Mysore J. Agric. Sci., 58 (4) : 375-388 (2024)

Influence of Planting Geometry and Nutrient Levels on Growth, Yield, Economics and Nutrient uptake of Field Bean

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Received : July 2024
Accepted : August 2024

Abstract

A field experiment was conducted to investigate performance of field bean with varying spacing and fertilizer levels at ZARS, UAS, GKVK, Bengaluru. The experiment consisted of two factors *i.e.,* spacing and fertilizer each at four different levels. Among spacing levels, growth parameters such as number of branches (6.9), number of leaves (17.5), leaf area (906.5 cm^2 plant^{-1}), dry matter production (31.1 g plant^{-1}) were recorded significantly higher in 60 cm × 30 cm spacing (S_4). Similarly yield parameters, pod length (5.4 cm), number of seeds pod^{-1} (4.2), number of pods plant^{-1} (25.3), seed yield plant^{-1} (16.1 g) were found significantly higher in 60 cm × 30 cm spacing whereas, higher seed yield (848.7 kg ha^{-1}) was recorded in 45 cm × 15 cm spacing (S_1). Among different fertilizer levels higher number of branches (6.8), number of leaves (16.5), leaf area (897.2 cm^2 plant^{-1}), dry matter production (28.6 g plant^{-1}) and higher yield parameters namely pod length (5.4 cm), number of seeds pod^{-1} (4.22), number of pods plant^{-1} (24.7) and seed yield (764.6 kg ha^{-1}) were recorded in 150 per cent RDF application (F_4). These parameters were found on par with 125% RDF (F_3). Among the treatment combinations between spacing and fertilizer levels S_1F_4 (45 cm × 15 cm spacing and 150% RDF) recorded higher seed (918.2 kg ha^{-1}) yield. Among spacing levels higher nitrogen, phosphorus and potassium uptake was recorded (53.20, 6.78 and 48.52 kg ha^{-1}, respectively) with spacing of 45 cm × 15 cm. Among different fertilizer levels higher nitrogen, phosphorus and potassium uptake (52.36, 6.68 and 48.17 kg ha^{-1}, respectively) was recorded in application of 150% RDF level compared with other levels of application.

Keywords : Field bean, Planting geometry, Fertilizer level, Growth, Yield, Economics of field bean

Pulses form an important component in diet of major population in the world and particularly in India. India being the largest producer of pulses, is also a largest importer of pulses annually. Due to vast 1.3 billion population, meeting their nutritional requirements and low productivity from the existing pulse cultivation has led for dependence on imports for domestic requirements. Maintenance of self-sufficiency and food security is essential, especially in case of pluses for a nation like India to meet domestic requirements and to end malnutrition. Climate change also poses an immense threat to global agriculture and food security. Adaption of climate resilient crops and good management practices supported by scientific community, can enhance the productivity of pulses over a period of time. Climate hardy crops like field bean can help in mitigating climate change and its adverse effect on agriculture. Adaptability of field bean to diverse climate and soils, makes the crop to yield better even in stress conditions than general pulse crops.

Field bean (*Dolichos lablab* L.) is bushy to spreading type and belongs to family *Fabaceae*. It is commonly known as Dolichos bean, Hyacinth bean, Indian bean, Sem, Avare *etc*., Dolichos bean is cultivated widely across the world under diverse climatic conditions as high genetic diversity is noticed within crop. It is a multi-purpose crop, as around the world it is cultivated for various purposes such as for vegetable, pulse grain, fodder, as cover crop and also as green manure crop (Ramesh and Byregowda, 2016). Pulse crops like field bean which can fix atmospheric nitrogen effectively also requires starter dose of nitrogen during initial stages. Moreover, in most pulse crops reduction in nitrogen fixation is noticed at pod formation and development stages. This may be due to competition between developing pods and root nodules for available photosynthates, since N fixation is also an energy demanding process. Field bean unlike other pulses has diverse variability and varied growth habit such as multiple flushes of flowering, succulent pod at early stage and longer plant greenness after pod maturity compared to other pulses. These diverse growth habits of field bean crop need investigation under varied management practices, which can help in establishing valid recommendations. Therefore, the study was conducted to access influence of different levels of spacing and fertilizers on growth, yield, economics and nutrient uptake of field bean.

Material and Methods

The experiment was conducted at Zonal Agricultural Research Station, Gandhi Krishi Vignana Kendra (GKVK), University of Agricultural Sciences, Bangalore (13 07' North latitude, 77 56' East longitude and 924 m above mean sea level altitude) under Eastern Dry Zone (ACZ- V) of Karnataka. The soil of experimental site is red sandy loam in texture with slightly acidic in pH (6.20), electric conductivity of 0.18 dS m^{-1} and organic content was 0.24 per cent. The soil is low in available nitrogen and medium in phosphorus and potassium availability. The experiment was laid in RCBD (factorial design) comprising of two factors spacing and fertilizers, each at four levels. All recommended package of practices followed during experimentation were as per PoP of UAS, Bangalore. The recommended spacing is 45 cm × 15 cm and dose of fertilizer (RDF) was 25:50:20 kg N, P_2O_5 and K_2O ha^{-1}. Spacing levels comprised of S_1- 45 cm × 15 cm, S_2- 45 cm × 15 cm, S_3- 60 cm × 15 cm and S_4- 60 cm × 15 cm. Fertilizer levels comprised of F_1- 75 per cent RDF, F_2- 100 per cent RDF, F_3- 125 per cent RDF and F_4- 150 per cent RDF. Variety used was Hebbal Avare- 4 (HA- 4) which is photo-insensitive and has determinate growth. The required quantity of seeds for each treatment were sown based on the spacing and the recommended seed rate of 30 kg ha^{-1} with 45 cm x15 cm as per UAS-B PoP. Pre-calculated quantities of fertilizers doses in the form of urea, diammonium phosphate and muriate of potash were applied at once as basal dose to each treatment plot. The crop was sown in the month of August and rainfall (881.2 mm) received during the crop period was adequate for growth. Plot size used for experiment was 5.4 m × 3.3 m which varied as per respective spacing followed.

