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Response of Row Ratio in Mustard (*Brassica juncea* L.) + Faba Bean (*Vicia faba* L.) Intercropping on Growth, Yield of Crops, System Productivity and Economics

R.S. Singh, I.B. Pandey, C.S. Choudhary, Amalendu Kumar, Ashish Narayan, Manoj Kumar

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ABSTRACT

Background: Mustard (*Brassica juncea* L.) as oilseeds and faba bean (*Vicia faba* L.) as pulses are very popular and potential crops but there is lack of research work on mustard + faba bean intercropping system. Therefore, this experiment was conducted to study the effect of mustard (*Brassica juncea* L.) + faba bean (*Vicia faba* L.) intercropping system on growth, yield of crops, economics and system productivity.

Methods: The study was carried out for three consecutive years during *rabi* seasons of 2015-16 to 2017-18 at the Research Farm of Tirhut College of Agriculture, Dholi under Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar. Treatments comprised of Sole mustard, Sole faba bean, Mustard + Faba bean (1:1), Mustard+Faba bean (1:2), Mustard + Faba bean (1:3), Mustard + Faba bean (1:4), Mustard + Faba bean (1:5), Mustard + Faba bean (2:4), Mustard+Faba bean (2:5) and Mustard + Faba bean (2:6) under replacement series.

Result: This study finds that significantly higher number of branches/plant (5.0), number of pods/plant (30.9), number of grains/pod (2.21), 100-grain weight (28.94 g) of faba bean were recorded in 2:5 row ratio than sole faba bean, sole mustard, intercropping systems of faba bean with mustard in 1:1, 1:2 and 1:3 row ratios while plant height (134.4), number of branches/plant (10.93), number of pods/plant (170.6), number of grains/pod (9.95), 100-grain weight (0.49 g) of mustard were also found better in all the row ratios of mustard + faba bean intercropping system than sole mustard. Maximum faba bean equivalent yield (3802 kg /ha) and net return (Rs. 92470/ha) were recorded under faba bean intercropped with mustard in 2:5 row ratio although it was found at par with mustard+faba bean in (1:5), (2:4) and (2:6) row ratios. Therefore, mustard and faba bean intercropping system in row ratio of 2:5 may be recommended.

Key words: Faba bean, Intercropping, Mustard, Net return, System productivity, Yield.

INTRODUCTION

Since the food security is being threatened by the increasing population pressure and the climatic changes all over the world, intercropping may provide an alternative cropping system that have the potential to solve many of the problems. Intercropping is an agroecological land management practice where at least two crop species are grown on the same field at the same time (Wezel *et al*., 2014). In the changing climatic condition all over the world and prevailing cereal-cereal cropping system in India, diversification of crops in a planned way has become imperative to get different food crops especially cereals, oilseeds and pulses to ensure food and nutrition security. It also enhances crop productivity, reduce the risk of crop failure, enhance the income of the farmers, increase the use efficiencies of costly resources, minimize environmental pollution, reduce diseases, pests and weed problems. Burgess *et al*. (2022) also reported several benefits by adopting intercropping/agro-forestry systems both at the farm and ecosystem levels encompassing biotic, abiotic, economic and social advantages.

Faba bean is one of the most important leguminous crops of the world next to soybean (*Glycine max* L.) and pea (*Pisum sativum* L.) (Mihailovic *et al*., 2005). Faba bean is mainly grown in Madhya Pradesh, Uttar Pradesh, Maharashtra, Punjab, Haryana, Rajasthan, Karnataka, Bihar, Jharkhand, states in India. In Bihar it is mainly grown in northern part (Samastipur, Muzaffarpur, Sita Sitamarhi, Darbhanga districts *etc*.) having multifarious uses as for its tender pods as vegetable purpose, dry grains for split pulse (dal) and flour for preparation of many confectionary items and sweets. Mustard (*B. juncea*) is the most important edible oilseeds crop in India in terms of production of oil yield and mainly grown in the states of Rajasthan, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, West Bengal and Bihar. Faba bean also lowers the soil pH in the rhizosphere that helps in increased nutrient availability (Tang *et al*., 2020). Since a long time there has been almost no increase in area and

Tirhut College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur-848 125, Bihar, india.

