Mysore J. Agric. Sci., 58 (2) : 131-142 (2024)

Response of Rice Bean (*Vigna umbellata*) to different Spacing and Fertilizer Levels under Eastern Dry Zone of Karnataka

Janhabi Sabar[1], S. R. Anand[2], K. N. Kalyana Murthy[3], Atheekur Rehaman[4] and K. Murali[5]
[1,3&5]Department of Agronomy, College of Agriculture, UAS, GKVK, Bengaluru, [2]All India Co-ordinated Research Network (AICRN) on Potential Crops, [4]AICRP on Pigeonpea, ZARS, UAS, GKVK, Bengaluru - 560 065
e-Mail : anuagron80@gmail.com

Authors Contribution

Janhabi Sabar : Trial plan, layout, recording observations, analysis and drafting;
S. R. Anand : Guidance for experimental layout;
K. N. Kalyana Murthy ; Atheekur Rehaman & K. Murali : Guidance for experimental layout, technical support during data analysis, writing thesis and draft correction

Corresponding Author :
Janhabi Sabar

Received : January 2024
Accepted : February 2024

Abstract

A field experiment was conducted during *kharif* 2020 at 'M' block, Field unit of AICRN on Potential Crops, University of Agricultural Sciences, Bangalore to optimise the spacing and fertilizer levels to rice bean crop. The data revealed that significantly higher seed yield and stover yield were recorded with the spacing of 30 cm × 10 cm (1545 and 2693 kg ha^{-1}, respectively). Among the fertilizer levels, application of 25:50:25 NPK kg ha^{-1} recorded higher seed yield (1626 kg ha^{-1}) which was on par with the application of 20:40:20 NPK kg ha^{-1} (1495 kg ha^{-1}) over 30:60:30 NPK kg ha^{-1} (1359 kg ha^{-1}), while stover yield was significantly higher with application 30:60:30 NPK kg ha^{-1} (2901 kg ha^{-1}) as compared to 25:50:25 NPK kg ha^{-1}. Nutrient content did not differ significantly due to different spacing. Whereas, significantly higher NPK content (2.73, 0.57 and 1.85%, respectively) was recorded with application of 30:60:30 NPK kg ha^{-1} which was on par with application of 25:50:25 NPK kg ha^{-1} (2.70, 0.54 and 1.82%, respectively). Significantly higher NPK uptake (48.74, 10.06 and 30.77 kg ha^{-1}, respectively) was observed with the optimum spacing of 22.5 cm × 10 cm. However, significantly higher NPK uptake (48.40, 9.91 and 33.57 kg ha^{-1}, respectively) was observed with application of 25:50:25 NPK kg ha^{-1} followed by application of 20:40:20 NPK kg ha^{-1} (42.82, 8.83 and 28.36 kg ha^{-1}, respectively). Significantly higher available nutrient status of NPK (278.67, 40.18 and 257.62 kg ha^{-1}, respectively) was observed in 30:60:30 NPK kg ha^{-1} fertilizer level, whereas the lower NPK availability (247.19, 31.18 and 223.40 kg ha^{-1}, respectively) was observed in control treatment. Similarly, net returns (Rs.100284 ha^{-1}) and B:C ratio (3.57) were higher in the spacing of 30 cm x 10 cm with the application of 25:50:25 NPK kg ha^{-1} (S_2F_3). Hence, spacing of 30 x 10 cm and fertilizer level of 20:40:20 NPK kg ha^{-1} is optimum for higher seed yield and economic benefit to the farmers of Karnataka.

Keywords : Economics of Rice Bean, Fertilizers, Growth, Nutrient uptake, Spacing and Seed yield in Rice Bean

Rice bean (*Vigna umbellata*) is an annual underutilized grain legume crop belongs to the family *Fabaceae* and native of South and South East Asia, commonly known as Japanese rice bean, Red bean, climbing bean etc. Regarded as a versatile legume because of its multiple value. It is a temperate to tropical grain legume primarily grown for food, fodder and green manure. It thrives well in marginal lands, rain-fed areas, drought-prone areas and exhausted soils. In India, it is being grown in north eastern states like Manipur, Tripura, Nagaland, Mizoram and Assam after rainfed rice and hence, named rice bean (Murthy *et al.,* 2020). It is estimated to be grown in around 15,000 ha and its cultivation is gradually extending in many parts of India. This is lesser known and underutilised legume that is gaining popularity as a potential crop because of its nutritional qualities. The nutritional quality of rice bean is higher as compared to many other legumes of *Vigna* family. The seeds are rich in protein (20.9%) and limiting amino acids like tryptophan (0.79-1.10%) and methionine (0.45-1.18%). It is very sensitive to day length as the reproductive stage initiates with the onset of short days (Rana *et al*., 1998). Ricebean is a vibrant potential fodder legume crop which has the capacity to enhance the productivity and quality of fodder to the livestock and sustain under wide range climatic conditions (Magan Singh *et al.,* 2020).

In recent years, it is gaining popularity because of its main useful character like food, fodder and green manure. It has considerable agricultural and nutritional potential in terms of its ability to grow better in comparatively poor soils in hot and humid areas and it has a rich genetic diversity and resistance to storage pests and serious diseases. It is very promising when compared to most of the traditional pulses grown in South and South East Asia. It is also resistant to Yellow Mosaic Virus (YMV), a prominent disease especially in pulses such as green gram and black gram and thus can easily replace green gram in plains (Singh *et al*., 2018). Being a new crop, development of agronomic practices for improvement of seed yield is necessary.