Plant height, number of branches, leaves, leaf area and dry matter production per plant at harvest stage were recorded from five randomly selected plants in each treatment plot. Yield parameters such as pod length, number of seeds per pod, pods per plant, seed yield per plant were recorded at harvest from five randomly selected plants in each plot. On the basis of seed weight obtained from net plot, seed yield was calculated and expressed in kg ha^{-1}.

The soil from each treatment were drawn after harvest of the crop and analysed for available nitrogen, phosphorus and potassium and these were determined by alkaline permanganate method as outlined by Subbiah and Asija (1956), Olsen's method using spectrophotometer and neutral normal ammonium acetate extractant using flame photometer as outlined by Jackson (1973), respectively. The plants from each treatment were collected, processed and used for nutrient uptake analysis. Nitrogen content was estimated by modified Micro-Kjeldhal's method as outlined by Jackson (1973) and expressed in per cent. The data obtained was subjected to statistical analysis by analysis of variance (ANOVA) to test the significance of difference among the treatments by 'F' test and a conclusion was drawn at 5 per cent probability level.

Results and Discussion

Growth Parameters of Field Bean as Influenced by Spacing and Fertilizer Levels

Growth parameters of field bean as influenced by different spacing and fertilizer levels is presented in Table 1.

Plant Height (cm)

At harvest stage, different spacing levels had significant influence on plant height. Significantly higher plant height (85.61 cm) was recorded in 45 cm × 15 cm spacing. Higher plant height under closer spacing (S_1) might be attributed due to higher plant population per unit area and close encounter by plants in terms of spatial interaction with each other, which has resulted in an increased plant height in order to intercept solar radiation for photosynthesis. Similar results were reported by Sabar (2021).

Significantly higher plant height at harvest (85.38 cm) was observed in 150 per cent RDF (F_4) level. Increase

Table 1

Effect of spacing and fertilizer levels on growth parameters of field bean at harvest

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of leaves plant^{-1}	Leaf area (cm^2 plant^{-1})	Dry matter (g plant^{-1})
Spacing levels (S)					
S_1: 45 cm × 15 cm	85.61	5.97	12.50	673.25	21.33
S_2: 45 cm × 30 cm	79.88	6.52	14.36	847.07	29.19
S_3: 60 cm × 15 cm	83.22	6.25	13.17	818.36	25.76
S_4: 60 cm × 30 cm	77.80	6.91	17.58	906.54	31.14
S.Em ±	1.62	0.16	0.64	50.76	1.28
C.D. at 5%	5.40	0.55	2.12	169.29	4.45
Fertilizer levels (F)					
F_1:75% RDF	78.29	5.88	12.63	681.71	25.16
F_2:100% RDF	79.98	6.22	13.44	784.70	26.28
F_3:125% RDF	82.86	6.66	15.02	881.52	27.34
F_4:150% RDF	85.38	6.89	16.53	897.28	28.65
S.Em ±	1.62	0.16	0.64	50.76	1.28
C.D. at 5%	4.68	0.47	1.83	146.61	3.69
Interactions (S × F)					
$S_1 F_1$	81.78	5.27	11.37	545.73	19.41
$S_1 F_2$	83.82	5.93	11.43	611.11	20.9
$S_1 F_3$	87.70	6.27	12.73	796.90	22.00
$S_1 F_4$	89.13	6.43	14.50	739.27	23.01
$S_2 F_1$	76.76	6.07	12.93	731.59	27.50
$S_2 F_2$	78.58	6.33	13.87	747.17	28.66

Continued....

Table 1 Continued....

Treatments	Plant height (cm)	No. of branches plant^{-1}	No. of leaves plant^{-1}	Leaf area (cm^2 plant^{-1})	Dry matter (g plant^{-1})
$S_2 F_3$	80.93	6.6	14.64	910.30	29.55
$S_2 F_4$	83.26	7.07	16.01	884.37	31.08
$S_3 F_1$	79.76	5.73	12.50	659.74	23.58
$S_3 F_2$	81.77	5.86	12.73	852.22	24.40
$S_3 F_3$	84.76	6.67	13.30	939.87	26.55
$S_3 F_4$	86.60	6.73	14.15	936.45	28.50
$S_4 F_1$	74.89	6.47	13.73	789.78	30.15
$S_4 F_2$	75.74	6.74	15.73	928.30	31.15
$S_4 F_3$	78.05	7.10	19.40	943.03	31.25
$S_4 F_4$	82.52	7.38	21.45	965.03	32.00
S.Em ±	3.24	0.33	1.27	101.52	2.56
C.D. at 5%	NS	NS	NS	NS	NS

in plant height with higher levels of fertilizer application (F_4) might be due to higher availability of major nutrients such as nitrogen, phosphorus and potassium which resulted in pronounced meristematic growth of the plants and might have resulted in higher plant height. Similar results were reported by Nimbargi (2005) and Jaisankar and Manivannan (2018). Interaction between spacing and fertilizer levels was found to be non-significant. However, higher plant height (89.13 cm) was recorded in S_1F_4.

