Effect of planting geometry and nutrient management on yield, economics and quality of dwarf rice bean (*Vigna umbellata*) under rainfed condition

ABSTRACT

Rice bean (*Vigna umbellata*) is one of the under-utilized crops which can become a promising pulse crop. A field experiment was carried out during *kharif* season of 2020 at Research Farm, College of Agriculture, Central Agricultural University, Imphal, Manipur to study the effect of planting geometry and nutrient management on yield, economics and quality of dwarf rice bean under rainfed condition. The experiment was laid out in Factorial Randomized Block Design (FRBD) and nutrient management which was replicated thrice. The treatments comprised of three planting geometry viz; S_1 : 30 cm x 10 cm, S_2: 45 cm x 10 cm and S_3: 60 cm x 10 cm and four nutrient management practices viz; F_0: Seed treatment with molybdenum + phosphate solubilizing bacteria (PSB), F_1: 20 kg P_2O_5/ha + seed treatment with molybdenum+ PSB, F_2:40 kg P_2O_5 /ha + seed treatment with molybdenum+ PSB and F_3: 60 kg P_2O_5 /ha + seed treatment with molybdenum+ PSB. Results indicate that planting geometry at 60 cm × 10 cm and nutrient management at 60 kg P_2O_5/ha with seed treatment of molybdenum + phosphate solubilizing bacteria (PSB) significantly influenced the yield and quality of dwarf rice bean and gave the maximum economic returns. The highest seed yield (14.65 q/ha) was recorded with spacing S_3 which was significantly superior over S_1 upto the tune of 8.7% (13.37q/ha). Among the different nutrient management practices, highest seed yield (16.01 q/ha) was recorded from F_3 which was found to be at par with F_2 (15.70 q/ha) and significantly superior over F_1 and F_0 (12.71 q/ha and 11.70 q/ha, respectively). The increase in seed yield in F_3 and F_2 were 26.9% and 25.5%, respectively over control (F_0). Among the various planting geometry, the highest gross return (Rs 117240/ha), net return (Rs 71334/ha) and benefit cost ratio (2.54) were recorded from S_3 and lowest gross return (Rs 106960/ha), net return (Rs 60304/ha) and benefit cost ratio (2.29) from S_1. In respect of nutrient management the maximum gross return (Rs128053/ha), net return (Rs 80877/ha) and benefit cost ratio (2.72) were associated with F_3 and lowest from F_0 (Rs 93360, Rs 48058 /ha 2.06, respectively). The interaction effect of S_3 and F_3 gave highest crude protein yield (397.75 kg/ha) which was 48.2 % higher than S_1 and F_0 (205.92 kg/ha).

Keywords: *Rice bean, planting geometry, nutrient management, yield, quality*

Introduction

"Pulses play a vital part in Indian agriculture. India is a leading pulse growing country and forms an essential part of the cropping system of the farmers around the country. The present average per capita consumption of pulses in India is 14 kg per year against the WHO recommendation of 20 kg per year. India with 28 Mha of pulses cultivation area with an annual productivity at 885 kg/ha, has also increased significantly over the last five years" (GOI, 2022). "Pulses can fix the soil atmospheric nitrogen in their root system, which enables the plants to meet the nitrogen requirement on their own. They are known to render a significant impact on soil health and considered to be the key component for sustainable agriculture" (Laishram *et al.*, 2020). "About 2-3 million tons of pulses are imported annually to meet the domestic consumption requirement. By 2050, the domestic requirements for pulse would be 26.50 M tonns, necessitating stepping up production by 81.50%, *i.e.*, 11.9 million tons of additional produce at 1.86 % annual growth rates" (Singh *et al.*, 2015). Thus, there is a need to increase the production and productivity of pulses in the country through more intensive interventions.