Spacing and nutrient management are the two basic agronomic practices which alters the yield potential of any crop which needs attention for higher productivity. However, nutrient doses beyond a threshold level have been proven to suppress the symbiotic process, plant growth and development specifically under limited moisture conditions. Similarly, higher application of fertilizer may hinder pod formation and reduce seed yield. As a result, the precise dose must be determined as well as their response to nutrients which are a critical input in the production system. Another important agronomic approach for achieving optimal production of a particular crop in a given environment is proper spacing which reduces plants competition for resources. This can be accomplished by using optimal spacing which not only makes better use of soil moisture and nutrients but also reduces plant competition. Hence, the experiment has been planned to find out optimum spacing and fertilizer level for higher seed yield of rice bean crop.

Material and Methods

A field experiment was conducted during *kharif* 2020 at 'M' block, Field unit of AICRN on Potential crops, University of Agricultural Sciences, Bangalore. The site is located in Agro Climatic Zone V (Eastern Dry Zone) of Karnataka at 12° 58' N latitude, 77° 35' E longitude with an altitude of 930 meters above mean sea level, to study the Response of rice bean (*Vigna umbellata*) to different spacing and fertilizer levels consisted of twelve treatments replicated thrice in split plot design. The texture of the soil was red sandy loam texture, acidic in reaction (5.32) and electrical conductivity was medium (0.18 dSm^{-1}). It had medium in available nitrogen (278 kg ha^{-1}), available phosphorous (31 kg ha^{-1}) and range of available potassium (226 kg ha^{-1}) and the treatments consisted varied levels of spacings (S_1: 22.5cm × 10cm, S_2: 30cm × 10cm and S_3: 45cm × 10cm) and four levels of fertilizers (F_1: control, F_2: 20:40:20 kg NPK ha^{-1}, F_3: 25:50:25 kg NPK ha^{-1} and F_4: 30:60:30 kg NPK ha^{-1}). Recommended dose of FYM @ 7.5 t ha^{-1} was applied three weeks before sowing. whereas, 100 per cent of N, P_2O_5 and K_2O were applied as basal dose in the form of urea, di-ammonium phosphate (DAP) and Muriate of Potash (MOP), respectively. The variety used was KBR-1 and sown as per the spacing followed in the treatments. Biometric observations and plant characters as an indicators of crop growth and yield *viz*., plant height, number of branches per plant, leaf area, number of clusters, number of pods, dry matter accumulation (g $plant^{-1}$), seed yield (kg ha^{-1}) and stover yield (kg ha^{-1}) were recorded. Plant samples were collected from each treatment at harvest. The samples were oven dried and grinded into fine powder by using mixer. Further, it was used for estimation of Nitrogen, Phosphorous and Potassium content in plant sample and expressed in percentage. Uptake of Nitrogen, Phosphorous and Potassium were calculated by using the following formula and expressed in kg ha^{-1}.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Biomass of seed/stover (kg ha}^{-1}\text{)}}{100}$$

Experimental observations collected were subjected to statistical analysis by adopting Fisher's method of analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). Critical difference (CD) values are calculated whenever the 'F' test values were found significant at 5 per cent level of significance.

Results and Discussion

Effect of Spacing and Fertilizer Levels on Growth Parameters of Rice Bean

Data revealed on the effect of different spacing on plant height was found significant and the higher plant height was observed by the closer spacing of 22.5 x 10 cm (56.36 cm) over other spacing levels. The increasing plant height under narrow spacing (22.5 x 10 cm) was apparently because individual plant from the plots with narrow spacing did not get opportunity to proliferate laterally due to the less lateral spacing. Hence plants were compelled to grow more in upward direction for the fulfilment of light requirement for photosynthesis. The above results were also in accordance with the findings of Kachare *et al.* (2009) in green gram. However, The wider spacing of 45 x 10 cm was recorded higher number of branches plant^{-1} (6.32), leaf area plant^{-1} (1189.57 cm^2) and dry matter production plant^{-1} (17.89 g plant^{-1}) followed by 30 x 10 cm spacing (5.58, 1069.60 cm^2 and 16.57 g plant^{-1}, respectively) and found significantly superior over closer spacing of 22.5 x 10 cm. This could be due to optimum space for horizontal expansion and less competition for resources available in the system, which led to development of more number of branches, leaf area and dry matter production plant^{-1}. Similar results were also reported by Singh *et al.* (2009) and Bunkar *et al.* (2013) in mung bean.

Similarly, significantly higher plant height (59.78 cm), number of branches per plant (6.35), leaf area plant^{-1} (1311.13 cm^2) and total dry matter plant^{-1} (18.24 g) were recorded with application of 30:60:30 NPK kg ha^{-1} over rest of the fertilizer levels. This might be due to the fact that preferable growth and pronounced uptake of nutrients helped in better cell division, cell elongation and protein synthesis which involved in the formation of chlorophyll and there by encourages vegetative growth. Similar trends were observed by Srikanth (2007) in lablab bean and Khanda and Mishra (1998) in rice bean.