Number of Branches Plant^{-1}

Significantly higher number of branches plant^{-1} (6.91) were noticed in 60 cm × 30 cm spacing (S_4) at harvest. This may be due to lower plant population (55,555 plants ha^{-1}) at wider spacing which had resulted in higher number of branches plant^{-1}. Increase in number of branches at wider spacing might be due to availability of space for lateral growth. These findings are in conformity with Sabar (2021) and Venugopala *et al*. (2014).

Significantly higher number of branches plant^{-1} (6.89) were observed in 150 per cent RDF level (F_4) at harvest stage. These observations were found on par (6.66 cm) with 125 per cent RDF level (F_3) at harvest. The higher doses of nutrients application might have helped in maintaining overall growth of the plant in terms of assimilation of nutrients to all parts of plant and would have resulted in higher number of branches plant^{-1}. Interaction between spacing and fertilizer levels was found to have non-significant influence, however, higher number of branches plant^{-1} (7.38) were recorded in S_4F_4.

Number of Leaves Plant^{-1}

Significantly higher (17.5) number of leaves plant^{-1} were recorded in plant spacing (S_4) with 60 cm × 30 cm at harvest. Whereas, lower number of leaves plant^{-1} (12.5) were recorded with spacing (S_1) 45 cm × 15 cm. The higher number of leaves plant^{-1} were found in wider spacing S_4 (60 × 30 cm) might be due to availability of adequate resources under wider spacing and more number of branches where less plant population (55,555 plants ha^{-1}) was existing.

Significant influence by different levels of fertilizer application was observed on number of leaves plant^{-1}. Higher number of leaves plant^{-1} (16.53) were observed in 150 per cent RDF level (F_4) and was followed by 125 per cent RDF application (15.02) as compared to other levels of fertilizer at harvest stage.

This might be mainly attributed to availability of major nutrients N, P and K which play an important role in early vegetative growth which resulted in increased number of leaves per plant. Similar findings were reported by Jagadale *et al*. (2017) and Jaisankar and Manivannan (2018). Interaction between spacing and fertilizer levels was found to be non-significant. However, higher number of leaves plant^{-1} (21.4) were recorded in S_4F_4.

Leaf Area (cm^2) Plant^{-1}

Significantly higher leaf area plant^{-1} (906.54 cm^2 plant^{-1}) was recorded in plant spacing of 60 cm × 30 cm (S_4) at harvest stage as compared to other spacings. Whereas, lower leaf area plant^{-1} (673.25 cm^2 plant^{-1}) was recorded in 45 cm × 15 cm plant spacing at harvest stage. The increase in leaf area per plant, in wider spacing might be due to promoted growth of individual plants as they were accommodated under low density per unit area.

Significant influence of fertilizer levels was found on leaf area plant^{-1}. Significantly higher leaf area (897.28 cm^2 plant^{-1}) was found in 150% RDF application (F_4) and followed by 125% RDF level (881.52 cm^2 plant^{-1}) compared to other fertilizer levels at harvest. The increase in leaf area with higher nutrient levels might be due to increased availability of nitrogen and phosphorus nutrients which would have promoted metabolic activities of plant such as cell division, differentiation and in turn higher leaf area of plant. These results are in accordance with findings of Shrikanth *et al.* (2008) and Vyas and Jamliya (2017). Interaction between spacing and fertilizer levels was found to have non-significant influence on leaf area plant^{-1}. However, higher leaf area plant^{-1} (965.03 cm^2 plant^{-1}) were recorded in S_4F_4.

Dry Matter Production (g plant^{-1})

Dry matter production (g plant^{-1}) was found statistically higher (31.14 g plant^{-1}) in spacing (S_4) 60 cm × 30 cm at harvest. Whereas, lower value of dry matter production (21.33 g plant^{-1}) was recorded with spacing 45 cm × 15 cm (S_1). Higher dry matter production per plant was recorded at wider spacing (60 cm × 30 cm) which may be attributed due to pronounced vegetative growth of plant in terms of branches and leaf area of field bean. These results are in accordance with findings of Joshi and Rahevar (2015).

Different fertilizer levels had significant influence on dry matter production in field bean. Significantly higher dry matter production (28.65 g plant^{-1}) was recorded in 150% RDF level (F_4) at harvest stage and was followed by 125% RDF application (F_3) (27.34 g plant^{-1}). Whereas, lower dry matter production (25.16 g plant^{-1}) was recorded in 75% RDF application. Optimum availability of nutrients to plants under higher levels of RDF application would have resulted in higher uptake. This further might have enhanced the vegetative growth and photosynthetic efficiency of plant and might have resulted in higher dry matter production per plant. These results are in conformity with Jaisankar and Manivannan (2018). Interaction between spacing and fertilizer levels was found to have non-significant influence on dry matter plant^{-1}. However, higher dry matter plant^{-1} (32.0 g) were recorded in S_4F_4.