Corresponding Author: R.S. Singh, Tirhut College of Agriculture, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur-848 125, Bihar, india. Email: dr.ramashankarsingh@gmail.com

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production of pulses and oilseeds in Bihar. There is marginal increase in productivity of some of the pulses and oilseeds but the requirement for these two items is very large in a time and situation where per capita availability is going down continuously. In a situation of shrinkage of cultivable land area and so the availability per capita, it is quite worthy and pertinent to explore any possibility for vertical expansion of area under pulses and oilseeds to enhance their production and to find out suitable and feasible management practices for increasing their productivity especially in the changing climatic scenario particularly in Bihar.

While going for intercropping, one must be careful to avoid yield reductions in individual crops due to interspecific crop competition especially for nitrogen. In this experiment also due to ability of nitrogen fixation by faba bean there was less competition for soil nitrogen. Keeping in view, the experiment was planned and carried out at the Research Farm of Tirhut College of Agriculture, Dholi under Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar for three consecutive years to access the performance of intercropping systems of mustard and faba bean on growth, yield, system productivity and economics.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Farm (25.98°N latitude, 85.60°E longitude and 52.10 MSL altitude) of Tirhut College of Agriculture, Dholi under Dr. Rajendra Prasad Central Agricultural University, Pusa (Bihar) during *rabi* seasons of 2015-16 and 2017-18. Representative soil samples were taken from the experimental field and were subjected to various mechanical, physical and chemical analysis to assess the physical and chemical properties of soil. The soil of the experimental site was calcareous alluvium in nature and alkaline in reaction. The soil of the experimental plot was sandy loam in texture (Table 1). Experimental site was situated almost in the middle of the Indo-Gangetic Alluvial Plain having deep, flat and well drained alluvial soils, moderately fertile being low in organic carbon (0.39%), available nitrogen (218.6 kg/ha), phosphorus (16.42 kg/ha) and potassium (137.3 kg/ha having pH value of 8.2 (Table 2). Ten treatments consisted of two sole crops of mustard and faba bean and eight different row arrangement of mustard with faba bean like- Mustard+Faba bean (1:1), Mustard + Faba bean (1:2), Mustard+Faba (1:3), Mustard + Faba bean (1:4), Mustard + Faba bean (1:5), Mustard + Faba bean (2:4), Mustard + Faba bean (2:5) and Mustard + Faba bean (2:6). Experiment was conducted in randomized block design and replicated thrice. Test varieties taken of mustard and Faba bean were - Rajendra Sufalam and Local, respectively. Recommended package of practices were adopted for both the sole crops of mustard and faba bean separately. However, in intercropping systems recommended dose of fertilizers of both the crops were applied proportionately of their plant population. For other cultural practices recommended for mustard was given. Row to row and plant to plant distance was maintained in similar fashion as in sole crops. Growth and yield indices were recorded by selecting randomly the five tagged plants of both the crops from the second row of each plot. Plant height, number of branched/plant, number of pods/siliqua per plant from each plot were recorded from the five tagged plants and were averaged. Number of grains per pod/siliqua from five randomly selected pods/ siliqua were taken from the same five tagged plants and was averaged. 100-grain weight of both the crops were calculated by taking randomly 100 grains of both the crops from each plot and their average was done. For grain yield from each plot, plants from net area were harvested after removing the border rows and then bundled and taken to threshing floor, sundried, manually threshed, winnowed, cleaned and weighed after sundrying. Yield obtained from each plot was then converted to quintal per hectare (q/ha). For comparison between the treatments, the yields of test crops were converted in to faba bean equivalent yield on prevailing market price. Net return was estimated by subtracting cost of cultivation from gross return. B:C ratio was calculated by dividing the net return by cost of cultivation. Analysis of data was for each parameters was done statistically by applying the standard procedure of randomized block design (Cochran and Cox, 1977) in every year and accordingly data was pooled.

Table 1: Physical properties (initial values) of experimental field.