"Rice bean (*Vigna umbellate)* is one of the under-utilized pulse crops which can become a promising pulse crop. This crop is a native of South and South East Asia from the Himalayas to South China and Indonesia" (Chandel and Pant, 1982). "In India, as cultigens, rice bean is mainly confined to the tribal regions of the North Eastern Hills, Western and Eastern Ghats in peninsular India" (Arora *et al.,* 1980). "In the North Eastern Region and also in the hilly regions of both North Bengal and Sikkim, rice bean is grown predominantly under rain fed condition in a mixed farming system, under shifting cultivation or in kitchen gardens and backyards". (Arora et al., 1980) Despite being a crop that is thought to be underutilised, rice beans are valued for their high nutritional content in Manipur state of India. Rice bean is highly nutritious and the protein is high in lysine. Rice bean foliage and dry straws are valuable green manure as it improves soil fertility.

However, in the north hilly region of India, it is mostly grown by subsistence farmers in poor soil environment conditions or barren land which limit their yield. Inappropriate planting time, high population density and spatial configuration are some of the major causes of low production (Devi, 2021). Crop establishment is an important factor which depends upon optimum plant population and uniform emergence for achieving higher yield (Devi *et al.,* 2022). Proper planting geometry can provide optimum plant stand thereby less competitive effect on each other without compromising the yield. "Plant geometry plays an important role in the dominance and suppression during the process of competition. Ideal plant geometry is precious and important for better and efficient utilization of available plant growth resources in order to get maximum productivity in crops" (Rana, 2011). Increase in yield can be ensured by maintaining appropriate plant population through different planting patterns. The influence of spacing on yield and quality of rice bean is still lacking in most of the rice bean growing areas in our country.

Apart from this, both biotic and abiotic factors play a major role in limiting rice bean production in rain-fed agriculture. Though pulses are able to fix atmospheric nitrogen, sufficient dose of nutrients are required at initial crop stages to maintain their proper crop growth. The North Hilly region India has more than 80% hilly area of pH less than 5.5 with acid in nature and poor availability of P, Mo, Ca and Mg as well as the toxicity of Al, Fe, and Mn has been blamed for the soil's low productivity. "Phosphorus serves a master nutrient for legume crop; it is involved in several plant functions, including energy storage and transfer, photosynthesis, transformation of sugars and starches, etc. Phosphorus application in rice bean promotes seed yield and dry matter production by enhancing root proliferation and nodulation. Yet, in acidic soil conditions, phosphorus is one of the main minerals that are limited for leguminous crops. Molybdenum a trace element found in the soil is required for growth of most biological organisms including plants" (Agarwala *et al.*, 1978). "Phosphate solubilizing bacteria (PSB) play fundamental roles in biogeochemical phosphorus cycling in agro-ecosystems. It mobilize insoluble form of phosphorus in the rhizosphere into available form. And hence, application of such naturally occurring organic inputs as a whole improved the soil support system and ensured nutrient availability which was ultimately reflected in yield performance of the crop" (Zaidi *et al.,* 2017). Hence, nutrient management are of immense significance which is to be managed properly for higher production.

With this background in view and the known possible reason, the present investigation was undertaken under rainfed condition with the following objectives:

1. To study the effect of planting geometry and nutrient management on seed yield and quality of dwarf rice bean
2. To work out the economics of the treatment.

1. Materials and Methods

A field experiment was conducted during *kharif* season of 2020 at Research Farm, College of Agriculture, Central Agricultural University, Imphal, Manipur to study the effect of planting geometry and nutrient management on yield, quality and economics of dwarf rice bean (*Vigna umbellata*) under rainfed condition. "The experimental site is located at 24.45˚N latitude and 93.56˚E longitudes at an elevation of 790 m above mean sea level. The soil of the experimental site was acidic with pH 5.1, available nitrogen 231.03 kg/ha, available phosphorous 10.95 kg/ha, available potash 150.00 kg/ha, available molybdenum 0.025 mg/kg and organic carbon 1.8 %. The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications consisting of three planting geometry treatments *viz.* (S_1: 30 cm × 10 cm, S_2: 45 cm × 10 cm and S_3: 60 cm × 10 cm) and four nutrient management treatments *viz.* (F_0: Seed treatment with molybdenum + PSB; F_1: 20 kg P_2O_5/ha + seed treatment with molybdenum + PSB; F_2: 40 kg P_2O_5/ha + seed treatment with molybdenum + PSB and F_3: 60 kg P_2O_5/ha + seed treatment with molybdenum + PSB)" (Devi et. Al. 2021). During the course of investigation, the mean minimum and maximum temperature recorded during the cropping season was 12.7^{o}C and 37.1^{o}C, respectively with total rainfall was 977.1 mm. The average relative humidity varied from 91.2 per cent in the morning and 65.44 per cent in the evening. The average bright sunshine hour was 4.2.