Yield Parameters of Field Bean as Influenced by Spacing and Fertilizer Levels

Yield parameters of field bean as influenced by different spacing and fertilizer levels are presented in Table 2.

Pod Length (cm)

Spacing at different plant populations had significant influence on pod length. Among different spacings significantly higher pod length (5.45 cm) was recorded in spacing (S_4) with 60 cm × 30 cm. Whereas, lower pod length (4.82 cm) was recorded in spacing at 45 cm × 15 cm. These increase in pod length with wider spacing was may be due to enhanced vegetative growth of plant under wider spacing in terms of number of branches and leaf area, would have improved the source potential. This might have resulted in partitioning of photosynthates adequately to developing pods.

Significantly higher pod length (5.44 cm) was recorded in 150% RDF level (F_4). Whereas, lower pod length (4.68 cm) was recorded in fertilizer

TABLE 2

Yield parameters of field bean as influenced by spacing and fertilizer level

Treatments	Pod length (cm)	Number of seeds pod^{-1}	Number pods $plant^{-1}$	Seed yield (g $plant^{-1}$)
Spacing levels (S)				
S_1: 45 cm × 15 cm	4.82	3.68	20.65	12.17
S_2: 45 cm × 30 cm	5.00	3.96	23.81	14.18
S_3: 60 cm × 15 cm	4.83	3.83	21.46	13.68
S_4: 60 cm × 30 cm	5.45	4.26	25.35	16.19
S.Em ±	0.08	0.12	0.74	0.58
C.D. at 5%	0.28	0.43	2.57	2.03
Fertilizer levels (F)				
F_1:75% RDF	4.68	3.68	21.05	12.72
F_2:100% RDF	4.85	3.82	21.90	13.14
F_3:125% RDF	5.12	3.97	23.55	14.28
F_4:150% RDF	5.44	4.22	24.78	16.08
S.Em ±	0.08	0.12	0.74	0.58
C.D. at 5%	0.23	0.36	2.13	1.69
Interactions (S × F)				
$S_1 F_1$	4.67	3.36	18.97	10.67
$S_1 F_2$	4.81	3.49	20.3	11.79
$S_1 F_3$	4.85	3.68	21.25	12.12
$S_1 F_4$	4.99	4.19	22.10	14.11
$S_2 F_1$	4.69	3.75	22.45	13.30
$S_2 F_2$	4.92	3.82	22.86	13.39
$S_2 F_3$	4.95	4.09	24.32	14.35
$S_2 F_4$	5.44	4.16	25.6	15.67
$S_3 F_1$	4.52	3.50	20.42	12.77
$S_3 F_2$	4.63	3.86	20.82	12.89
$S_3 F_3$	4.93	3.90	21.35	13.75
$S_3 F_4$	5.19	4.05	23.25	15.32
$S_4 F_1$	4.86	3.97	22.36	14.13
$S_4 F_2$	5.06	4.23	23.6	14.52
$S_4 F_3$	5.75	4.22	27.27	16.89
$S_4 F_4$	6.14	4.61	28.17	19.22
S.Em ±	0.16	0.25	1.48	1.17
C.D. at 5%	NS	NS	NS	NS

application at 75% RDF level (F_1). Optimum levels of nutrients in plant, enhances effective translocation of photosynthates to developing pods which is catalysed by mineral nutrients. The above results are in validation with Dalai *et al.* (2020) and Chaudary (2020). Interaction effect between spacing and fertilizer levels was non-significant with respect to pod length. However, higher pod length (6.14 cm) was recorded under treatment combination S_4 F_4 (spacing at 60 cm × 30 cm and 150% RDF fertilizer level).

Number of Seeds Pod^{-1}

Within different spacing levels, significantly higher number of seeds pod^{-1} (4.26) was recorded in 60 cm × 30 cm spacing (S_4). Whereas, lower number of seeds pod^{-1} was recorded in spacing 45 cm × 15 cm (3.68) as compared to different spacing levels. Under wider spacing optimum availability of space per plant might have ultimately enhanced availability of nutrients, moisture and light consequently better development and increased number of seeds per pod. The increased number of seeds per pod are in accordance with findings of Murade *et al*. 2014. Among different fertilizer levels imposed, significantly higher number of seeds pod^{-1} (4.22) was recorded in 150% RDF level (F_4), which is on par with 125% RDF level (3.97) compared with other fertilizer levels.

Number of Pods Plant^{-1}

Different spacings had significant influence on number of pods plant^{-1}. Among different spacings followed, spacing with 60 cm × 30 cm (S_4) had resulted in significantly higher number of pods plant^{-1} (25.35). Whereas, lower number of pods plant^{-1} were observed in spacing 45 cm × 15 cm (20.65). Increased number of pods plant^{-1} recorded in wider spacing (S_4), was may be due to higher number of branches and access to available resources to plants under wider spacing would have resulted in establishing greater source potential of plant.

