of Horticulture, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, during the *Kharif* season of 2015-16. The experiment consisted of seven different spacing to study the effect of these spacing on growth and yield of lima bean.

The topography of the land under experiment was fairly uniform. Soil of the experimental plot was medium black, well drained with uniform texture with gentle slope.

Lima bean cv. AKLB-2 is a high yielding variety recommended for vidarbha region of Maharashtra. This variety is developed by Dr. PDKV Akola with high yielder and earliness with good yield potential. AKLB-2 is a tender annual grown for their large flat, crescent, oval shaped seeds. Observations were recorded for growth parameters like height of plant (cm), trifoliate leaves per plant, Primary branches per plant, Secondary branches per plant, length of primary branch (cm), length of secondary branch (cm), leaf area (cm^2) and flowering parameters like Days to first flowering, Days to 50% flowering, Inflorescence per plant and Flowers per and collected data which was statistically analyzed as per method suggested by Pansey and Sukhatme (1985) [14].

Result and Discussion

Growth Parameters

Plant Height

The treatment S_1-0.75m x 0.75m recorded significantly maximum plant height of 296.53 cm at 120 days after sowing which was followed by S_2-1.0m x 0.5m. Whereas plant spacing of S_7-1.5m x 1.0m recorded minimum plant height of 205.66 cm at 120 days after sowing.

The results revealed that plant height increased with decrease in plant spacing. This might be due to higher competition for space, moisture, light, nutrients resulting taller plants under narrow plant geometry due to higher absorption and utilization of plants nutrients, rapid meristematic activity and growth in terms of plant height.

These results are in confirmation with the findings of Edje *et al.* (1971) [5], Kumar *et al.* (1997) [9], Moniruzzaman *et al.* (2009) [10], and Joshi *et al.* (2015) [8] for Indian bean.

Trifoliate leaves per plant

Plant spacing of S_7-1.5m x 1.0m recorded maximum number of trifoliate leaves per plant 127.20 at 120 days after sowing which was followed by S_4-1.0m x 1.0m and minimum in the plant spacing S_1-0.75m 0.75m.

It might be due to sufficient availability of essential resources such as nutrients, moisture and space to wide spaced plants compared to close spaced plants. This is in agreement with the findings of NareshBabu (2000) [12], Pawar *et al* (2007) [15], Achakzai and Panizai (2007).

Primary branches per plant

Lima bean planted at the spacing of S_7-1.5m x 1.0m recorded significantly maximum number of primary branches per plant of 19.86 at 120 days after sowing which was followed by S_4-1.0m x 1.0m. However, minimum primary branches per plant (15.86) were observed in the plant spacing S_1-0.75m x 0.75m.

It is well evident from the above data that, increase in spacing from closer spacing (S_1) to wider spacing (S_7) increased the number of primary branches per plant. More number of primary branches per plant under wider spacing might be due to the better vegetative growth of plants in wider spacing which resulted in more horizontal growth and plant canopy area due to its less population density and competition compared to those in closer spacing.

Secondary branches per plant

Highest number of secondary branches were recorded to be significantly maximum (39.6) when lima bean was planted at the spacing of S_7-1.5m x 1.0m which was followed by S_4-1.0m x 1.0m. Whereas plant spacing of S_1-0.75m x 0.75m recorded minimum secondary branches per plant.

More number of secondary branches was observed in widely spaced crop because of more vegetative and horizontal growth due to less population density and competition for nutrients and water as compared to those in closely spaced crop. These results are in conformation with the findings of Ghosh and Bandopadhyay (2008) [6] and Joshi and Rahewar (2014a) [7].

Length of primary branch

The treatment S_1-0.75m x 0.75m recorded significantly maximum length of primary branch of 224.16cm at 120 days after sowing and was followed by the plants spaced at S_2-1.0m x 0.5m. However minimum length of primary branch was observed in the plant spacing S_7-1.5m x 1.0m.

It is well evident from the above data that the length of primary branches was increased with decrease in plant spacing. This is confirmation with the findings of Srikanth *et al.* (2008) in lablab bean. Increase in shoot length in closely spaced plants may be attributed due to higher plant population density resulting in less canopy area and more vertical growth due to competition for space, light, nutrients and moisture.

Length of Secondary branch

The length of secondary branch was found to be significantly maximum in the plant spacing S_1-0.75m x 0.75m i.e. 135cm at 120 days after sowing and it was followed by S_2-1.0m x 0.5m. However length of secondary branch was found minimum in the plant spacing S_7-1.5m x 1.0m at all growth stages.

It is observed from the data that lima bean planted at closer spacing exhibited more shoot length of secondary branches as compared to wider spacing. This may be due to the fact that higher plant population density at closer spacing resulting in less space, light, nutrients and moisture uptake which finally results into more vertical growth of plants.