The land was properly prepared by tractor driven cultivator and leveller. Adequate drainage channels were made in the field to drain the excess water as and when required. A uniform dose of 20 kg N/ha through urea and 20 kg K_2O/ha through muriate of potash was applied to all the plots. "Phosphorus was applied as per treatments through single superphosphate. The required quantity of different fertilizers as per treatments weighted separately and mixed together. After this, all fertilizers of each plot were applied in the rows at the time of sowing nearly 2 cm below the seed". (Devi et. Al. 2021)

The rice bean variety used was a local variety (chak-hawai) and were treated with the mixture of 0.2% sodium molybdate per kg of seed just before sowing and 20 ml of phosphate solubilizing bacteria (PSB) per kg of seed as per treatment. Sowing was done manually on 8 July 2020 by using 15 kg seeds/ha in the rows for all three spacing treatments. The seeds were then covered with a thin layer of soil. "The crop was infested with several weed species during early growth stage; hence, one hand weeding was done manually in all plots with the help of khurpi at 20 days after sowing (DAS). One spray of Emamectin benzoate 5 % (Proclaim) @ 1 liter/ha was given as a preventive measure at 30 DAS to control aphids and leafhoppers during early vegetative stage. Plant protection measures were provided as and when required". (Devi et. Al. 2021)

The crude protein content was determined by multiplying percentage of nitrogen content which was determined by by kjeldahl method (Jackson, 1973) in seed of rice bean with a factor of 6.25 (Piper, 1966).

- $\text{Crude protein \%} = \text{Nitrogen \%} \times 6.25$

The crude protein yield in q/ha under a particular treatment was calculated by multiplying crude protein content with dry matter yield (q/ha) of the respective treatments

- $\text{Crude protein yield (kg/ha)} = \frac{\text{Crude protein content (\%) x seed yield (q/ha)}}{100}$

The economics of the experiment was worked out from the cost of inputs and income from the seed yield. The gross and net returns as well as the cost benefit ratio were worked out by using the formulae:

- $\text{Gross returns (Rs/ha)} = \text{Cost of seed yield of ricebean}$
- $\text{Net returns (Rs/ha)} = \text{Gross returns} - \text{total cost of cultivation}$
- $\text{Cost bene it ratio} = \frac{\text{Gross returns}}{\text{Total cost of cultivation}}$

All the data obtained were statistically analyzed by the method of analysis of variance to test the significance of the treatment effects as well as result interpretation as given by Gomez and Gomez (1984).

2. Results and Discussion

Effect of planting geometry and nutrient management on yield (q/ha) of dwarf rice bean

Perusal of data revealed that the effect of planting geometry and nutrient management significantly influenced the seed yield and stover yield of rice bean (Table 1). Increasing the planting geometry upto 60 cm × 10 cm (S_3) gave the highest seed yield (14.66 q/ha), stover yield (89.71 q/ha) and harvest index (33.12%). Planting geometry (S_1) *i.e.* 30 cm × 10 cm gave the lowest yield. This might be ascribed to less inter-plant competition and better availability of growth resources, such as light, moisture, nutrients, and space for one another in broader planting geometry, which had improved yield-attributing features and ultimately raised the yield of rice bean. These results are in conformity with the findings of Goud *et al.* (2016) and Ramanjaneyulu *et al.* (2017). Among the different nutrient management practices, the highest seed yield (16.01 q/ha), stover yield (105.18 q/ha) and harvest index (33.37%)

were recorded in (F_3) *i.e.* 60 kg P_2O_5/ha + seed treatment with molybdenum+ PSB and it was found lowest in seed treatment with molybdenum + PSB (F_0). Such increase in yield might be due to the increase in vegetative growth with the increasing doses of phosphorus. This result is in agreement with those reported by Bhuiyan *et al.* (2016) and Nissa *et al.* (2017).