Fertilizer levels also had significant influence on number of pods plant^{-1}. Among different levels of fertilizers applied, significantly higher number of pods plant^{-1} (24.78) were recorded at 150% RDF level (F_4), which were on par with 125% RDF (F_3) application (23.55). Whereas, lower number of pods plant^{-1} (21.05) were recorded in 75% RDF application. Increased availability of nutrients with higher levels of fertilizer application would have augmented the morphological and metabolic changes in terms of growth and differentiation, ultimately resulting in higher number of pods plant^{-1}. The above findings are in conformation with the findings of Dalai *et al.* (2021) and Chaudary (2020).

Seed Yield (g) Plant^{-1}

There was significant effect of different spacing levels on seed yield per plant. Spacing at 60 cm × 30 cm (S_4) resulted in significantly higher seed yield plant^{-1} (16.19 g) compared to other spacings. Whereas, lower seed yield plant^{-1} (12.17 g) was recorded in spacing at 45 cm × 15 cm (S_1). This might be due to less competition for existing resources such as moisture, light and nutrients with wider spacing (S_4) which has favoured in producing more reproductive parts compared to higher plant density S_1 (45 cm × 15 cm). The above findings are in accordance with Joshi & Rahevar (2015) and Damoar *et al.* (2020).

Significantly higher seed yield plant^{-1} (16.08 g) was recorded in fertilizer level of 150% RDF (F_4) compared with other levels of fertilizer application, which was on par with 125% RDF level (14.28 g plant^{-1}). Whereas, lower seed yield plant^{-1} (12.72 g) was recorded in 75% RDF level of fertilizer application. Higher seed yield plant^{-1} in higher fertilizer dose which might be due to increased photosynthetic efficiency of plants in higher level of nitrogen, phosphorus and potassium availability which resulted in increased seed yield per plant. Similar results are reported by Desai *et al*. (2021) and Sabar (2021).

Yield of Field Bean as Influenced by Spacing and Fertilizer Levels

Yield of field bean as influenced by different spacing and fertilizer levels is presented in Table 3.

Seed Yield (kg ha^{-1})

Different levels of spacing imposed in field bean crop found to have significant influence on seed yield. Among the different spacings followed, significantly higher seed yield (848.70 kg ha^{-1}) was recorded in 45 cm × 15 cm spacing (S_1) as compared to other spacing levels. However, lower seed yield (568.16 kg ha^{-1}) was recorded in 60 cm × 30 cm spacing (S_4). The increased seed yield (kg ha^{-1}) in closer spacing S_1 (45 cm × 15 cm) may be due to establishment of optimum balance between source and sink aspects of individual plants and overall performance per unit area

TABLE 3

Seed, haulm yield and harvest index of field bean as influenced by spacing and fertilizer levels

Treatments	Seed yield (kg ha^{-1})	Haulm yield (kg ha^{-1})	Harvest index
Spacing levels (S)			
S_1: 45 × 15 cm	848.70	1495.24	0.36
S_2: 45 × 30 cm	683.41	1683.83	0.34
S_3: 60 × 15 cm	787.54	1829.22	0.31
S_4: 60 × 30 cm	568.16	1291.83	0.33
S.Em ±	15.69	55.73	0.02
C.D. at 5%	52.33	193.99	0.01
Fertilizer levels (F)			
F_1:75% RDF	657.34	1405.81	0.33
F_2:100% RDF	717.34	1517.89	0.34
F_3:125% RDF	748.53	1616.08	0.34
F_4:150% RDF	764.61	1760.34	0.33
S.Em ±	15.69	55.73	0.01
C.D. at 5%	45.32	160.97	NS
Interactions (S × F)			
$S_1 F_1$	712.03	1369.91	0.34
$S_1 F_2$	861.86	1424.23	0.36
$S_1 F_3$	902.63	1547.67	0.37
$S_1 F_4$	918.28	1639.16	0.37
$S_2 F_1$	650.87	1438.67	0.34
$S_2 F_2$	685.87	1626.67	0.34
$S_2 F_3$	691.63	1736.66	0.34
$S_2 F_4$	705.28	1933.33	0.33
$S_3 F_1$	721.05	1636.89	0.31
$S_3 F_2$	764.18	1768.89	0.31
$S_3 F_3$	821.10	1866.66	0.32
$S_3 F_4$	843.85	2044.44	0.31
$S_4 F_1$	545.40	1177.78	0.34
$S_4 F_2$	551.71	1251.78	0.34
$S_4 F_3$	584.50	1313.33	0.32
$S_4 F_4$	591.02	1424.44	0.31
S.Em ±	31.38	114.72	0.01
C.D. at 5%	NS	NS	NS

of land. In case of wider spacing S_4 (60 cm × 30 cm), though superior yield parameters were reported, this phenomenon did not compensate the reduced plant population per unit area (Shrikanth *et al.,* 2008) and (Nath *et al*., 2023).

Different fertilizer levels had significance influence on seed yield of field bean. Among different levels of nutrients applied, application of 150% RDF (F_4) has resulted in significantly higher seed yield (764.61 kg ha^{-1}) compared to other levels, which was on par (748.53 kg ha^{-1}) with 125% RDF level (F_3). Whereas, lower seed yield (657.34 kg ha^{-1}) was obtained in 75% RDF level of application as compared with other levels. This can be attributed to better growth of plants in terms of number of leaves, branches and dry matter production per plant under higher doses of fertilizer application, which in turn improved the photosynthesis and photosynthates assimilation for development of sink. The above results were in line with findings of Dalai *et al.* (2020). The interaction effect between different spacing and fertilizer levels recorded non-significant influence on seed yield per ha. However, higher seed yield (918.28 kg ha^{-1}) was recorded in treatment combination $S_1 F_4$ (spacing at 45 cm × 15 cm and 150% RDF level).