Effect of Spacing and Fertilizer Levels on Yield and Yield Parameters of Rice Bean

Among different spacing levels, wider spacing of 45 × 10 cm recorded significantly higher number of clusters plant^{-1} (17.71), pods plant^{-1} (78.27) and dry matter accumulation (17.89 g plant^{-1}) which was on par with spacing of 30 × 10 cm (16.61, 70.92 and 16.57 g plant^{-1}) as compared to closer spacing of 22.5 × 10 cm (Table 2). This could be due to enhanced mutual shading led to increased abortion of reproductive parts in the lower canopy layer in the densely populated plants. These results were also in agreement with the findings of Kotwal and Prakash (2006) in green gram. The data revealed that significantly higher seed and stover yield were recorded with the spacing of 30 ×10 cm (1545 and 2693 kg ha^{-1}, respectively). This might be due to better availability of all the natural resources and least competition between the plants which led to accumulation and translocation of maximum photosynthates in sink. This could also be due to the increment in the morphological and physiological processes in the yield attributing characters which contributed to the final yield. These results were also in conformity with the findings of Patel *et al.* (2005) and Keerthi *et al.* (2015) in green gram.

The data revealed that the application of 25:50:25 NPK kg ha^{-1} recorded significantly higher number of clusters plant^{-1} (16.82) and number of pods

TABLE 1
Growth parameters of rice bean as influenced by different spacing and fertilizer levels

Treatments	Plant height (cm)	Number of branches plant^{-1}	Leaf area (cm^2 plant^{-1})	Dry matter accumulation \(g plant^{-1})
Main plot (Spacing)				
S_1 -22.5 cm × 10 cm	56.36	4.21	875.67	14.13
S_2 -30 cm × 10 cm	50.54	5.58	1069.60	16.57
S_3 -45 cm × 10 cm	47.24	6.32	1189.57	17.89
S.Em±	1.73	0.24	46.97	0.59
CD (0.05)	6.80	0.93	139.92	1.78
Sub plot (Fertilizer levels)				
F_1 -Control	42.49	4.40	733.36	14.30
F_2 -20:40:20 NPK kg ha^{-1}	48.99	5.30	1055.43	15.59
F_3 -25:50:25 NPK kg ha^{-1}	54.25	5.74	1179.86	16.66
F_4 -30:60:30 NPK kg ha^{-1}	59.78	6.35	1311.13	18.24
S.Em±	0.98	0.14	42.59	0.39
CD (0.05)	2.95	0.40	126.53	1.16
Interaction (S × F)				
S_1F_1	46.21	3.49	667.38	12.54
S_1F_2	54.84	3.94	780.11	13.96
S_1F_3	59.76	4.47	967.49	14.47
S_1F_4	64.61	4.94	1087.69	15.57
S_2F_1	41.65	4.43	724.32	14.37
S_2F_2	47.38	5.18	978.59	16.28
S_2F_3	53.55	5.98	1191.91	17.32
S_2F_4	59.59	6.72	1383.59	18.32
S_3F_1	39.61	5.27	808.39	15.98
S_3F_2	44.75	5.87	1107.60	16.54
S_3F_3	49.46	6.75	1380.18	18.20
S_3F_4	55.14	7.40	1462.10	20.83
F test	NS	NS	NS	NS
S.Em±	3.46	0.47	93.93	1.19
CD (0.05)	NS	NS	NS	NS

plant^{-1} (74.84) which was on par with 20:40:20 NPK kg ha^{-1}. This could be due to optimum level of fertilizer promoted the effective and expeditious growth alone to increase in photosynthetic efficiency which led to development of more photosynthates in sink and source. Moreover, the positive effect of P on number of pods per plant.

Might be due to various enzymatic activities which controlled flowering and pod formation. Similar

TABLE 2

Yield and yield attributes of rice bean as influenced by different spacing and fertilizer levels

Treatments	Clusters plant^{-1}	No. of pods plant^{-1}	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})
Main plot (Spacing)				
S_1 -22.5 cm × 10 cm	13.07	63.91	1329	2139
S_2 -30 cm × 10 cm	16.61	70.92	1545	2693
S_3 -45 cm × 10 cm	17.71	78.27	1125	2416
S.Em±	0.59	1.97	72.04	107.35
CD (0.05)	2.32	7.75	216.86	321.51
Sub plot (Fertilizer levels)				
F_1 -Control	11.18	37.11	847	1727
F_2 -20:40:20 NPK kg ha^{-1}	15.56	64.57	1495	2438
F_3 -25:50:25 NPK kg ha^{-1}	16.82	74.84	1626	2686
F_4 -30:60:30 NPK kg ha^{-1}	13.17	50.70	1359	2901
S.Em±	0.43	1.46	44.02	78.70
CD (0.05)	1.27	4.34	131.72	235.83
Interaction (S × F)				
S_1F_1	5.68	19.02	869	1572
S_1F_2	14.48	62.84	1440	2240
S_1F_3	16.62	78.28	1583	2452
S_1F_4	12.49	51.83	1413	2292
S_2F_1	8.57	30.42	918	1663
S_2F_2	16.34	82.35	1718	2824
S_2F_3	20.03	103.35	1833	3027
S_2F_4	14.51	77.48	1610	3259
S_3F_1	10.30	42.02	755	1946
S_3F_2	18.20	93.36	1328	2646
S_3F_3	20.82	113.26	1362	2878
S_3F_4	15.52	78.22	1054	2994
F test	NS	NS	NS	NS
S.Em±	1.18	3.95	144.08	215
CD (0.05)	NS	NS	NS	NS

results were also reported by Rathore *et al.* (2010) in green gram and Behera *et al.* (2015) in rice bean.

