DOI : 10.5958/0974-0112.2019.00111.7

Indian J. Hort. 76(4), December 2019: 707-713

Evaluation of faba bean based crop diversification in Eastern India

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ABSTRACT

Crop diversification experiment was undertaken with faba bean, a potential vegetable legume crops for rainfed as well as irrigated ecosystem and performs well over wide range of soils and agro-climatic conditions. Experimentation was done with five cropping systems under the partial rainfed and fully irrigated conditions. The highest rice equivalent yield of 25.01 t/ha was recorded under irrigated conditions with cropping system rice-faba bean + maize (cob) - green gram cropping system; however, the lowest yield of 16.29t/ha was recorded with rice-faba bean + lentil- green gram, under partial rainfed condition. Overall maximum land productivity of Rs. 2.0/ha was for the rice-faba bean + maize (cob) - green gram cropping system under the irrigated conditions with system's water productivity 1.42-1.79 kg/m^3. The maximum net return of Rs.1.28/ha was for rice - faba bean - green gram under the irrigated ecosystem. The benefit-cost ratio in such diversification was ranged from 1.53 - 2.99. The crop diversification with faba bean not only improved the system productivity but also strengthen the sustainability of the soil.

Keywords: *Vicia faba*, broad bean, potato, lady's finger, cowpea.

INTRODUCTION

Enhancing Land productivity of small and marginal farmers, who owns a small piece of land-less than 2.0 ha and are facing a series of challenges arising from increased competition for water, rising farm inputs cost and climate change (Chand and Chauhan, 2). As crop diversification could regulate farm income, withstand weather aberrations and conserve natural resources and reduces chemical fertilizer and pesticide loads; therefore, crop diversification is an effective strategy for achieving food and nutrition security, generating income and employment (Gill and Ahlawat, 5; Jensen *et al*., 6).

The Eastern Indo-Gangetic Plain of India is predominant rice-wheat cropping system under the irrigated ecosystem and system's sustainability is on threat due to a decline in factor productivity (Ali *et al.,* 1). Several interventions for conservation agriculture were advocated either to break cereal- cereals cropping system or for inclusion of legumes and addition of adequate organic contents to the soil (Mc Ewen *et al.,* 7). Faba bean is a vegetable legume crop, grown in winter in subtropical and warmer temperate climates on moisture residue left after crops such as maize and sorghum (Singh *et al*., 10). Faba bean being vegetable crop is seen as an agronomically viable alternative to the cereal grains (Singh *et al*., 9). Faba bean is grown under rainfed conditions during the winter and typically rotated with cereals, cotton or sugar beet in the coastal regions (Singh, 11).

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In other countries such as China, faba bean is autumn-sown after rice or intercropped with cotton or maize and winter wheat (FAOSTAT, 3). Faba bean is one of the best performing crops under global warming and climate change scenario because of its unique ability to excel under almost all type of climatic conditions coupled with its wide adaptability to range of soil environment (Singh *et al.,* 12). Faba bean is a nitrogen-fixing plant, capable of fixing atmospheric nitrogen, which results in increased residual soil nitrogen for use by subsequent crops and can be used as green manure having potential of fixing free nitrogen up to 150-300 kg/ ha (Singh and Bhatt, 8). Therefore, Faba bean is typically followed by one or more cereals to exploit the "Break Crop" and N effect of faba bean in a cropping system (Gasim and Link, 4 and Ewen *et al.,* 7).

Despite being so much beneficial crop, this still comes as minor crop in India and underutilized and its potential still remains unexploited (Singh and Bhatt, 8). Therefore, keeping these facts in view, an experiment was undertaken to evaluate the suitability and sustainability of faba bean under different cropping systems in Eastern Indo Gangatic Plains of Eastern Region of India where most of the land holdings are of small and marginal category (Chand and Chauhan, 2).