Haulm Yield (kg ha^{-1})

Among different spacings followed, significantly higher haulm yield was recorded (1829.22 kg ha^{-1}) in 60 cm × 15 cm spacing. Whereas, lower haulm yield was recorded (1291.83 kg ha^{-1}) in spacing 60 cm × 30 cm compared to other spacings. This might be due to effective utilization of available growth resources such as interception of solar radiation, moisture and nutrient uptake.

Different fertilizers levels had significant influence on haulm yield of field bean. Application of 150% RDF level has recorded (1760.34 kg ha^{-1}) significantly higher haulm yield, which was on par with (1616.08 kg ha^{-1}) application of 125% RDF level. Whereas, lower haulm yield was (1405.81 kg ha^{-1}) recorded in 75% RDF application level when compared to other levels of fertilizers application. The increased haulm yield under 150% RDF might be due to optimum availability of major nutrients which increased both vegetative and root growth of plant. Further, this could be due to enhanced vegetative growth as a complimentary effect due to adequate and balanced availability of necessary nutrients during the crop growth period (Suresh *et al*. 2021) and (Nath *et al*., 2023). Interaction between spacing and fertilizer levels recorded non-significant effect on haulm yield in field bean. Among different treatment combinations, higher haulm yield (2044.44 kg ha^{-1}) was recorded in treatment combination $S_3 F_4$ (spacing at 60 cm × 15 cm and 150% RDF level).

Harvest Index

Significantly higher harvest index (0.36) was recorded in spacing 45 cm × 15 cm (S_1) compared to other spacing levels. Whereas, lower harvest index (0.31) was observed in spacing at 60 cm × 15 cm among other spacing levels. This may be due to varied response of plant growth, in terms of seed, straw yield and overall biomass production. Harvest index, which is proportion between seed yield and total biomass, both components were found varied with different spacings. Similar results were reported by Nagamani *et al.* (2020) and Patel *et al.* (2018).

Different levels of fertilizer application had non-significant influence upon harvest index in field bean. Higher harvest index (0.34) was recorded in 125% RDF level (F_3). Among different treatment combinations between spacing and fertilizer levels higher harvest index (0.37) was recorded in treatment combination $S_1 F_4$ (spacing at 45 cm × 15 cm and 150% RDF level).

Economics of Field Bean as Influenced by Spacing and Fertilizer Levels

Economics of field bean as influenced by different spacing and fertilizer levels was presented in Table 4.

Gross Returns, Net Returns and B:C Ratio of Field Bean

Higher gross returns, net returns and B:C ratio were observed (Rs.61784 ha^{-1}, Rs.61784 ha^{-1} and 2.99) with 45 cm × 15 cm spacing (S_1), which has higher plant

TABLE 4

Economics of field bean as influenced by spacing and fertilizer levels

Treatments	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C ratio
Spacing levels (S)			
S_1: 45 × 15 cm	61784	41090	2.99
S_2: 45 × 30 cm	50094	30900	2.61
S_3: 60 × 15 cm	57774	37829	2.90
S_4: 60 × 30 cm	41708	22889	2.22
S.Em ±	-	-	-
C.D. at 5%	-	-	-
Fertilizer levels (F)			
F_1:75% RDF	48126	29677	2.61
F_2:100% RDF	52499	33241	2.72
F_3:125% RDF	54727	34659	2.73
F_4: 150% RDF	56008	35130	2.68
S.Em ±	-	-	-
C.D. at 5%	-	-	-
Interactions (S × F)			
$S_1 F_1$	51999	32520	2.67
$S_1 F_2$	62620	42330	3.09
$S_1 F_3$	65639	44539	3.11
$S_1 F_4$	66879	44970	3.05
$S_2 F_1$	47631	29651	2.65
$S_2 F_2$	50185	31395	2.67
$S_2 F_3$	50735	31136	2.59
$S_2 F_4$	51828	31418	2.54
$S_3 F_1$	52928	34199	2.83
$S_3 F_2$	56145	36606	2.87
$S_3 F_3$	60201	39852	2.96
$S_3 F_4$	61820	40660	2.92
$S_4 F_1$	39944	22082	2.27
$S_4 F_2$	40497	22340	2.20
$S_4 F_3$	42885	23660	2.23
$S_4 F_4$	43507	23473	2.17
S.Em ±	-	-	-
C.D. at 5%	-	-	-

population per unit area and resulted in higher seed yield. In case of different levels of fertilizer application, higher gross returns, net returns and B:C ratio (Rs.56008 ha^{-1}, Rs.35130 ha^{-1} and 2.73) were recorded in 150% RDF level (F_4). Higher gross returns, net returns and B:C ratio were recorded (Rs.66879 ha^{-1}, Rs.44970 ha^{-1} and 3.11) in treatment combination $S_1 F_4$ (spacing at 45 cm × 15 cm and 150% RDF level). This might be due to ideal combination of planting geometry and fertilizers application would have enhanced crop growth in terms of both vegetative and yield attributes relatively, with specific combination of inputs used. Similarly, these factors combination might be efficient in utilizing available growth resources which has enhanced formation of higher number of fruit bearing branches and pods, which ultimately contributed in the final yield. Higher yield per unit area and inputs applied finally resulted in higher B:C ratio. These results are in validation with findings of Shrikanth (2008) and Dalai *et al.* (2021) in field bean.