Among the fertilizer levels application of 25:50:25 NPK kg ha^{-1} recorded higher seed yield (1626 kg ha^{-1}) and stover yield (2686 kg ha^{-1}) which was on par with the application of 20:40:20 NPK kg ha^{-1} (1495 kg ha^{-1} and 2438 kg ha^{-1}, respectively) over 30:60:30 NPK kg ha^{-1} which was recorded lower seed yield (1359 kg ha^{-1}) and higher stover yield (2901 kg ha^{-1} (Table 3.) . This could be due to the optimum fertilizer level which involved in the biochemical processes in

TABLE 3

Protein and nutrient content of rice bean as influenced by different spacing and fertilizer levels

Treatments	Nitrogen (%)	Phosphorous (%)	Potassium (%)	Protein content (%)
Main plot (Spacing)				
S_1 -22.5 cm × 10 cm	1.69	0.42	1.60	20.64
S_2 -30 cm × 10 cm	1.89	0.48	1.66	20.63
S_3 -45 cm × 10 cm	1.91	0.45	1.63	20.70
S.Em±	0.02	0.03	0.01	0.03
CD (0.05)	NS	NS	NS	NS
Sub plot (Fertilizer levels)				
F_1 -Control	2.09	0.29	1.33	20.04
F_2 -20:40:20 NPK kg ha^{-1}	2.45	0.50	1.60	20.64
F_3 -25:50:25 NPK kg ha^{-1}	2.70	0.54	1.85	20.24
F_4 -30:60:30 NPK kg ha^{-1}	2.73	0.57	1.82	21.71
S.Em±	0.02	0.01	0.01	0.03
CD (0.05)	0.07	0.03	0.03	0.10
Interaction (S × F)				
S_1F_1	2.07	0.29	1.33	20.03
S_1F_2	2.45	0.51	1.61	20.64
S_1F_3	2.73	0.52	1.85	20.86
S_1F_4	2.69	0.57	1.82	21.05
S_2F_1	2.08	0.29	1.34	20.03
S_2F_2	2.46	0.50	1.60	20.73
S_2F_3	2.75	0.56	1.86	20.41
S_2F_4	2.70	0.58	1.83	21.34
S_3F_1	2.13	0.29	1.32	20.05
S_3F_2	2.44	0.50	1.60	20.53
S_3F_3	2.71	0.54	1.84	20.86
S_3F_4	2.70	0.55	1.82	21.34
S.Em±	0.02	0.01	0.01	0.05
CD (0.05)	NS	NS	NS	NS

plant *i.e.,* formation of chlorophylls and synthesis of proteins resulted in an increment in the vegetative growth which accumulated and translocated the highest amount of solar radiation to the yield attributing characters. Similar results were also reported by Khan *et al.* (2017), Singh *et al.* (2011), Kalasaria *et al.* (2017) and Chatterjee and Bandyopadhyay (2017) in green gram.

Effect of Different Spacing and Fertilizer Levels on Nutrient Content and Nutrient Uptake of Rice Bean Nutrient Content in Rice Bean Seeds

Major nutrients (NPK) content of rice bean as influenced by different spacing and fertilizer levels is presented in Table 3. Nitrogen, Phosphorous and Potassium content has depicted non-significant difference due to different spacing and fertilizer levels.

However, numerically higher NPK content (1.91, 0.48 and 1.66%, respectively) was recorded for spacing of 45 × 10 cm, whereas, lower NPK content (1.69, 0.42 and 1.60%, respectively) was observed in spacing of 22.5 × 10 cm (Table 3).

Similarly, significant difference was observed for NPK contents due to different fertilizer levels. Significantly higher NPK content (2.73, 0.57 and 1.85%, respectively) was recorded with application of 30:60:30 NPK kg ha^{-1} which was on par with application of 30:60:30 NPK kg ha^{-1} (2.70, 0.54 and 1.82, respectively) (Table 3). This might be due the balanced supply of nutrient promoted greater accumulation of chlorophyll pigment in the plant, which ultimately led to better enzymatic reactions and productions of higher amount of amino acids which is the major constituent of N. These results were in conformity with the findings of Rana *et al.* (1998) in French bean, Teotia *et al.* (2001) and Shete *et al.* (2010) in mung bean.

NPK content in seed of rice bean had shown non-significant due to interaction of different spacing and fertilizer levels (Table 3). However, numerically higher NPK content (2.75, 0.56 and 1.86%, respectively) was observed in S_2F_3 (30 × 10 cm spacing with 30:60:30 NPK kg ha^{-1}). Whereas, lower NPK content (2.07, 0.29 and 1.33%, respectively) was observed in S_1F_1 (22.5 × 10 cm with controlled fertilized treatment). This might be due to the accumulation of higher amount of solar radiation by the green leaves, which enhanced the enzymatic reactions and added nutrient in the grain. These results were in conformity with the findings of Rana *et al.* (1998) in French bean, Teotia *et al.* (2001) and Shete *et al.* (2010) in mung bean.

Protein content also analysed in seeds and data indicated that row spacing has no significant effect whereas fertility levels significantly varied (Table 3). When the fertility levels were considered, the higher protein content (21.71%) was observed when the NPK was applied @ 30:60:30 NPK kg ha^{-1} which was followed by application of 25:50:25 NPK kg ha^{-1} (20.24%). This might be due to the progressive enzymatic activities at higher doses of fertilizer led to protein accumulation in the grain. Since N is an essential component of protein which might had resulted in more crude protein in plants receiving more NPK fertilizer. Iqbal *et al.* (1998) found that protein content increased with successive increase in N and P fertilizer application in fodder rice bean. These results were in conformity with the findings of Kumar *et al.* (2016) and Fayique *et al.* (2018) in fodder rice bean and Malik *et al.* (2003) in mung bean among the two factor interactions, the same percentage of crude protein (21.34%) was found in S_2F_4 and S_3F_4. This can be accounted to the fact that nitrogen enhanced the protein synthesis in plants. The lower value for crude protein (20.03%) was found in S_1F_1.