Integration of phosphatic fertilizer with molybdenum and phosphate solubilizing bacteria significantly influenced the seed yield and stover yield of rice bean. The treatment combination (S_3F_3) *i.e.* 60 cm x 10 cm and 60 kg P_2O_5/ha + seed treatment with molybdenum + PSB gave the highest seed yield (17.10 q/ha), stover yield (105.84 q/ha) and harvest index (37.70%) while the least was observed in treatment combination of 30 cm x 10 cm and seed treatment with molybdenum + PSB (S_1F_0). Such increase in the yield with the application of phosphorus is obvious due to acidic condition of the soil where the availability of phosphorus was limiting and in the medium range. Further, the seed treatment with molybdenum might have enhanced the nitrogen fixation resulting in better growth and yield. The optimum activities of phosphate solubilizing bacteria also increase the availability of phosphorus to the plant which ultimately increases the yield of rice bean. These findings are in line with those obtained by Yadav and Yadav (2011) and Manohar (2014).

Effect of planting geometry and nutrient management on economics (Rs/ha) of dwarf rice bean

The data presented in Table 1 revealed the economics of treatments (only seed cost @Rs. 80 per kg) that the planting geometry S_3 gave the maximum gross return (117240 Rs/ha), net return (71335 Rs/ha) and B:C (2.55). The lowest was for the planting geometry S_1. Among the different nutrient management practices, the maximum gross return (128054 Rs/ha), net return (80877 Rs/ha) and B:C (2.72) was found in F_3 and it was found lowest in F_0.

The treatment combination (S_3F_3) *i.e.* 60 cm x 10 cm and 60 kg P_2O_5/ha + seed treatment with molybdenum + PSB gave the maximum gross return (136800 Rs/ha), net return (89207 Rs/ha) and benefit cost ratio (2.8) while the least was observed in treatment combination of 30 cm × 10 cm and seed treatment with molybdenum + PSB (S_1F_0). The increase in net return might be due to increase in yield of dwarf rice bean and relatively low production cost per unit of yield under the treatment. It is clear from the data presented in Table 1 that B-C ratio increased in treatments S_3F_3 (*i.e.* 60 cm × 10 cm and 60 kg P_2O_5/ha + seed treatment with molybdenum + PSB) due to successive increase in varying levels of phosphorus up to 60 P_2O_5/ha + seed treatment with molybdenum + PSB. It recorded the B: C ratio of 2.8 which was higher by 32.14 per cent over control (S_1F_0). This might be due to maximum recovery from application of phosphorus with less expenditure and also higher gross and net return with comparative lower cost of cultivation as compared with other treatments. The result is in conformity with the findings of Vikram *et al.* (2018). They revealed that B: C ratio increased due to successive increase in varying levels of phosphorus up to 40 kg P_2O_5 ha^{-1} in chickpea. Application of P_2O_5 ha^{-1} recorded the B: C ratio of 2.40 which was higher by 11.62 per cent over control. This might be due to maximum recovery from application of phosphorus with less expenditure.

Effect of planting geometry and nutrient management on quality of dwarf rice bean

The effect of planting geometry and nutrient management significantly influenced the crude protein content of rice bean (Table 1). Increasing the planting geometry upto 60 cm × 10 cm gave the highest crude protein content (20.32%). It was found lowest in planting geometry 30 cm × 10 cm. Among the nutrient management practices, the highest crude protein content (21.67%) were recorded in 60 kg P_2O_5/ha + seed treatment with molybdenum+ PSB (F_3) and it was found lowest in seed treatment with molybdenum + PSB (F_0). Integration of phosphatic fertilizer with molybdenum and phosphate solubilizing bacteria significantly influenced the crude protein content of rice bean. The treatment combination (S_3F_3) *i.e.* 60 cm × 10 cm and 60 kg P_2O_5/ha + seed treatment with molybdenum + PSB gave the highest crude protein content (23.26%) while the least was observed in treatment combination of 30 cm × 10 cm and seed treatment with molybdenum + PSB (S_1F_0).