Leaf Area (cm^2)

Highest leaf area ($29.34cm^{2)}$ was recorded in the plants spaced at the treatment S_7-1.5m x 1.0m at 120 days after sowing which was at par with S_4. However minimum leaf area of $23.43cm^2$ was observed in the plant spacing S_1-0.75m x 0.75m.

The results revealed that lima bean planted at wider spacing recorded maximum leaf area. This might be due to the less population density of wider spacing resulting in less competition for essential resources such as nutrients, moisture and space and more interception of sunlight within the plant canopy. This is in agreement with the findings of Pawar *et al.* (2007) [15] and Deka *et al.* (2015) [4].

Yield parameters

Number of pods per cluster

Ssignificant differences were observed for number of pods per cluster as influenced by different plant spacing of lima bean. The number of pods per cluster (5.21) was found to be

superior in the spacing S_3-1.0m x 0.75m followed by S_4-1.0 m x 1.0 m and minimum in S_5-1.5m x 0.5m (3.25).
The present findings confirm that optimum plant spacing is required for obtaining maximum number of pods per cluster.

Length of pod (cm)
Ssignificant differences were observed in length of pod as influenced by different plant spacing. Significantly maximum length of pod (10.73cm) was observed in spacing S_3 -1.0m × 0.75 m followed by spacing S_4-1.0m x 1.0 m (9.68cm) and minimum pod length occurred in spacing S_5 -1.5m x 0.5m.
The present findings suggests that pod length was reduced with too closer and too wider spacing whereas it was increased in the plant spacing of 1.0m x 0.75m which might be due to optimum vegetative growth and uptake of nutrients and moisture from soil. In contradictory Achakzai and Panizai (2007) [1] has reported maximum pod length at narrower row spacing of 25cm in mash bean while Joshi and Rahewar (2014) [7] in wider row spacing of 60cm in Indian bean however the results were non-significant.

Width of pod (cm)
Width of pod as influenced by different spacing was found to be significant in the study. Significantly maximum width of pod (2.27cm) was observed in spacing S_3-1.0m x 0.75 m followed by S_4-1.0m x 1.0 m (2.08) whereas minimum (1.94) width of pod occurred in spacing S_5 -1.5m x 0.5 m.
The results are in agreement with Samnotra *et al.* (1998) [16] who reported significant effect of row spacing on width of pod.

Seeds per pod
Significant differences were observed for seeds per pod as influenced by different plant spacing in lima bean. The present results revealed that too closer and too wider spacing resulted in less number of seeds per pod. Whereas the plant spacing of S_3 and S_4 showed maximum number of seeds per pod and minimum number of seeds per pod was observed in the spacing S_7.This is confirmation with the findings of Pawar *et al*. (2007) [15].

Weight of fresh pod
Significant maximum weight of pod (7.74g) was observed in plant spacing S_3-1.0m x 0.75m which was followed by S_4-1.0m x 1.0m (7.46 g) and minimum (6.58g) weight of pod occurred in spacing S_6 -1.5m x 0.5 m.
The data revealed that highest fresh pod weight was obtained in the plant spacing of S_3-1.0m x 0.75m whereas too close and wider spacing reduced the pod weight. Similar findings were reported by Pawar *et a.l* (2007) [15] whereas Mozumdar *et al.* (2007) [11] found the effect of spacing on pod weight to be non-significant.

Weight of fresh seed
Weight of fresh seed as influenced by different plant spacing was found to be significant. The weight of fresh seed (2.28g) was significantly maximum in plant spacing S_3-1.0m x 0.75m followed by (1.75) in S_4-1.0m x 1.0m. However minimum weight of fresh seed was observed in the plant spacing S_7-1.5m x 1.0m.

Weight of dry seed (g)
Weight of dry seed (g) due to different spacing was found to be statistically significant. Weight of dry seed (1.72g) was found significantly superior in S_3-1.0m x 0.75m followed by (1.34 g) in S_4-1.0m x 1.0m and minimum (0.90g) in plant spacing S_7-1.5m x 1.0m.
The results revealed that the optimum plant spacing of S_3-1.0m x 0.75m recorded highest dry weight of seed which may be attributed due to more weight of fresh seeds in S_3.

Weight of dry seed per pod (g)
Weight of dry seed per pod (g) as influenced by different spacing were found to be significant. Weight of dry seed per pod (4.84 g) was found to be significantly superior among all the treatment in S_3-1.0m x 0.75m (4.83 g) followed by (3.96 g) in S_4-1.0m x 1.0m and minimum (2.73 g) in S_7-1.5m x 1.0m.
The results revealed that weight of dry seed per pod was increased in optimum plant spacing and not in too closer or wider spacing. This might be due to the optimum vegetative growth and reproductive parameters occurred in this spacing resulting in optimum plant population of lima bean with better utilization of space, light, moisture and nutrients. However it is not in agreement with the findings of Akhtar *et al*. (2012) [2] who found non-significant effect of row spacing on number of seed**.**

Weight of 100 dry seeds (g)
Weight of 100 dry seeds (g) as influenced by different spacing was found to be significant. Weight of 100 dry seeds (91.66g) was significantly superior among all the treatment in S_3-1.0m x 0.75m followed by (87g) in S_4-1.0m x 1.0m and minimum (77.66g) in S_7 -1.5m x 1.0m
It is well evident that weight of 100 dry seeds decreased in too closer and wider plant spacing whereas it was maximum at a plant spacing of S_3-1.0m x 0.75m. This might be due to the increased dry seed weight of lima bean in the same treatment. Similar results were reported by Joshi and Rahewar (2014[b]).