Nutrient uptake by the Rice Bean

Nutrient uptake (kg ha^{-1}) by the rice bean as influenced by different spacing and fertilizer levels are presented in Table 4. Major nutrients *viz.,* nitrogen, phosphorous and potassium uptake by rice bean has shown significant difference due to different spacing levels. Significantly higher NPK uptake (48.74, 10.06 and 30.77 kg ha^{-1}, respectively) was observed with the closer spacing of 30 cm × 10 cm, whereas, lower nitrogen uptake (35.65, 7.02 and 23.48 kg ha^{-1}, respectively) was recorded with the spacing of 45 cm × 10 cm (Table 4).

NPK uptake value by the rice bean has depicted significant difference due to different fertilizer levels. Significantly higher NPK uptake (48.40, 9.91 and 33.57 kg ha^{-1}, respectively) was observed with application of 25:50:25 NPK kg ha^{-1} followed by application of 20:40:20 NPK kg ha^{-1} (42.82, 8.83 and 28.36 kg ha^{-1}, respectively). Significantly less NPK uptake was recorded with control plot (28.64, 5.94 and 19.60kg ha^{-1}, respectively). There was no significant difference observed for NPK uptake by the interaction effects of different spacing and fertilizer levels. Numerically higher NPK uptake (56.95, 12.05 and 39.09 kg ha^{-1}, respectively) was observed in S_2F_3 (30× 10 cm with 25:50:25 NPK kg ha^{-1}) whereas, lower nitrogen uptake (26.63kg

TABLE 4

Plant nutrient uptake of rice bean as influenced by different spacing and fertilizer levels

Treatments	Nitrogen (kg ha^{-1})	Phosphorous (kg ha^{-1})	Potassium (kg ha^{-1})
Main plot (Spacing)			
S_1 -22.5 cm × 10 cm	48.74	10.06	27.07
S_2 -30 cm × 10 cm	46.60	9.85	30.77
S_3 -45 cm × 10 cm	35.65	7.02	23.48
F test	*	*	*
S.Em±	1.76	0.49	1.29
CD (0.05)	6.89	1.93	5.07
Sub plot (Fertilizer levels)			
F_1 -Control	28.64	5.94	19.60
F_2 -20:40:20 NPK kg ha^{-1}	42.82	8.83	28.36
F_3 -25:50:25 NPK kg ha^{-1}	48.40	9.91	33.57
F_4 -30:60:30 NPK kg ha^{-1}	41.45	8.56	26.91
F test	*	*	*
S.Em±	1.11	0.32	0.95
CD (0.05)	3.31	0.95	2.84
Interaction (S × F)			
S_1F_1	26.63	5.53	19.63
S_1F_2	39.68	8.31	26.39
S_1F_3	46.01	9.27	32.92
S_1F_4	42.66	9.11	29.34
S_2F_1	32.46	7.30	19.94
S_2F_2	48.15	9.56	30.56
S_2F_3	56.95	12.05	39.09
S_2F_4	48.83	10.50	33.51
S_3F_1	26.85	4.99	19.22
S_3F_2	40.63	7.82	23.79
S_3F_3	42.23	8.42	28.69
S_3F_4	32.87	6.87	22.23
F test	NS	NS	NS
S.Em±	3.51	0.98	2.58
CD (0.05)	NS	NS	NS

ha^{-1}) was observed in S_1F_1 (22.5 × 10 cm with controlled treatment).

Among crop geometry 30 cm × 10 cm resulted in significantly higher nutrient uptake than all other spacing levels. This might be due to the optimum plant density and effective utilization of natural resources with least competition among individual plants encouraged vegetative and reproductive growth of the crop and resulted in higher nutrient uptake. These results were in agreement with the findings of Dewangan *et al.* (1992) and Gohil *et al.* (2017) in green gram.

Significantly higher nutrient (N, P and K) uptake was observed in higher fertilizer level. This was due to synergistic effect of NPK fertilization, better development of root and shoot resulted into higher N, P, K content and thereby increasing uptake. This might be due the higher doses of fertilizer, which accelerated the healthy vegetative growth and promoted higher nutrient uptake by the roots. It was also due to maintenance of water in the soil and increased nutrient solution which is readily available to the plants so it increases the nutrient uptake. Almost similar findings were reported by Singh *et al.* (2018) in Rajmash and Kumar *et al.* (2009) in French bean, Takankhar *et al.* (1998), Patel *et al.* (2013) and Ghule *et al.* (2020) in green gram.

Available NPK Status of Soil after Harvest of Rice Bean

Soil available NPK after harvest of crop did not show significant difference due to different spacing levels. Numerically, higher available NPK status (269.39, 35.74 and 242.68 kg ha^{-1}) was observed in S_3 (45 × 10 cm) whereas lower available NPK status was observed in S_1 (22.5 × 10 cm).