MATERIALS AND METHODS

The experiment was conducted in rainfed and irrigated ecosystem in Eastern Indo Gangatic Plain where under irrigated ecosystem the rice-wheat

cropping system and under rainfed or restricted irrigated ecosystem rice-lentil are the prominent cropping systems. Being staple food rice is the automatic choice for *Kharif* for the growers. During *Rabi* season, the diversification was done with faba bean as main crop/sole crop and crop diversification was done with lentil, maize (cob), potato as companion intercrop. During summer / *zaid* lady's finger, cow pea (green pod) and green gram was the crop selected for crop diversification. Total five cropping systems were evaluated and these were rice-faba bean - ladies finger (CS_1), rice-faba bean-green gram (CS_2), rice-faba bean+ potato - cowpea (Green pod) (CS_3), rice-faba bean + maize- green gram (CS_4) and rice-faba bean + lentil- green gram (Green pod) (CS_5) under the rainfed (I_1) and irrigated (I_2) conditions. Here, it is worth to mention that the rainfed and irrigated condition was provided only in *rabi* season, as it was not practically feasible to undertake rice and summer crop without assured irrigation.

The field experiment was conducted at ICAR Research Complex for Eastern Region, Patna **(**25°35'N, 85° 05'E); during 2011-12, 2012-13, and 2013-14 in a randomized block design (RBD) with four replications. The experimental plot size was 8.0 m × 6.0 m. All the nutrients, especially the NPK, and the agronomic management practices were as per the recommended standard. Soil sampling was done for each plot before the onset of experiment and after completion of each crop cycle. Keeping in view the root zones, surface soil up to 30 cm depth was sampled, air dried, mixed and passed through 2.0 mm sieves and analyzed for various physical and chemical properties relevant to our experiment (Table 1). Economic yield data were recorded and converted it into rice equivalent yield for each crop, and for the system as whole. Based on unit sale price of individual crops, pooled analysis was done to workout system's productivity for assessing economic feasibility of cropping system under Eastern Indo Gangetic Plains Conditions.

To compute water productivity, the irrigation water applied and the rainfall received were taken in to account. System's water productivity was also work out for the developed cropping system for both, rainfed and irrigated ecosystem. The analysis was done and economics was carried out for all the tested cropping systems assess their economic viability. Based on dynamics of soil physiochemical statuses of experimental plots soil sustainability were evaluated for all the five cropping systems under rainfed and irrigated ecology.

Further, the average rainfall during *kharif, rabi, summer* and in whole year over the three years of experimentation period was 855.2 mm, 44.1 mm, 16.5mm and 915.8 mm, respectively. Again, the number of irrigations applied to the individual crops varied from 2 to 6 and irrigation water applied in each irrigation was 40 mm. For rice there were maximum (06) irrigations; whereas, sole faba bean received (02), potato (03), lentil (02), maize (03), mung bean (02), cow pea (03), and ladies finger (04) irrigations. This irrigation schedule might be only for I_2 i.e. irrigated conditions and not for I_1 i.e. rainfed.

Table 1. Soil properties of the experimental site and respective methods employed for analysis at the research farm of ICAR-RCER, Patna.

Soil Property	Value	Method employed for estimation
Sand (%)	41.3	Hydrometer method (Bouyoucos, 1962)
Silt (%)	24.5	
Clay (%)	34.2	
Particle density (g cm^{-3})	2.53	Black and Hartage (1986)
Bulk density (g cm^{-3})	1.50	
pH (1:1 soil: water)	6.93	Elico pH meter (Piper, 1950) USDA (1967)
EC (dSm^{-1}) (1:1 soil: water)	0.18	USDA (1967)
TOC (%)	0.66	Walkley and Black (1934)
N (ppm)	114.8	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)
Olsen P (ppm)	13.54	Olsen's method (Olsen *et al*., 1954)
K (ppm)	87.4	Ammonium acetate method (Merwin and Peech, 1951)
Sulphur (ppm)	3.41	DTPA extract method (Williams and Steinbergs, 1969)
Average Zn (ppm)	0.37	0.01M CaCl2 method (Lindsay and Norvell, 1978)

RESULTS AND DISCUSSION

Data were recorded for three successive years of experimentation and statistical analysis was done for the individual years. Pooled analysis were also done to summarize the results and to draw the inferences. Yields of different crops for various cropping systems are reported in Table 2. During *Kharif* season same set of treatment were applied to all the five cropping systems. However, no significant change in rice yield was seen in any of the cropping system, and its yield ranged between 6.68 to 6.72 t/ha. During *Rabi* season faba bean was introduced as sole and also under intercropping system with assured irrigation water supply. Under irrigated ecosystem, the seed yield of faba bean, under sole cropping system, ranged between 4.15 to 4.19 t/ha; whereas, under the intercropping system, seed yield ranged from 1.39 to 1.89 t/ha. Further, under the rainfed ecology and sole cropping systems, faba bean seed yield was recorded in between 2.11 to 2.14 t/ha; whereas, under intercropping system it ranged between 0.94 to 1.41 t/ha (Jensen *et al*., 6; (Singh *et al.*, 12).