Seed yield per plant (g)
Significant differences were observed for seed yield per plant as influenced by different spacing. Significantly maximum seed yield per plant (251.66 g) was found in the treatment S_3-1.0m x 0.75m which was at par (248g) in S_4-1.0m x 1.0m and minimum (112g) in S_2-1.0m x 0.5m.
The present results revealed that seed yield per plant was reduced in closer and wider spacing and maximum in optimum plant spacing of 1.0m x 0.75m. This might be due to optimum vegetative and reproductive growth of plants spaced at 1.0m x 0.75m which is reflected in terms of more number of inflorescence per plant, flowers per inflorescence, weight of seeds and pods per plant.

Seed yield per hectare (q)
Seed yield per hectare (q) as influenced by different spacing was found to be significant. The seed yield per hectare (33.5q) was found significantly superior in the treatment S_3-1.0m x 0.75m followed by (27q) in S_4-1.0m x 1.0m and minimum (14.71q) in S_7-1.5m x 1.0m.
It is well evident from the present findings that seed yield per hectare was maximum in the optimum plant spacing than closer and wider spacing. Maximum seed yield per hectare may be attributed due to the optimum vegetative and reproductive growth of plants spaced at 1.0m x 0.75m with superior flowering and seed parameters. This is in confirmation with Achakzai and Panizai (2007) [1] who reported positive correlations of number of pods per plant and seed yield per plant with grain yield per hectare. However too closer spacing resulted in less yield per hectare. Besides poor

flowering parameters more incidences of pest and diseases in dense canopy of closely spaced plants may have resulted in less yield per hectare. Whereas widely spaced plants resulted in less yield due to accommodation of less number of plants per hectare i.e, less plant density.

Table 1: Growth of lima bean as influenced by plant spacing.

Treatments	Plant height at 120 DAS (Cm)	Trifoliate leaves/plant At 120 DAS	Primary branches/ plant at 120 DAS	Secondary branches/ plant at 120 DAS	Length of Primary branch at 120 DAS	Length of secondary branches at 120 DAS	Leaf area (cm^2) 120 DAS
S_1-0.75mx 0.75m	296.53	110.24	15.86	31.53	224.16	135.00	23.43
S_2-1.0m x 0.5m	281.86	117.53	16.06	32.80	200.86	130.00	26.38
S_3-1.0m x 0.75m	258.33	116.80	17.00	36.20	187.50	125.33	25.18
S_4-1.0mx 1.0m	230.53	120.80	18.80	37.93	164.51	120.00	28.65
S_5-1.5m x 0.5m	226.53	113.23	17.80	37.00	157.51	116.00	26.29
S_6-1.5m x 0.75m	240.20	115.16	16.53	34.33	152.12	111.66	25.04
S_7-1.5m x 1.0m	205.66	127.20	19.86	39.60	142.68	108.00	29.34
'F' test	Sig.	Sig	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)±	1.00	0.48	0.18	0.18	1.31	0.69	0.43
CD at 5%	3.12	1.36	0.57	0.58	4.10	2.16	1.36

Table 2: Yield of lima bean as influenced by plant spacings.

Treatments	No.of pods/Cluster	Length of pod (cm)	Width of pod (cm)	Wt.of dry seed (g)	Wt. of dry seed/pod (g)	Wt.of 100 dry seeds	Seed yield/plant (g)	Seed yield/ha (q/ha)
S_1-0.75mx 0.75m	3.51	7.74	1.95	0.98	2.96	81.33	120.00	21.33
S_2-1.0m x 0.5m	3.45	7.81	2.00	0.99	2.83	79.33	112.00	22.40
S_3-1.0m x 0.75m	5.21	10.73	2.27	1.72	4.84	91.66	251.66	33.50
S_4-1.0mx 1.0m	3.76	9.68	2.08	1.34	3.96	87.00	248.00	27.00
S_5-1.5m x 0.5m	3.25	7.62	1.93	1.21	3.54	82.33	165.00	20.00
S_6-1.5m x 0.75m	3.50	8.34	1.98	1.11	3.34	84.66	224.33	19.93
S_7-1.5m x 1.0m	3.46	8.07	1.96	0.90	2.73	77.66	220.66	14.71
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SE(m)±	0.09	0.36	0.04	0.07	0.20	0.85	1.72	0.81
CD at 5%	0.30	1.01	0.12	0.24	0.64	2.66	4.82	2.26

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