NPK availability after the harvest of rice bean has shown significant difference due to different fertilizer level. Significantly higher available status of NPK (278.67, 40.18 and 257.62 kg ha^{-1}, respectively) was observed in 30:60:30 NPK kg ha^{-1} fertilizer level. Whereas, lower NPK availability (247.19, 31.18 and 223.40 kg ha^{-1}, respectively) was observed with control treatment (Table 5). The greater availability of nitrogen may be through direct addition of higher amount of fertilizer helped better biomass production, which might have helped in multiplication of soil microbes, ultimately enhancing the conversion of organically bound N to mineral form. As rice bean is a legume crop which is having the capacity to fix atmospheric nitrogen, which is ultimately added to the available nitrogen pool. Simialrly, the increased value for available phosphorus

TABLE 5

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

Treatments	Soil available N(kg ha^{-1})	Soil available P_2O_5 (kg ha^{-1})	Soil available K_2O (kg ha^{-1})
Main plot (Spacing)			
S_1-22.5 cm × 10 cm	267.33	35.66	241.18
S_2-30 cm × 10 cm	268.38	35.22	240.79
S_3-45 cm × 10 cm	269.39	35.74	242.68
S.Em±	13.83	1.83	11.14
CD (0.05)	NS	NS	NS
Sub plot (Fertilizer levels)			
F_1-Control	247.19	31.18	223.40
F_2-20:30:20 NPK kg ha^{-1}	272.21	33.97	244.64
F_3-30:40:25 NPK kg ha^{-1}	275.38	36.83	248.56
F_4-40:50:30 NPK kg ha^{-1}	278.67	40.18	257.62
S.Em±	7.92	1.03	7.18
CD (0.05)	23.52	3.05	21.35
Interaction (S × F)			
S_1F_1	247.53	31.73	230.03
S_1F_2	272.55	33.99	236.58
S_1F_3	274.42	36.59	246.00
S_1F_4	278.84	40.32	256.13
S_2F_1	245.97	30.70	220.48
S_2F_2	271.88	33.86	247.24
S_2F_3	276.75	36.33	244.50
S_2F_4	278.92	39.99	250.93
S_3F_1	248.06	31.11	219.68
S_3F_2	272.22	34.06	250.09
S_3F_3	274.97	37.58	255.17
S_3F_4	278.26	40.23	265.79
S.Em±	27.66	3.67	22.28
CD (0.05)	NS	NS	NS

might be due to the capacity of rice bean to fix atmospheric nitrogen, which produced organic acids near the rhizosphere zone, which acted as a feed stock for the microorganisms, helped in the proliferation of the microflora which automatically taken part in the solubilisation of fixed form of P to available P. Further, higher potassium status may be due to the enhancement of root biomass production in higher fertilizer doses, which acted as organic feed source for the microorganisms present in the soil and helped in better proliferation. These microbial populations actively taken part in the solubilisation of the fixed form of K to available K. Similar results were also reported by Kantwa *et al.* (2019), Sipai *et al.* (2015), Patel *et al.* (1992) and Hangsing *et al.* (2020) in green gram.

Nitrogen availability after the harvest of rice bean has shown non-significant difference by the interaction of different spacing and fertilizer levels. However, numerically higher Nitrogen availability (278.92, 39.99 and 250.93 kg ha^{-1}, respectively) was observed in S_2F_4 (45 × 10 cm with 30:60:30 NPK kg ha^{-1}) whereas lowest Nitrogen availability (247.53, 31.73 and 230.03 kg ha^{-1}, respectively) was observed in S_1F_1 (22.5 × 10 cm with controlled fertilizer level).

Economics

Data on interaction effect of different spacing and fertilizer levels on economics of rice bean production was presented in Table 6. The results revealed that the net return and benefit cost ratio of rice bean was influenced by the population densities and fertilizer levels. It was revealed that spacing of 30 cm × 10 cm in combination with application of 25:50:25 NPK kg ha^{-1} (S_2F_3) recorded higher net return (Rs.100284 ha^{-1}) and benefit cost ratio (3.57) followed by spacing of 30 cm × 10 cm in combination with application of 20:40:20 NPK kg ha^{-1} (Rs.92968 ha^{-1} and 3.40, respectively) (S_2F_2) and at 22.5 cm × 10 cm spacing in combination with application of 30:60:30 kg ha^{-1} (Rs.82296 ha^{-1} and 2.88, respectively) (S_1F_3). The lower net return and benefit cost ratio was obtained in 45 × 10 cm spacing in combination with controlled fertilized treatment. This could be due to the fact that more yield, higher market price and less cost of production resulted in higher net returns and B:C ratio. The above results were also supported by Singh *et al.* (2009), Bunkar *et al.* (2013), Patel (2013), Hansing *et al.* (2020) in green gram, Dhanjal *et al.* (2001) in French bean, Jagadale *et al.* (2017) in cowpea and Malik *et al.* (2003) in rice bean.

TABLE 6

Economics of rice bean as influenced by different spacing and fertilizer levels

Treatments	Cost of cultivation (Rs ha^{-1})	Gross returns (Rs ha^{-1})	Net returns (Rs ha^{-1})	B:C Ratio
Interaction (S × F)				
S_1F_1	25568	60830	35262	1.37
S_1F_2	27780	100800	73020	2.62
S_1F_3	28514	110810	82296	2.88
S_1F_4	29254	98910	69656	2.38
S_2F_1	25080	64260	39180	1.56
S_2F_2	27292	120260	92968	3.40
S_2F_3	28026	128310	100284	3.57
S_2F_4	28766	112700	83934	2.91
S_3F_1	24009	52850	28841	1.20
S_3F_2	26221	92960	66739	2.54
S_3F_3	26955	95340	68385	2.53
S_3F_4	27695	73780	46085	1.66

Note : S_1: 22.5cm × 10 cm, S_2: 30 cm × 10 cm and S_3: 45 cm × 10 cm

F_1: Control, F_2: 20:40:20 kg NPK ha^{-1}, F_3: 25:50:25 kg NPK ha^{-1}

F_4: 30:60:30 kg NPK ha^{-1}).