Particulars	Values	Method employed
Soil separates (%)		
Sand	56.72	Hydrometric method
Slit	28.45	(Bouyoucos, 1962)
Clay	14.83	
Textural class	Sandy loam	
Bulk density (g/cc)	1.38	Core sampler (Piper, 1950)

Table 2: Chemical properties (initial values) of experimental field.

Particulars	Values	Method employed	Reference
Organic carbon (%)	0.39	Rapid titration method	Walkley and Black method (1934)
pH (1:2.5)	8.2	Glass electrodes pH meter	Jackson, 1973
Electrical conductivity (m. mhos cm^{-1} at 25°C)	0.56	Systronics electrical conductivity meter	Richards, 1954
Available nitrogen (kg N ha^{-1})	218.6	Alkaline permanganate method	Subbiah and Asija, 1956
Available phosphorus (kg P_2O_5 ha^{-1})	16.42	Olsen's method	Olsen *et al.*, 1954
Available potassium (kg K_2O ha^{-1})	137.3	Flame photometric method	Jackson, 1967

RESULTS AND DISCUSSION

Crop and yield attributes

Study of this experiment after three years completion in the field finds that there was significant effect of row ratios of intercropping system of mustard + faba bean on plant height of both the crops (Table 3). Plant height of faba bean recorded under sole crop (1 : 1 row ratio) significantly superior than the plant height of faba bean recorded under other treatments because of severe competition for growth factors specially above ground factors particularly sunlight and in response faba bean plants might have tried to compensate by increasing its height.

Plant height of mustard observed in M+FB (1:1) and M+FB (2:4) row ratios was significantly higher as compared to sole mustard because of additional nitrogen supplied by faba bean through biological nitrogen fixation in the soil and also the higher intra competition for light by mustard plants which was also corroborated by Jamont *et al*., (2013). However, plant heights of mustard plant was found comparable in other treatments of different row ratios.

Number of branches/plant under sole faba bean unlike the plant height was significantly higher than the number branches/plant recorded under M+FB (1:1), M+FB (1:2) and M+FB (1:3) which might be due to severe competition for growth resources like- nutrients, moisture, light, space, CO_2 *etc.* and shading and suppressing effect of mustard plants on faba bean. However, number of branches/plant under under wider row ratio combintions like-M+FB (1:4), M+FB (1:5), M+FB (2:4), M+FB (2:5) and M+FB (2:6) were found comparable. This might be due to lesser competition offered by mustard plants and due to better utilization efficiency of resources in which four or more rows of faba bean were adjusted after single row of mustard or between two rows planting of mustard. Similar finding was also reported by (Shanmugam *et al*., 2022). Significantly least value of branches/plant of faba bean was observed under M+FB (1:1) row arrangement in which mustard and faba bean might have felt maximum competition for growth factors. However, number of branches/plant of mustard plant under sole mustard and in M+FB (1:1) was significantly lower than M+FB (1:5) and M+FB (2:6) which may be due to additional nitrogen supply biologically fixed by faba bean from the atmosphere to the mustard plants. Similar observations were also repored by (Jeromela *et al*., 2017) in their legume-brassica experiment. It was very clear and obvious finding of this experiment that the treatment having higher row ratios of faba bean between mustard rows performed better than the treatment having lower row ratios of faba bean in mustard + faba bean intercropping system because of additional nitrogen supply biologically fixed by faba bean from the atmosphere and might be due to enhanced microbial activities in the rhizosphere.

Yield attributing characters like- number of pods/plant, number of grains/pod, 100-grain weight are dependent on the foundation laid down by different growth characters and are in fact the reflection of their growth parameters. Apropos the above, significantly higher number of pods/plant (33.7) was recorded in sole faba bean than M+FB (1:1), M+FB (1:2), M+FB (1:3) and M+FB (2:4) may be due to the competition for growth resources like-light, moisture, nutrients and space between mustard and faba bean plants but it was found at par with M+FB (1:4), M+FB (1:5), M+FB (2:5) and M+FB (2:6) row ratiosas also corroborated by Singh *et al*. (2022). Lowest number of pods/plant (22.4) of faba bean was recorded in M+FB (1:1) which was significantly lower than all other treatments on account of severe competition for growth resources like- nutrients, moisture, light, space, CO_2 *etc*. and shading and suppressing effect of mustard plants

Table 3: Plant height, number of branches/plant, number of pods/plant and number of grains/pod of component crops as affected by different row ratios of mustard + faba bean intercropping system.