Further, under intercropping, Potato yields in rice - faba bean + potato - cowpea (Green pod) system were found to be 9.4 t/ha and 5.9 t/ha under irrigated and rainfed ecosystem, respectively. Similarly the maize yield under rice-faba bean + maize (Cob) - green gram cropping system, was 15.5 and 6.8 t/ha under irrigated and rainfed ecosystem, respectively. Lentil production was ranged between 0.42 to 0.95 t/ha under rice - faba bean + lentil - green gram cropping system under irrigated and rainfed ecosystems, respectively. During summer season all crop were raised under assured irrigation. In summer crops- the third crops in cycle- lady's finger and cowpea were grown for vegetable purpose and green gram for dry seed consumption purpose. Ladies finger yield under rice - faba bean lady's Finger was 8.15t/ha and green gram yield was ranged in between 1.78 - 1.84 t/ha. However, in case of cowpea, under rice-faba bean+ potato -cowpea (Green Pod) cropping system, the green pod yield was 7.93 t/ha (Singh *et al*., 9 and Singh *et al*.,12).

The water productivity of the system is reported in the Table 3. It is categorized under two heads - "irrigation water productivity" and "total water productivity" for irrigated and rainfed cropping systems. Irrigation water productivity is calculated by considering only irrigation water applied to the crops; whereas, total water productivity is calculated by considering irrigation water and rainfall both. In case of *Kharif* season*,* only one crop i.e. rice was grown as irrigated crop for which the total water productivity for rice was ranged from 0.61 - 0.62 kg/m^3. During *rabi* season, water productivity for faba bean was recorded between 3.34 -3.38 kg/m^3 under sole cropping system whereas under inter cropping it ranged between 1.11 - 1.15 kg/m^3. Similarly, in case

Table 2. Yield (t/ha) of different crops in the cropping systems.

Cropping System	Rice	Faba bean	Potato	Maize	Lentil	Ladies Finger	Green Gram	Cow pea
Irrigated System								
Rice-Faba Bean – Lady's Finger (CS_1)	6.72	4.15	-	-	-	8.15	-	-
Rice-Faba Bean- Green Gram (CS_2)	6.68	4.19	-	-	-	-	1.84	
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3)	6.67	1.89	9.4	-	-	-	-	7.93
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	6.69	1.82	-	15.5	-	-	1.78	-
Rice-Faba Bean + Lentil- Green Gram (CS_5)	6.74	1.39	-	-	0.95	-	1.81	-
CD (P=0.05)	NS	0.23	-	-	-	-	0.12	-
*Rainfed during rabi season								
Rice-Faba Bean – Lady's Finger (CS_1)	6.72	2.11	-	-	-	8.15	-	-
Rice-Faba Bean- Green Gram (CS_2)	6.68	2.14	-	-	-	-	1.84	
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3)	6.67	1.41	5.9	-	-	-	0	7.93
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	6.69	1.37	-	6.8	-	-	1.78	-
Rice-Faba Bean + Lentil- Green Gram (CS_5)	6.74	0.94			0.42	-	1.81	-
CD (P=0.05)	NS	0.15	-	-	-	-	0.12	-

Table 3. Water Productivity WP (kg/m3) of different crop components in cropping system.

Cropping System	Rice	Faba bean	Potato	Maize	Lentil	Ladies Finger	Green Gram	Cow pea	System water productivity	
									Irrigation water productivity	Total water productivity
Irrigated System										
Rice-Faba Bean - Lady's Finger (CS_1)	0.61	3.34				3.77			4.27	1.55
Rice-Faba Bean- Green Gram (CS_2)	0.61	3.38					1.35		5.44	1.77
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3)	0.61	1.15	5.73					4.50	4.17	1.51
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	0.61	1.11		9.45			1.31		5.21	1.79
Rice-Faba Bean + Lentil- Green Gram (CS_5)	0.62	1.12			0.77		1.33		4.36	1.42
CD (P= 0.05)	NS	0.18	-	-	-	-	-	-	0.13	0.11
*Rainfed during *Rabi*										
Rice-Faba Bean - Lady's Finger (CS_1)	0.61	4.78				3.77			3.77	1.22
Rice-Faba Bean- Green Gram (CS_2)	0.61	4.85					1.35		5.09	1.44
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3)	0.61	3.20	13.38					4.50	4.55	1.38
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	0.61	3.11		15.42			1.31		5.39	1.52
Rice-Faba Bean + Lentil- Green Gram (CS_5)	0.62	2.13			0.95		1.33		4.53	1.28
CD (P= 0.05)	NS	0.21	-	-	-	-	-	-	0.12	0.10