Based on the results obtained it can be concluded that 30 x 10cm spacing has found optimum for rice bean crop for better growth and development and fertilizer levels of 25:50:25 NPK kg ha^{-1} for higher seed yield and benefit cost ratio of rice bean under eastern dry zone of Karnataka.

REFERENCES

BEHERA, J., MOHANTY, P. K., LOKOSE, R. Y. AND MISHRA, A., 2015, Response of promising rice bean [*Vigna umbellata* (Thunb.) Ohwi & Ohashi] genotypes in different levels of nitrogen. *Int. J. Sci. Res.*, **6** : 272 - 275.

BUNKAR, D., SINGH, R. K., CHOUDHARY, H. R., JAT, A. L. AND SINGH, K., 2013, Effect of row spacing and mulching on growth and productivity of mung bean (*Vigna radiata* L. Wilczek) in Guava (*Psidium guajava* L.) based agri-horti system. *Env. Ecol.*, **31** (1) : 160 - 163.

CHATTERJEE, B. AND BANDYOPADHYAY, K., 2017, Influence of micronutrients on pulses. *Mysore J. Agric. Sci.*, **4** (2) : 128 - 131.

DHANJAL, R., PRAKASH, O. AND AHLAWAT, I. P. S., 2001, Response of french bean (*Phaseolus vulgaris*) varieties to plant density and nitrogen application. *Indian J. Agron.,* **46** (2) : 277 - 281.

FAYIQUE, A. C. AND THOMAS, U. C., 2018, Effect of spacing and nutrient levels on the quality and yield of fodder rice bean [*Vigna umbellata* (Thunb.)]. *Forage Res.*, **44** (2) : 125 - 128.

GHULE, N. S., BHOSALE, A. S., SHENDE, S. M. AND GEDAM, V. B., 2020, Effect of fertilizer levels on yield, nutrient content and uptake of summer green gram (*Vigna radiata* L.). *Int. J. Crop Sci.*, **8** (6) : 1670 - 1673.

GOHIL, K. O., KUMAR, S. AND JAT, A. L., 2017, Effect of plant geometry, seed priming and nutrient management on growth, yield and economics of summer green gram [*Vigna radiata* (L.) Wilczek]. *Int. J. Curr. Microbiol. App. Sci.*, **6** (9) : 2386 - 2390.

HANGSING, N., TZUDIR, L. AND SINGH, A. P., 2020, Effect of spacing and levels of phosphorus on the growth and yield of green gram (*Vigna radiata*) under rainfed condition of Nagaland. *Agric. Sci. Dig.*, **40** (2) : 656 - 659.

IQBAL, K., TANVEER, A., ALI, A., AYYUB, M. AND TAHIR, M., 1998, Growth and yield response of rice bean (*Vigna umbellata*) fodder to different levels of N and P. *Pak. J. Biol. Sci.,* **1** : 212 - 214.

JAGADALE, A. R., BAHURE, G. K., MIRZA, I. A. B., MIRCHE, S. H. AND GHUNGARDE, S. R., 2017, Effect of plant geometry and fertilizer levels on yield and economic of cowpea (*Vigna unguiculata* L. Walp). *Int. J. Curr. Microbiol. App. Sci.,* **6** (5) : 1518 - 1522.

KACHARE, G. S., POL, K. M., BHAGAT, A. A. AND BHOGE, R. S., 2009, Effect of spacing and sowing directions on growth, yield and yield attributes of green gram. *Int. J. Agr. Sci.,* **6** (3) : 251 - 252.

KALSARIA, R. N., VEKARIYA, P. D., HADIYAL, J. G. AND ICHCHHUDA, P. K., 2017, Effect of spacing, fertility levels and bio-fertilizers on growth and yield of summer green gram (*Vigna radiata* L. Wilczek). *J. Pharmacogn. Phytochem.,* **6** (5) : 934 - 937.

KANTWA, S., SWAROOP, N., RAO, P. S. AND THOMAS, T., 2019, Effect of different levels of NPK and FYM on soil physico-chemical properties and yield attribute of green gram (*Vigna radita* L.) Var. Samrat. *Int. J. Cosmet. Sci.*, **7** (3) : 2163 - 2166.

KEERTHI, M. M., BABU, R., JOSEPH, M. AND AMRUTHA, R., 2015, Optimizing plant geometry and nutrient management for grain yield and economics in irrigated green gram. *Am. J. Plant Sci.,* **6** : 1144 - 1150.

KHAN, M. M. S., SINGH, V. P. AND KUMAR, A., 2017, Studies on effect of phosphorous levels on growth and yield of *kharif* mung bean (*Vigna radiata* L. wilczek). *Inter. J. Pure Appl. Biosci.*, **5** : 800 - 808.

KHANDA, C. M. AND MISHRA, P. K. (1998), Effect of plant density and nitrogen fertilization on growth and yield of rice bean. *Indian J. Agron.,* **43** : 700 - 703.

KOTWAL, V. D. AND PRAKASH, O. M., 2006, Effect of row spacing on growth, yield attribute and yield of green gram. *Advances Plant Sci.,* **19** (2) : 481 - 483.

