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Priyaranjan Swain
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Joy Dawson
Professor and Head, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Abhisekh Mahapatra
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

B Shekhar Mahanta
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Corresponding Author:
Priyaranjan Swain
M.Sc. Scholar, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj, Uttar Pradesh, India

Yield and economics of moth bean [*Vigna aconitifolia* (Jacq.) Marechal] as influence by the levels of phosphorus, spacing and manures

Priyaranjan Swain, Joy Dawson, Abhisekh Mahapatra and B Shekhar Mahanta

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Abstract
A field experiment was conducted during kharif 2018 at Central Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P.). The soil of experimental plot was sandy loam in texture, nearly neutral in soil reaction (pH 6.7), low in organic carbon (0.35%), available N (230 kg ha^{-1}), available P (20 kg ha^{-1}) and available K (189 kg ha^{-1}). The experiment was laid out in Randomized Block Design with factorial concept. There were 13 treatments including 12 treatment combinations including three levels of phosphorus, two spacing and two organics and one control.

Result show that higher dose of phosphorus recorded significantly higher yield parameters *viz.*, plant pods per plant (28.14), grains per pod (4.57) and Test weight (27.54 g). Wider spacing recorded significantly higher yield parameters *viz* pod per plant (4.60), grains per pod (4.60), seed yield (14.52 g plant^{-1}) and test weight (27.54 g). 1 t ha^{-1}. Vermicompost recorded significantly higher yield parameters *viz.*, plant height (49.26 cm), total dry matter at harvest (19.15 g plant^{-1}), pods per plant (28.14), grains per pod (4.57),and Test weight (27.54) and due to significantly higher harvest index (7.89%).

The moth bean produced significantly higher seed yield (324.50 kg ha^{-1}) due to higher level of phosphorus (P_1 50 kg ha^{-1}). The spacing of 45 cm x 10 cm recorded significantly higher seed yield (326.44 kg ha^{-1}) compared to 30 cm x 15 cm (322.06 kg ha^{-1}). Application of 1 t ha^{-1}vermicompost produced significantly higher seed yield (348.28 kg ha^{-1}) compared to 2.5 t ha^{-1} FYM (300.22 kg ha^{-1}).

In Uttar Pradesh (Prayagraj), cultivation of moth bean with phosphorus dose of 50 kh ha at a spacing of 45cm x 10cm with application of 1 t ha vermicompost produce significantly higher seed yield (386.67 kg/ha), net return (Rs.7170.33 ha) and a better B:C ratio (1.42).

Keywords: Moth bean, phosphorus levels, spacing, FYM, vermicomost

Introduction
Moth bean [*Vigna aconitifolia* (Jacq.) Marechel] is an important pulse crop of arid and semi-arid regions of India. It has multi-uses and adapts to extremes or uncongenial ecological niches particularly, in areas receiving fewer rains with erratic distribution. It is a hot weather, drought resistant legume. It can very well stand drought conditions and is probably the most drought resistant crop among the grain legumes.

The crop has spreading growth habit forming a mat like covering on the soil surface. It thus helps greatly in the conservation of soil, water and serve as a very efficient and suitable cover crop for checking soil erosion. The lower productivity of this crop is attributed to several factors *viz.*, growing the crop under moisture stress, marginal lands with very low inputs and without pest and disease management, non-availability of high yielding varieties and late sowing.

Choosing the optimum plant population and organic source are the major factors for better yield. Hence, there is a scope for improving the production potential of this crop by adopting optimum plant population and use of organic manures *viz.*, farm yard manure and vermicompost.

The role and importance of phosphorus applications is not only essential for the development of root system but also plays a vital role in the formation of energy rich bond phosphates like Adenosine di phosphate (ADP), Adenosine tri phosphate (ATP), nucleoproteins, phospholipids, etc. It is also essential for the growth of bacteria responsible for nitrogen fixation. Phosphorus application to moth bean has also been justified even in low-rainfall years because of its ability to improve yield under water-limited conditions (Garg *et al.*, 2004) [4]. The lower productivity of this crop is attributed to several factors *viz.*, growing the crop under moisture stress, marginal lands with very low inputs and without pest and disease management, non-availability of high yielding varieties and late sowing. Besides, farmers are interested to cultivate moth bean during *kharif* season. Moth been is also credited with the fixation of atmospheric nitrogen through symbiotic process. In addition, it sheds its leaves after physiological maturity and thus enhances soil fertility.