Available Nutrient Status in Soil (kg ha^{-1}) after the Harvest of Field Bean as Influenced by Spacing and Fertilizer Levels

Available nutrient status in soil (kg ha^{-1}) after the harvest of field bean as influenced by different spacing and fertilizer levels is presented in Table 5.

Available Nitrogen, Phosphorus and Potassium (kg ha^{-1})

Available nitrogen, phosphorus and potassium after the harvest of field bean crop was not affected significantly by different levels of spacing. However, higher available nitrogen, phosphorus and potassium (194.64, 38.15 and 213.07 kg ha^{-1}, respectively) after the harvest of field bean crop was observed in spacing 60 cm × 30 cm and lower available nitrogen, phosphorus and potassium (184.53, 33.07 and 203.77 kg ha^{-1}, respectively) after the harvest of field bean crop was observed in spacing 45 cm × 15 cm.

Different levels of fertilizer application had significant influence on available nitrogen, phosphorus and potassium status after the harvest

TABLE 5

Available nutrient status in soil after the harvest of field bean as influenced by spacing and fertilizer levels

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Spacing levels (S)			
S1: 45 cm × 15 cm	184.53	33.07	203.77
S2: 45 cm × 30 cm	185.55	34.47	204.71
S3: 60 cm × 15 cm	190.82	37.30	209.55
S4: 60 cm × 30 cm	194.64	38.15	213.07
S.Em ±	4.65	1.17	3.03
C.D. at 5%	NS	NS	NS
Fertilizer levels (F)			
F1:75% RDF	175.97	31.45	195.89
F2:100% RDF	185.22	35.61	205.44
F3:125% RDF	192.66	36.70	210.21
F4: 150% RDF	201.69	39.23	219.55
S.Em ±	4.65	1.17	3.03
C.D. at 5%	13.43	3.39	8.74
Interactions (S × F)			
S1 F1	172.11	30.73	192.64
S1 F2	176.36	32.67	196.25
S1 F3	192.30	33.82	210.92
S1 F4	197.02	35.05	215.26
S2 F1	177.00	32.51	196.84
S2 F2	180.82	33.14	200.36
S2 F3	185.36	34.39	204.53
S2 F4	199.03	37.84	217.11
S3 F1	172.44	31.69	192.34
S3 F2	188.07	37.68	207.03
S3 F3	194.57	37.76	213.01
S3 F4	198.52	40.09	220.83
S4 F1	182.33	30.89	201.74
S4 F2	195.62	38.94	213.97
S4 F3	198.42	40.82	216.55
S4 F4	202.19	41.95	225.01
S.Em ±	9.30	2.35	6.05
C.D. at 5%	NS	NS	NS

of field bean crop. Significantly higher available nitrogen, phosphorus and potassium status after the harvest (201.69, 39.23 and 219.55 kg ha^{-1}, respectively) was recorded in fertilizer application at 150% RDF, followed by (192.66, 36.70 and 210.21 kg ha^{-1}, respectively) 125% RDF application level and lower available nitrogen, phosphorus and potassium status (175.97, 31.45 and 195.89 kg ha^{-1}, respectively) after harvest, was observed in 75% RDF level of nutrient application.

Different treatment combinations were found to have non-significant influence on the available nitrogen, phosphorus and potassium status after the harvest of field bean. However, higher available nitrogen, phosphorus and potassium (202.19, 41.95 and 225.01 kg ha^{-1}, respectively) was found in treatment S_4 F_4 (spacing at 60 cm × 30 cm and 150% RDF level) and lower available nitrogen, phosphorus and potassium (172.11, 30.73 and 192.64 kg ha^{-1}, respectively) was recorded in treatment combination S_1 F_1 (spacing at 45 cm × 15 cm and 75% RDF level).

Higher soil available status of N, P and K after the harvest were resulted in F_4 even though higher uptake of nutrients in this level of fertilizer application was recorded. This may be due to excess of nutrients after accommodating crop growth requirements, that might have eventually resulted in higher available status of N, P and K. Field bean being a legume crop, higher levels of available nutrient with increased levels of nutrients application, might have reached optimum crop need during initial growth and pod development stages, when biological nitrogen fixation was considerably low. Further, higher levels of fertilizer application would have resulted in enhanced growth and simultaneous biological phenomenon of crop due to optimum availability of nutrients ultimately resulting in higher uptake and available status of N, P and K after the harvest of the crop. These results are in validation with Walchand (2016), Vyas and Kushwaha (2015) in soybean, Sabar (2021) in rice bean, Siddaram (2012) and Babubhai (2017) in field bean.

Nutrient Uptake of Field Bean as Influenced by Spacing and Fertilizer Levels

Nutrient uptake by field bean as influenced by different spacing and fertilizer levels is presented in Table 6.