KUMAR, B., SURIN, S. S. AND TUTI, A., 2016, Response of rice bean genotypes to varied levels of phosphorus under rainfed condition of Jharkhand. *Int. J. Sci. Environ. Tech*., **5** : 4607 - 4611.

KUMAR, R. P., SINGH, O. N., SINGH, Y., DWIVEDI, S. AND SINGH, J. P., 2009, Effect of integrated nutrient management on growth, yield, nutrient uptake and economics of French bean (*Phaseolus vulgaris*). *Indian J. Agric. Sci.,* **79** : 122 - 128.

MAGAN, SINGH, RUNDAN, V. AND SANTOSH ONTE, 2020, Ricebean : High valued fodder crop. *Indian Farming,* **70** (06) : 27 - 31.

MALIK, M. A., SALEEM, M. F., ALI, A. AND MAHMOOD, I., 2003, Effect of nitrogen and phosphorus application on growth yield and quality of mung bean (*Vigna radiata* L.). *Pak. J. Agric. Sci.,* **40** : 133 - 136.

MURTHY NIRANJANA, ANAND, S. R. AND S. K. PRITHVIRAJ, 2020, Underutilized potential crops for food and nutritional security under Changing Climate. *Mysore J. Agric. Sci.,* **54** (1) : 1 - 14.

PANSE, V. G. AND SUKHATME, P. V., 1978, Statistical methods for agricultural workers. *Indian Council of Agricultural Research,* New Delhi.

PATEL, A. R., PATEL, D. D., PATEL, T. U. AND PATEL, H. M., 2013, Nutrient management in summer green gram (*Vigna radiata* L. Wilczek). *Int. J. Appl. Agric. Sci.,* **2** (2) : 133 - 142.

PATEL, I. C., PATEL, M. M., PATEL, A. G. AND TIKKA, S. B. S., 2005, Effect of seed rate and row spacing on yield of *kharif* green gram. *Arid Legumes Sustain. Agric. Trade.*, **1** : 8 - 9.

PATEL, J., 2013, Response of green gram (*Vigna radiata* L.) to spacing, levels of fertilizer with and without FYM under south Gujarat condition. *Ph.D. Thesis,* Navsari Agric. Univ. Navsari.

PATEL, L. R., SALVI, N. M. AND PATEL, R. H., 1992, Response of green gram (*Vigna radiate*) varieties to sulphur fertilization under different levels of nitrogen and phosphorus. *Indian J. Agron.,* **37** (4) : 831 - 833.

RANA, N. S., SINGH, R. AND AHLAWAT, I. P. S., 1998, Dry matter production and nutrient uptake in French bean (*Phaseolus vulgaris*) as affected by nitrogen and phosphorus application. *Indian J. Agron.,***43** (1) : 114 - 117.

RATHORE, S. S., DASHORA, L. N. AND KAUSHIK, M. K., 2010, Effect of sowing time and fertilization on productivity and economics of urd bean genotypes. *J. Food Leg.,* **23** (2) : 154 - 155.

SHETE, P. G., THANKI, J. D., BAVISKAR, V. S. AND ADHAV, S. L., 2010, Effect of land configuration, fertilizer and FYM levels on quality and nutrient status of *Rabi* green gram. *Green Farming*, **1** (4) : 409 - 410.

SINGH, B. P., SRIVASTAVA, G. P., PANDEY, A. C., PRASAD, P., MARDI, G., KRISHNA, G., ANIL, K. AND MINISH, K., 2009, Response of black gram (*Vigna mungo*) to nitrogen levels and plant geometry under late sown condition. *Indian J. Trop. Agric.,* **27** (2) : 297 - 300.

Singh, G., Ram, H., Sekhon, H. S., Aggarwal, N., Kumar, M., Kaur, P. and Sarma, P., 2011, Effect of nitrogen and phosphorus application on productivity of summer mung bean sown after wheat. *J. Food Legumes*, **24** (4) : 327 - 329.

Singh, V. K., Kumari, C., Singh, Y. P. and Singh, R. K., 2018, Effect of different levels of nitrogen, phosphorus and sulphur on growth and yield of Rajmash (*Phaseolus vulgaris* L.) Variety PDR 14. *J. Community Mobilization Sustain. Dev.*, **13** (3) : 573 - 577.

Sipai, A. H., Jat, J. S., Rathore, B. S., Kuldeep, S., Jodha and Singh, J., 2015, Effect of phosphorus, sulphur and bio fertilizer on productivity and soil fertility after harvest of moong bean grown on light textured soil of Kachchh. *Asian J. Soil Sci.,* **10** : 228 - 236.

Srikanth, 2007, Effect of spacing and fertilizer levels on crop growth, seed yield and quality in lablab bean (*Lablab purpureus* L.). *M. Sc. Agri Thesis.* University of Agricultural Sciences, Dharward.

Takankhar, V. G., Mane, S. S., Kamble, B. G. and Surywanshi, A. P.,1998, Phosphorus uptake at different stages and yield attributes of grain crops as affected by P and N fertilization and *Rhizobium* inoculation. *J. Soils Crops.,* **8** : 53 - 58.

Teotia, U. S., Mehta, V. S., Ghosh, D. and Srivastava, P. C., 2001, Phosphorus and sulphur interaction in moong bean on yield, phosphorus and sulphur contents. *Legume Res.,* **23** (1) : 106 - 109.