Materials and Methods

Field experiment entitled "Growth and yield of Moth bean [*Vigna aconitifolia* (jacq.) Marechal] as influence by phosphorus, spacing and manures." was conducted at the crop research farm Naini Agricultural Institute, SHUATS, Prayagraj during *kharif*season 2018. The experiment was carried out during the *kharif season* of 2018 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (U.P.), which is located at geographical coordinates 25^0 24' 42" N latitude, 81^0 50' 56" E longitude and 98 m altitude above the mean sea level. Situation of the area is to the right side of the river Yamuna by the side of Prayagraj Rewa Road about 7 km away from Prayagraj city.

The treatment consisted of 3 levels of Phosphorus *viz.* P_1 (50 kg P_2O_5 ha^{-1}), P_2 (40 kg P_2O_5 ha^{-1}), P_3 (30 kg P_2O_5 ha^{-1}), two type of spacing *viz.* S_1 (45cm 10 cm) and S_1 (30cm 15cm) and two type of organics O_1 (2.5 t ha^{-1} FYM) and O_2 (1 t ha^{-1}vermicompost) whose effect is observed on moth bean.

The soil of the experimental field constituting a part of central Gangetic alluvium is neutral and deep. Ph7.2 Digital pH meter (Jackson, 1967) [5] EC0.34 (dS m^{-1}) Method No.4 USDA Hand Book No.16 (Richards, 1954) [19] Organic carbon0.35 (%) Walkley and Black method (Jackson, 1967) [5] Available nitrogen203.7 kg ha^{-1} Alkaline Permanganate Method Available phosphorus 17.2 kg ha^{-1} Olsen's colorimetric method (Olsen *et al.*, 1954) [10] Available potassium208.8 kg ha^{-1} Flame Photometer method (Toth and Prince, 1949) [20].

Table 1: a) Number of pods per plant, grains per pod and test weight as influenced by different levels of phosphorus, spacing and manure

Treatment	No of pods per plant	No of grainsper pod	Test weight	Cost of cultivation (Rsha^{-1})	Gross return (Rsha^{-1})	Net return (Rsha^{-1})	B:C Ratio
Phosphorus (P)							
P_1 (50Kg ha^{-1})	28.14	4.57	27.54	15450	20792.00	5342.00	1.34
P_2 (40Kg ha^{-1})	26.06	4.47	27.52	15158	20362.25	5204.00	1.35
P_3 (30kg ha^{-1})	27.31	4.17	27.51	14325	19603.17	5278.17	1.37
SEm ±	0.031	0.049	0.003		12.39	12.39	0.012
CD (P=0.05)	0.095	0.151	0.009		38.18	38.18	NS
Spacing (S)							
S_1 (45 cm x 10 cm)	28.45	4.60	27.54	15102.67	20467.11	5364.44	1.35
S_2 (30 cm x 15 cm)	26.09	4.24	27.52	15102.67	20213.94	5110.78	1.34
SEm ±	0.020	0.040	0.002		8.26	8.26	0.009
CD (P=0.05)	0.062	0.123	0.006		25.45	25.45	NS
Organics (O)							
O_1 (2.5 t ha^{-1} FYM)	25.72	4.24	27.51	13852.67	19140.94	5288.27	1.38
O_2 (1 t ha^{-1} vermi compost)	28.82	4.60	27.55	16352.67	21539.61	5186.94	1.32
SEm ±	0.020	0.040	0.002		8.26	8.26	0.009
CD (P=0.05)	0.062	0.123	0.006		25.45	25.45	0.028

Table 1 b): Number of branches per plant, pods per plant, grains per pod and test weight as influenced by different levels of phosphorus, spacing and manure:

Treatment	No of pods per plant	No of grains per pod	Test weight (g)	Cost of cultivation	Gross return	Net return	B:C Ratio
				(Rsha^{-1})	(Rsha^{-1})	(Rsha^{-1})	
Interaction (P×S)							
P_1S_1	29.28	4.93	27.56	15825	21267.88	5442.83	1.34
P_2S_1	28	4.7	27.53	15158	20523	5365	1.35
P_3S_1	28.06	4.17	27.52	14325	19610.5	5285.5	1.37
P_1S_2	27.61	4.33	27.54	15825	20843	5018	1.32
P_2S_2	24.11	4.23	27.51	15158	20201.5	5043.5	1.34
P_3S_2	26.56	4.17	27.49	14325	19959.83	5370.83	1.37
SEm ±	0.061	0.069	0.004		24.77	24.77	0.016
CD (P=0.05)	0.188	0.213	0.012		76.33	76.33	NS
Interaction (P×O)							
P_1O_1	25.33	4.27	27.53	14575	19737.67	5162.67	1.35
P_2O_1	24.56	4.33	27.5	13908	19251.33	5343.33	1.38
P_3O_1	27.28	4.13	27.49	13075	18433.83	5358.83	1.41
P_1O_2	31.55	5	27.58	17075	22373.17	5298.17	1.3
P_2O_2	27.56	4.6	27.54	16408	21473.17	5065.17	1.31
P_3O_2	27.34	4.2	27.52	15575	20772.5	5197.5	1.33
SEm ±	0.061	0.069	0.004		24.77	24.77	0.016
CD (P=0.05)	0.188	0.213	0.012		76.33	76.33	0.049
Interaction (S×O)							
S_1 O_1	26	4.27	27.52	13852.67	19090.67	5238	1.37

$S_2 O_1$	25.44	4.22	27.49	13852.67	19191.22	5338.56	1.38
$S_1 O_2$	30.89	4.93	27.55	16352.67	21843.56	5490.89	1.33
$S_2 O_2$	26.74	4.27	27.54	16352.67	21235.67	4883	1.3
SEm ±	0.041	0.057	0.003		16.51	16.51	0.013
CD (P=0.05)	0.126	0.176	0.009		50.88	50.88	0.04
Interaction (P×S×O)							
$P_1S_1 O_1$	25.89	4.33	27.54	14575	19790.33	5215.33	1.34
$P_2S_1 O_1$	25.22	4.33	27.51	13908	19208	5300	1.38
$P_3S_1 O_1$	26.89	4.13	27.51	13075	18273.67	5198.67	1.4
$P_1S_2 O_1$	24.78	4.2	27.51	14575	19685	5110	1.35
$P_2S_2 O_1$	23.89	4.33	27.49	13908	19294.67	5386.67	1.39
$P_3S_2 O_1$	27.67	4.13	27.48	13075	18594	5519	1.41
$P_1S_1 O_2$	32.67	5.53	27.57	17075	24245	7170.33	1.42
$P_2S_1 O_2$	30.78	5.06	27.55	16408	21838	5430	1.33
$P_3S_1 O_2$	29.22	4.2	27.53	15575	20947.33	5372.33	1.34
$P_1S_2 O_2$	30.44	4.46	27.58	17075	22001	4926	1.28
$P_2S_2 O_2$	24.33	4.13	27.53	16408	21108.33	4700.33	1.3
P3S2 O2	25.45	4.2	27.51	15575	20597.67	5022.67	1.32
Control	27.33	4.07	27.54	12928	18020	5092	1.39
SEm ±	0.222	0.102	0.006		89.31	89.31	0.024
CD (P=0.05)	0.684	0.314	0.018		275.21	275.21	NS

Note NS – Non significant; Control – moth bean with RDF at 45 cm×10 cm spacing

Yield and yield components

1. No. of pods per plant Table No. 1(a) and 1(b)

Total no of pods plant^{-1} was significantly influenced by the levels of phosphorus, spacing and organics at harvest. Among the phosphorus levels higher dose recorded significantly higher no of pods plant^{-1} (P_1 28.14 no. plant^{-1}).Spacing of 45cm x 10 cm recorded significantly higher no of pods plant^{-1} (S_1 28.45no. plant^{-1}) compared to 30 cm x 15 cm (S_2 26.19 no. plant^{-1}).Total no of pods plant^{-1} due to 1 t ha^{-1}vermicompost (O_2 28.82no. plant^{-1}) recorded higher no of pods plant^{-1} than 2.5 t ha^{-1} FYM (O_1 25.72 no. plant^{-1}).