A perusal of data depicted graphically in Figure 1 revealed that there was significant increase in crude protein yield due to increase in spacing from S_1 to S_3. The highest crude protein yield 297.54 kg/ha in widest spacing 60 cm x 10 cm was found to be at par with the medium spacing 45 cm x 10 cm. The narrow spacing 30 cm x 10 cm recorded the minimum 258.17 kg/ha crude protein yield. The application of different phosphorus combination with molybdenum and PSB significantly increased the crude protein yield of rice bean. The maximum crude protein yield 346.93 kg/ha was associated with the application of 60 kg P_2O_5 with seed treatment of molybdenum + PSB and it remained at par with 40 kg P_2O_5 kg/ha+ seed treatment of molybdenum + PSB but significantly higher to the Treatment F1 and F0 respectively . The treatment F_0 recorded the minimum crude protein yield (205.92 kg/ha). The interaction between spacing and nutrient management was found to be significant in respect of crude protein yield. The highest order of interaction for crude protein yield

(397.75kg/ha) was observed in 60 cm x 10 cm and 60 kg P_2O_5 + seed treatment of molybdenum + PSB. The lowest order of interaction was observed in S_1F_0 for crude protein yield. The application of phosphorus maximum also significantly increased the crude protein yield.

The higher crude protein yield in wider spacing may be attributed to higher crude protein content and also higher seed yield in this treatment as discuss earlier. The higher crude protein might be due to the fact that wider spacing has less plant population than the narrow spacing so the nutrient content in seed is more as there is less competition among the plants. In addition, it may be due to adequate availability of phosphorus besides the contribution from the phosphate solubilizing bacteria which play a major role in protein synthesis. Application of phosphorus along with biofertilizers and micronutrients have increased early root growth and development and later on increases the vegetative growth of plant, which might have stimulated crude protein content and crude protein yield. This observation was supported by the findings of Singha and Sarma (2001) and Gupta *et al.* (2012).

Conclusion

Based on the experimental results, the interaction effect of spacing (S_3) and nutrient management (F_3) gave highest seed yield (17.10 q/ha) and crude protein yield (397.75 kg/ha) among all the treatments. Similarly, the highest gross return (Rs 136800/ha), net return (Rs 89207/ha) and benefit cost ratio (2.8) were recorded from S_3F_3. The increase in seed yield, net return and benefit cost ratio were 34%, 50% and 32% respectively over control (S_1F_0). Therefore, it can be concluded that for obtaining higher seed yields, good quality of seed after harvest and economic profitability of rice bean (local variety chak-hawai) wider spacing and higher dose of phosphorous treatments i.e. 60 cm × 10 cm and 60 kg P_2O_5/ha + seed treatment with molybdenum + PSB under rainfed conditions of Manipur was found effective and it can be recommended to other similar climatic conditions of north eastern regions of India.

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Table 1. Effect of planting geometry and nutrient management on seed yield, crude protein content and economics of dwarf rice bean