Treatments	Plant height (cm)		No. of branches/plant		No. of pods/plant		No. of grains/pods		Plant population (%)	
	Mustard	Faba bean	Mustard	Faba bean	Mustard	Faba bean	Mustard	Faba bean	Mustard	Faba bean
Sole mustard	123.6		8.51		154.8		8.96		100	-
Sole faba bean	-	73.4	-	5.3		33.7		2.24	-	100
M+FB (1:1)	134.4	80.6	8.54	3.8	153.2	22.4	9.23	2.16	50	50
M+FB (1:2)	132.8	79.2	8.92	4.6	159.8	26.8	9.42	2.17	33.3	66.7
M+FB (1:3)	131.5	76.6	9.34	4.7	162.3	30.0	9.71	2.18	25	75
M+FB (1:4)	130.9	74.4	10.23	4.8	169.4	30.4	9.91	2.20	20	80
M+FB (1:5)	130.2	74.1	11.06	5.0	174.3	30.5	9.97	2.21	16.7	83.3
M+FB (2:4)	133.6	75.3	9.68	4.9	165.1	30.2	9.84	2.21	33.3	66.7
M+FB (2:5)	132.8	74.5	10.02	5.0	165.5	30.9	9.88	2.20	28.6	71.4
M+FB (2:6)	131.7	74.3	10.93	5.0	170.6	31.1	9.95	2.22	25	75
SEm (±)	3.3	2.1	0.7	0.07	4.5	1.1	-	0.02	-	-
CD (p=0.05)	9.8	6.3	2.2	0.20	13.6	3.3	NS	0.07	-	-
CV (%)	8.73	9.81	14.98	19.73	12.59	19.33		5.93		

M = Mustard ; FB = Faba bean.

on faba bean. However, the effect of different row ratios on number of grains/pod of faba bean and mustard was non-significant except for faba bean in M+FB (1:1) where number of grains/pod was significantly lower than sole faba bean may be due to severe competition for growth factors and shading and suppressing effect of mustard on faba bean where faba bean plants might have utilized comparatively more energy in increasing their plant height.

Apropos the above, number of pods/plant of mustard was also significantly affected by mustard+faba bean intercropping system. Number of pods/plant in sole mustard and M+FB (1:1) was significantly lower than M+FB (1:4), M+FB (1:5) and M+FB (2:6) row ratios may be due to enhanced nitrogen use efficiency in intercropping system, additional nitrogen supply biologically fixed by faba bean from the atmosphere and its partial utilization by the intercrops than in sole cropping. Similar finding were reported by Shanmugam *et al*., (2022) where they found 75% nitrogen use efficiency in intercropping system of faba bean + cabbage than sole crop of faba bean (44%) and cabbage (75%) and by (Xiao *et al*., 2018) where 18-26% yield increase was obtained in wheat in wheat + faba bean intercropping system. Although the effect of different row arrangements of mustard+Faba bean intercropping system on number of grains/pod of mustard was found insignificant; it was numerically higher in all the treatments of different row combinations. Mustard yield was significantly lower in all the treatments of mustard + faba bean intercropping systems than sole mustard because of lower plant population/ unit area but the grain yield realized on the basis of per plant was higher. Similar results were also reported by Zabih and Saeedipour (2015) and Shekhawat *et al*. (2012).