The interaction effect due to phosphorus with the spacing, phosphorus with organics and spacing with organics show significant differences. Higher dose of phosphorus with spacing 45cm x 10 cm recorded higher total no of pods plant^{-1} (P_1S_1 29.28 no. plant^{-1}).Higher dose of phosphorus with 1 t ha^{-1} vermicompost recorded significantly higher total no of pods plant^{-1} (P_1O_2 31.55 no. plant^{-1}). Spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded significantly higher no of pods plant^{-1} (S_1O_2 30.89 no. plant^{-1}).

The interaction effect due to level of phosphorus, spacing and organics showed significant difference. Higher level of phosphorus with wider spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded higher no of pods plant^{-1} ($P_1S_1O_2$ 32.67 no plant^{-1}). Control treatment recorded the total pods of 27.33 no. plant^{-1}.

Singh *et al.* (2010) [21], Ram and Dixit (2001) [13] and Kumar and Sharma (2005) [6] reported higher no of pods per plant with higher dose of phosphorus. However Subrat Saha *et al.* reported higher no of pods per plant with wider spacing.

2. No. of grains per pod Table No. 1(a) and 1(b)

Total no of grains pod^{-1} was significantly influenced by the levels of phosphorus, spacing and organics at harvest. Among the phosphorus levels higher dose recorded significantly higher no of grains pod^{-1} (P_1 4.57 no. pod^{-1})and is at par with P_1(4.47 grains pod^{-1}).Spacing of 45cm x 10 cm recorded significantly higher no of grains pod^{-1} (S_1 4.60no. pod^{-1}) compared to 30 cm x 15 cm (S_2 4.24 no. pod^{-1}).Total no of grains pod^{-1}due to 1 t ha^{-1}vermicompost (O_2 4.60no. pod^{-1}) recorded higher no of grains pod^{-1}than 2.5 t ha^{-1} FYM (O_1 4.24 no. pod^{-1}).

The interaction effect due to phosphorus with the spacing, phosphorus with organics and spacing with organics show significant differences. Higher dose of phosphorus with spacing 45cm x 10 cm recorded higher total no of grains pod^{-1} (P_1S_1 4.93 no. pod^{-1}) and is at par with P_2S_1 (4.70 no.pod^{-1}). Higher dose of phosphorus with 1 t ha^{-1} vermicompost recorded significantly higher total no of grains pod^{-1} (P_1O_2 31.55 no. pod^{-1}).Spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded significantly higher no of grains pod^{-1} (S_1O_2 4.93 no. pod^{-1}).

The interaction effect due to level of phosphorus, spacing and organics showed significant difference. Higher level of phosphorus with wider spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded higher no of grains pod^{-1} ($P_1S_1O_2$ 5.53 no pod^{-1}). Control treatment recorded the total pods of 4.07 no. pod^{-1}.

Singh *et al.* (2010) [21], Ram and Dixit (2001) [13] and Kumar and Sharma (2005) [6] reported higher no of grains per pod with higher dose of phosphorus. Subrat Saha *et al.* reported higher no of grains per with wider spacing.

3. Test weight Table No. 1(a) and 1(b)

Test weight was significantly influenced by the levels of phosphorus, spacing and organics at harvest. Among the phosphorus levels higher dose recorded significantly higher test weight (P_1 27.54 g) Spacing of 45cm x 10 cm recorded significantly higher test weight (S_1 27.54g) compared to 30 cm x 15 cm (S_2 27.52 g).Test weight due to 1 t ha^{-1}vermicompost (O_2 27.55g) recorded higher test weight than 2.5 t ha^{-1} FYM (O_1 27.51 g).