Nitrogen, Phosphorus and Potassium uptake (kg ha^{-1})

Nitrogen, phosphorus and potassium uptake was significantly influenced by different levels of spacings. Among different spacings followed, significantly higher nitrogen, phosphorus and potassium uptake was recorded (53.20, 6.78 and 48.52 kg ha^{-1}, respectively) with spacing of 45 cm × 15 cm, which was on par (52.05, 6.64 and 47.89 kg ha^{-1}, respectively) with 60 cm × 15 cm spacing. Whereas, significantly lower nitrogen, phosphorus and potassium uptake (37.95, 4.84 and 34.91 kg ha^{-1}, respectively) was recorded with spacing 60 cm × 30 cm.

Different levels of fertilizer application had significant influence on nitrogen, phosphorus and potassium uptake of field bean. Significantly higher nitrogen, phosphorus and potassium uptake (52.36, 6.68 and 48.17 kg ha^{-1}, respectively) was recorded in application of 150% RDF level compared with other levels of application, followed by (48.73, 6.21 and 44.83 kg ha^{-1}, respectively) with 125% RDF application. Whereas, lower nitrogen, phosphorus and potassium uptake (40.77, 5.20 and 37.09 kg ha^{-1}, respectively) was observed in 75% RDF level of application.

Different treatment combinations were found to have non-significant influence upon nitrogen, phosphorus and potassium uptake by field bean. However, higher nitrogen, phosphorus and potassium uptake (62.11, 7.92 and 57.14 kg ha^{-1}, respectively) was found in treatment S_1 F_4 (spacing at 45 cm × 15 cm and 150% RDF level) and lower nitrogen, phosphorus and potassium uptake (33.74, 4.30 and 31.05 kg ha^{-1}) was recorded in treatment combination S_4 F_1 (spacing at 60 cm × 30 cm and 75% RDF level).

Increase in nutrient uptake of N, P and K in closer spacing levels (S_1 and S_3) might be due to optimum

Table 6

Nutrient uptake of field bean as influenced by spacing and fertilizer levels

Treatments	Nitrogen (kg ha^{-1})	Phosphorus (kg ha^{-1})	Potassium (kg ha^{-1})
Spacing levels (S)			
S1: 45 cm × 15 cm	53.20	6.78	48.52
S2: 45 cm × 30 cm	44.80	5.71	41.21
S3: 60 cm × 15 cm	52.05	6.64	47.89
S4: 60 cm × 30 cm	37.95	4.84	34.91
S.Em ±	1.10	0.14	1.02
C.D. at 5%	3.68	0.47	3.39
Fertilizer levels (F)			
F1:75% RDF	40.77	5.20	37.09
F2:100% RDF	46.13	5.88	42.44
F3:125% RDF	48.73	6.21	44.83
F4: 150% RDF	52.36	6.68	48.17
S.Em ±	1.10	0.14	1.02
C.D. at 5%	3.19	0.41	2.94
Interactions (S × F)			
S1 F1	40.51	5.21	38.37
S1 F2	50.75	6.47	46.69
S1 F3	56.41	7.19	51.89
S1 F4	62.11	7.92	57.14
S2 F1	41.17	5.25	37.88
S2 F2	43.78	5.58	40.28
S2 F3	45.91	5.85	42.24
S2 F4	48.33	6.16	44.46
S3 F1	44.65	5.69	41.08
S3 F2	51.37	6.55	47.26
S3 F3	54.91	7.00	50.52
S3 F4	57.28	7.30	52.69
S4 F1	33.74	4.30	31.05
S4 F2	36.48	4.65	33.57
S4 F3	39.83	5.08	36.64
S4 F4	41.73	5.32	38.39
S.Em ±	2.21	0.28	2.03
C.D. at 5%	NS	NS	NS

growth of the plants under ideal spacing which might have resulted in maximum exploitation of available above and below ground resources. Plant biomass production and nutrient uptake being complimentary in nature, higher plant population (1,48,048 and 1,11,111 plants ha^{-1}, respectively) in close spacing might have increased biomass production per unit area further increasing nutrient uptake. Similar findings were reported by Kishor (2020) in chia, Devaraj (2020) in pigeon pea and Shrikanth (2008) in field bean.

Increased uptake of N, P and K by field bean were reported in application of 150% RDF compared to other levels. This might be due to optimum availability of nutrients under increased levels enhanced the uptake of nutrients. Further, phosphorus which plays an important role in root growth and proliferation, would have resulted in better absorption of moisture and nutrients with higher levels of nutrient application. These results are in validation with findings of Gupta (2007) in black gram, Vyas and Kushwaha (2015) in soybean, Suresh *et al.* (2021) in pigeon pea and Sabar (2021) in rice bean.

The study revealed that both spacing and fertilizer levels significantly influenced the growth and yield parameters of field bean. Closer spacing (45 cm × 15 cm) resulted in higher plant height and seed yield per hectare, attributed to optimized resource utilization by the optimum plant density. Wider spacing (60 cm × 30 cm) improved the number of branches, leaves, leaf area and dry matter production per plant due to reduced competition. Higher fertilizer application (150% RDF) consistently enhanced plant growth, yield attributes and nutrient uptake. The combination of closer spacing and higher fertilizer levels (S_1F_4) provided the best results for maximizing seed yield and economic returns, indicating the importance of optimal spacing and nutrient management in field bean cultivation.

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