System productivity

Faba bean equivalent yield recorded in M+FB (2:5) row arrangement was significantly superior than different row ratios and sole cropping of mustard and faba bean except M+FB (1:5), M+FB (2:4) and M+FB (2:6) row ratios. This might be due to better performance of yield attributes and yield of crops that ultimately reflected into realization of higher equivalent yield of Faba bean. Similar findings of species complementarities on yield advantage were also reported by Xu *et al*. (2020) in their maize-soybean intercropping experiment. Yield advantage of intercropping in terms of faba bean equivalent yield was up to 16.89% higher in M+FB (2:5) with respect to sole cropping of faba bean. Similar findings were also reported by Hunady and Hochman (2014). Significantly lower faba bean equivalent yield was estimated in M+FB (1:1) row ratio might be due to poor performance of growth as well as yield attributing characters of component crops especially faba bean that resulted into lowest equivalent yield. In fact, the reason of high equivalent yield of crop in intercropping systems is the efficient utilization of environmental resources such as light, water, nutrients, space and nitrogen fixed by faba bean and its partial utilization by the intercrops than in sole cropping. Similar result was also reported by Esmaeil *et al*. (2010) from Maize+Faba bean intercropping system. Bechem *et al* (2018) also reported similar observations in maize+soybean intercropping system where he found 25-80% yield advantages over sole cropping of either crop.

Economics

Successful crop production aims at higher economic returns through proper management of production resources as well as efficient use of growth resources. Economics is the ultimate scale on which success or failure of a treatment in getting recommendations and consequently, this happens to be the ultimate deciding factor in choosing profitable and viable treatment (variety, fertilizer levels, crop combination, row ratio *etc*.) for a particular agro-climatic situation. The study indicated that net return of mustard+Faba bean

Table 4: Effect of row ratios of mustard + faba bean intercropping system on 100-grain weight, yield of mustard and faba bean, faba bean equivalent yield (FBEY), net return and B:C ratio of the intercropping systems.

Treatments	100-grain wt.(g)		Yield (kg/ha)			Net return (Rs./ha)	B : C ratio
	Mustard	Faba bean	Mustard	Faba bean	Faba bean equivalent yield		
Sole mustard	0.41	-	1964	-	3367	83219	2.40
Sole faba bean	-	29.01	-	3162	3162	78803	2.47
M+FB (1:1)	0.41	27.89	1086	1395	3257	76419	2.03
M+FB (1:2)	0.43	28.12	743	2022	3296	78304	2.11
M+FB (1:3)	0.45	28.41	587	2366	3372	81242	2.21
M+FB (1:4)	0.49	28.44	496	2583	3433	83533	2.28
M+FB (1:5)	0.51	28.53	443	2734	3493	85741	2.35
M+FB (2:4)	0.46	28.47	803	2316	3693	92194	2.49
M+FB (2:5)	0.48	28.54	713	2474	3696	92470	2.51
M+FB (2:6)	0.49	28.62	599	2644	3671	91692	2.49
SEm (±)	-	-	-	-	69	1891	0.07
CD (p=0.05)	NS	NS	-	-	208	5673	0.21
CV (%)					14.89	18.13	18.67

M = Mustard; FB = Faba bean.

intercropping system as affected by different row ratios was significantly influenced (Table 4). Highest net return (Rs.92470/ha) was obtained in M+FB (2:5) which was significantly higher than other treatments of row ratios but was found at par with M+FB (1:4), M+FB (1:5), M+FB (2:4) and M+FB (2:6) obviously due to highest faba bean equivalent yield and gross return. Economic advantage of intercropping in terms of net return was up to 21.0% higher in M+FB (2:5) with respect to M+FB (1:1) and 11.1% and 17.3% higher with respect to sole crop of mustard and faba bean, respectively. Significantly higher B:C ratio (2.51) was also estimated in M+FB (2:5) than M+FB (1:1), M+FB (1:2), M+FB (1:3) and M+FB (1:4) which may be due variation in the values of net return and cost of cultivation. Similar findings were also reported by Yang *et al*. (2018).

CONCLUSION

Based on three years field experimentation and performance of growth, yield, system productivity and economic indices like - net return and B:C ratio, it can be concluded that faba bean can be taken as an intercrop with mustard in row ratio of 2:5 for higher productivity and net return per unit area and time with the reduced risk of crop failure.

Conflict of interest

All authors declared that there is no conflict of interest.

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