The interaction effect due to phosphorus with the spacing, phosphorus with organics and spacing with organics show significant differences. Higher dose of phosphorus with spacing 45cm x 10 cm recorded higher test weight (P_1S_1 27.56 g).Higher dose of phosphorus with 1 t ha^{-1} vermicompost recorded significantly higher test weight (P_1O_2 27.58 g).Spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded significantly higher test weight S_1O_2 27.55 g) and is at par with S_1O_2 (27.54g).

The interaction effect due to level of phosphorus, spacing and

organics showed significant difference. Higher level of phosphorus with wider spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded test weight ($P_3S_1O_2$ 27.58 g) and is at par with $P_3S_1O_2$(27.57g). Control treatment recorded higher test weight of 27.54 g.
Singh and Agrawal (2010) [21] and Sepat (2005) [15] reported higher test weight with higher level of phosphorus

2. Economic analysis
2.1 Gross returns Table No. 1(a) and 1(b)
Gross returns differed significantly due to the levels of phosphorus, spacing and organics. Among the phosphorus levels higher dose recorded significantly higher test weight (P_1 Rs. 20792.0 ha^{-1}).Spacing of 45cm x 10 cm recorded significantly higher test weight (S_1Rs. 20467.11 ha^{-1}) compared to 30 cm x 15 cm (S_2Rs. 20213.94 ha^{-1}).Test weight due to 1 t ha^{-1}vermicompost (O_2 Rs. 21539.61 ha^{-1}) recorded higher test weight than 2.5 t ha^{-1}FYM (O_1 Rs. 19140.94 ha^{-1}).
The interaction effect due to phosphorus with the spacing, phosphorus with organics and spacing with organics show significant differences. Higher dose of phosphorus with spacing 45cm x 10 cm recorded significantly higher test weight (P_1S_1Rs. 21267.83 ha^{-1}).Higher dose of phosphorus with 1 t ha^{-1} vermicompost recorded significantly higher test weight (P_1O_2Rs. 22373.17 ha^{-1}).Spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded significantly higher test weight (S_1O_2Rs. 21843.56 ha^{-1}).
The interaction effect due to level of phosphorus, spacing and organics showed significant difference. Higher level of phosphorus with wider spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded significantly higher seed yield ($P_1S_1O_2$Rs. 24245.00 ha^{-1}). Control treatment recorded higher test weight of Rs. 18020.0 ha^{-1}.
Sadashivanagowda *et al.* (2017) [14] and Shishupal Singh *et al.* (2017) [16] reported higher gross income with the application of vermicompost.

2.2 Net returns Table No. 1(a) and 1(b)
Net returns differed significantly due to the levels of phosphorus, spacing and organics. Among the phosphorus levels higher dose recorded significantly higher test weight (P_1 Rs. 5342.0 ha^{-1}).Spacing of 45cm x 10 cm recorded significantly higher test weight (S_1Rs. 5364.44 ha^{-1}) compared to 30 cm x 15 cm (S_2Rs. 5110.78 ha^{-1}).Test weight due to 2.5 t ha^{-1}FYM (O_1 Rs. 5288.27 ha^{-1}) recorded higher test weight than 1 t ha^{-1} vermicompost (O_2 Rs. 5186.94 ha^{-1}).
The interaction effect due to phosphorus with the spacing, phosphorus with organics and spacing with organics show significant differences. Higher dose of phosphorus with spacing 45cm x 10 cm recorded significantly higher test weight (P_1S_1Rs. 5442.83 ha^{-1}) and is at par with P_3S_2 (Rs. 5370.83 ha^{-1}).Lower dose of phosphorus with 2.5 t ha^{-1} FYM recorded significantly higher test weight (P_3O_1Rs. 5358.83 ha^{-1}).Spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded significantly higher test weight (S_1O_2Rs. 5490.89 ha^{-1}).
The interaction effect due to level of phosphorus, spacing and organics showed significant difference. Higher level of phosphorus with wider spacing of 45cm x 10 cm with 1 t ha^{-1} vermicompost recorded significantly higher seed yield ($P_1S_1O_2$Rs. 7170.33 ha^{-1}). Control treatment recorded higher test weight of Rs. 5092.0 ha^{-1}.
Sadashivanagowda *et al.* (2017) [14] and Shishupal Singh *et al.* (2017) [16] reported higher gross income with the application of vermicompost.