Planting geometry	Seed yield (q/ha)	Stover yield (q/ha)	Harvest index (%)	Gross return (Rs/ha)	Net return (Rs/ha)	B-C ratio	Crude protein content (%)
30 cm × 10 cm (S_1)	13.39	78.81	29.11	106960	60305	2.29	19.32
45 cm × 10 cm (S_2)	14.07	83.72	31.81	112320	66165	2.45	19.91
60 cm × 10 cm (S_3)	14.66	89.71	33.12	117240	71335	2.55	20.32
S. Em (±)	0.29	2.55	0.73	-	-	-	0.35
C.D. (P = 0.05)	0.60	5.29	1.51	-	-	-	0.72
Nutrient management							
Seed treatment with molybdenum + PSB (F_0)	11.71	65.91	28.91	93360	48058	2.07	17.61
20 kg P_2O_5 /ha + seed treatment with molybdenum+ PSB (F_1)	12.71	75.45	29.31	101654	55728	2.22	18.92
40 kg P_2O_5 /ha + seed treatment with molybdenum+ PSB (F_2)	15.71	89.79	33.80	125627	79076	2.70	21.20
60 kg P_2O_5 /ha + seed treatment with molybdenum+ PSB (F_3)	16.01	105.18	33.37	128054	80877	2.72	21.67
S. Em (±)	0.33	2.94	0.84	-	-	-	0.40
C.D. (P = 0.05)	0.688	6.10	1.75	-	-	-	0.84
Interaction (Planting geometry ×Nutrient management)							
S_1F_0	11.27	59.83	28.06	90080	44361	1.9	17.44
S_1F_1	12.65	74.07	28.62	101120	54777	2.1	18.65
S_1F_2	14.19	76.92	29.62	113440	66472	2.4	20.19
S_1F_3	15.41	104.42	30.13	123200	75607	2.5	20.99
S_2F_0	11.53	64.10	29.30	91440	45721	2.0	17.43
S_2F_1	12.67	75.78	30.02	101280	54937	2.1	19.28
S_2F_2	16.55	89.74	35.65	132400	85432	2.8	22.16
S_2F_3	15.53	105.27	32.29	124160	76567	2.6	20.77
S_3F_0	12.32	73.79	29.36	98560	52841	2.1	17.94
S_3F_1	12.82	76.50	29.29	102560	56217	2.2	18.82
S_3F_2	16.38	102.71	36.13	131040	84072	2.7	21.25
S_3F_3	17.10	105.84	37.70	136800	89207	2.8	23.26
S. Em (±)	0.57	5.10	1.46	-	-	-	0.70
C.D. (P = 0.05)	1.19	10.58	3.03	-	-	-	1.45

F0= seed treatment of molybdenum + PSB
F1= 30 kg P2O5 + seed treatment of molybdenum + PSB
F2= 40 kg P2O5 + seed treatment of molybdenum + PSB
F3= 60 kg P2O5 + seed treatment of molybdenum + PSB

S1= 30 cm x 10 cm
S2= 45 cm x 10 cm
S3= 60 cm x 10 cm

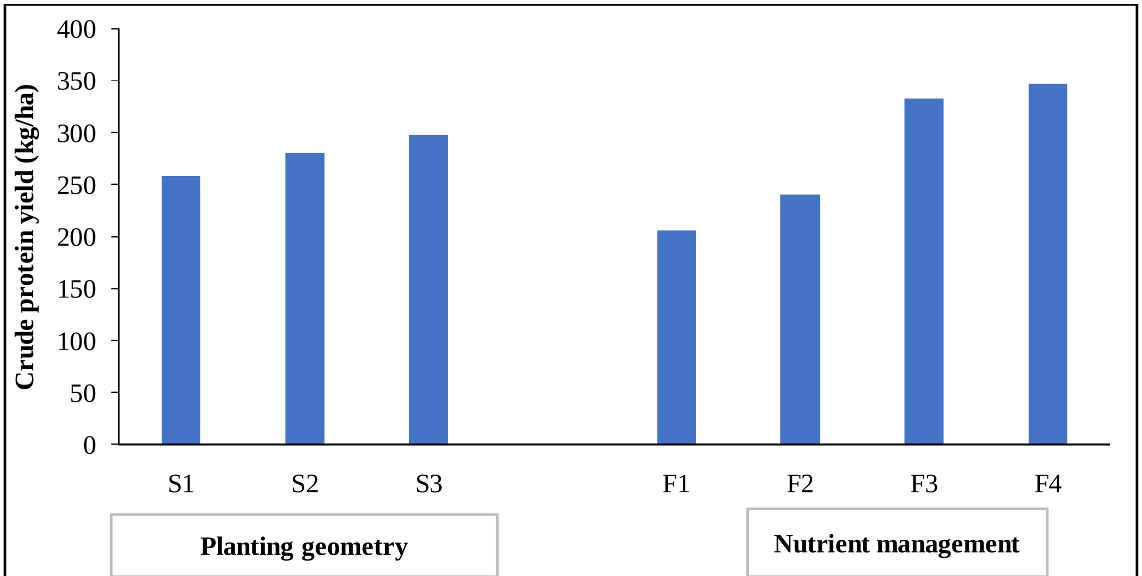

Figure 1. Effect of planting geometry and nutrient management on crude protein yield of dwarf rice bean