3.2 B: C Ratio Table No. 1(a) and 1(b))
B: C ratio was significantly influenced by the levels of organics. B: C ratio due to 2.5 t ha^{-1} FYM (O_1 7.80) recorded higher harvest index than 2.5 t ha^{-1} vermicompost (O_2 6.79).B: C ratio was not significantly influenced by phosphorus and spacing. Among the phosphorus levels higher dose recorded higher B: C ratio (P_3 7.38). Spacing of 45cm x 10 cm recorded significantly higher B: C ratio (S_1 7.30) compared to 30 cm x 15 cm (S_2 7.29).
The interaction effect due to spacing with organics show significant differences. Spacing of 30 cm x 15 cm with 1 t ha^{-1} vermicompost recorded significantly higher B: C ratio S_2O_2 (7.89) and is at with S_2O_2 (7.70).The interaction effect due to phosphorus with the spacing, phosphorus with organics did not show significant differences. Lower dose of phosphorus with spacing 45cm x 10 cm recorded significantly higher B: C ratio (P_3S_1 7.43 kg ha^{-1}).Higher dose of phosphorus with 1 t ha^{-1} vermicompost recorded higher B: C ratio (P_3O_2 7.89 kg ha^{-1}).
The interaction effect due to level of phosphorus, spacing and organics did not show significant difference. Lower level of phosphorus with wider spacing of 45 cm x 10 cm with 1 t ha^{-1} vermicompost recorded numerically higher B: C ratio ($P_1S_1O_2$ 1.42). Control treatment recorded higher B: C ratio of 1.39.
Sadashivanagowda *et al.* (2017) [14] and Shishupal Singh *et al.* (2017) [16] reported higher gross income with the application of vermicompost.

Summary and Conclusion
Effect of Phosphorus and Spacing
Application of Phosphorus at 50 kg/ha at 45cm x 10 cm spacing recorded highest pods/plant grain /pod test weight and grain yield.

Effect of organics
Application of 1 t ha^{-1}vermi compost produced significantly higher seed yield (348.28 kg ha^{-1}) compared to 2.5 t ha^{-1} FYM (300.22 kg ha^{-1}).

Interaction effect
There was significant interaction among the phosphorus levels, spacing and organics on growth and yield of moth bean. Higher dose of phosphorus(50 kg ha^{-1}) at 45 cm x 10 cm spacing with 1 t ha^{-1} vermicompost application ($P_1S_1O_2$) recorded significantly higher seed yield (386.67 kg ha^{-1}), haulm yield (4912.0 kg ha^{-1}).

Economics
Higher level of phosphorus recorded significantly higher gross return (Rs.20792 ha^{-1}), net return (Rs.5342 ha^{-1}) and B:C ratio 1.34 compared to the other two levels. The wider row spacing 0f 45 cm x 10 cm recorded significantly higher gross return (Rs. 20467.11 ha^{-1}), net return (5346.44 ha^{-1}), and B:C ratio (1.35) compared to closer row spacing 30 cm x 15 cm. Application of 1 t ha^{-1} vermicompost recorded significantly higher gross returns (Rs. 21539.61 ha^{-1}) but significantly lower net return (Rs.5186.94 ha^{-1}) and B:C ratio (1.32).
Significantly higher interaction effect was recorded with $P_1S_1O_2$*i.e.* with higher level of phosphorus at 45cm x 10cm

spacing with 1 t ha^{-1} vermicompost application compared to the other rest interactions for gross return (Rs.22745.0 ha^{-1}), and net returns (Rs.5670.33 ha^{-1}) with numerically at par B:C ratio 1.42.

Conclusion

In Uttar Pradesh (Prayagraj), cultivation of moth bean with phosphorus dose of 50 kg ha^{-1}along with N and K_2O at 10 and 20 kg ha^{-1}at a spacing of 45cm x 10cm with application of 1 t ha^{-1} vermicompost produce significantly higher seed yield (386.67 kg ha), net return (Rs.7170.33 ha) and numerically higher B:C ratio (1.42).

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