of rainfed condition it ranged from 4.78 - 4.85 kg/m^3 and 2.13 - 3.20 kg/m^3 under sole and intercropped conditions, respectively. The total water productivity was found to be higher under rainfed condition as compared to irrigated one. The highest total water productivity was recorded in case of maize as 15.42 kg/m^3 followed by potato as13.38kg/$m^3$and the least was for lentil i.e., 0.95 kg/m^3. During summer season, maximum water productivity of 4.50 kg/m^3 was recorded for lady's finger followed by cowpea, 3.77 kg/m^3. In case of mungbean total water productivity ranged from 1.31 - 1.35kg/m^3. Except rice, the significant difference in total water productivity was recorded among all the tested crops in different cropping systems. This is due to the fact that rice was grown in *kharif* season only and other crops, in different cropping systems, were grown either in *rabi* or *summer* season (Jensen *et al*., 6 and Singh *et al.*, 12).

The *System Productivity* and S*ystem Water Productivity* of various components and for the aggregate are reported in Table 4. The system productivity (t/ha) was worked out on the basis of rice equivalent yield (REY); whereas, *Land Productivity* (LP) is based on total output from particular cropping system in a years in terms of monetary gain. Similarly, system water productivity (SWP) was also worked out as per the process, described in materials and methods. Results were summarised in the Table 4. Perusal of data pertaining to rice equivalent yield (REY), it was noticed that all the tested cropping systems produced significantly higher rice equivalent yield under the irrigated ecology as compared to rainfed situation. Maximum (25.01 t/ha) was recorded with rice-faba bean + maize (cob) - green gram cropping system under irrigated conditions; whereas, corresponding minimum (19.19 t/ha) was obtained with rice-faba bean + lentil- green gram cropping system (Singh *et al.*, 9).

Likewise in case of partial rainfed cropping system, the highest (19.42 t/ha) rice equivalent yield was recorded under rice-faba bean + maize (cob) - green gram and lowest (16.29 t/ha) was with rice-faba bean + lentil- green gram. In case of land productivity, similar trend, i.e., higher returns in irrigated ecology compared to rainfed ecology were obtained, as were in case of rice equivalent yield. Overall maximum land productivity (Rs 2.0 lakh /ha) worked out for rice-faba bean + maize (cob) - green gram cropping system under irrigated conditions; whereas, corresponding lowest (Rs. 1.3 lakh /ha) was computed in rice-faba bean + lentil- green gram

Table 4. Rice Equivalent Yield (t/ha) and System Water Productivity (kg/m^3).

Cropping System	Rice Equivalent Yield (t/ha)	Land Productivity (Rs /ha)	System Water Productivity (kg/m^3)
Irrigated Cropping System			
Rice-Faba Bean - Lady's Finger (CS_1)	22.21	177660	1.55
Rice-Faba Bean- Green Gram (CS_2)	23.95	191620	1.77
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3)	21.71	173660	1.51
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	25.01	200060	1.79
Rice-Faba Bean + Lentil- Green Gram (CS_5)	19.19	153500	1.42
CD (P=0.05)	1.78	4831	0.13
Rainfed Cropping System (*Rabi Season)			
Rice-Faba Bean - Lady's Finger (CS_1)	16.60	132780	1.22
Rice-Faba Bean- Green Gram (CS_2)	18.32	146520	1.44
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3)	18.20	145600	1.38
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	19.42	155360	1.52
Rice-Faba Bean + Lentil- Green Gram (CS_5)	16.29	130350	1.28
CD (P=0.05)	1.82	5172	0.14

cropping system under partial rainfed situation (Singh *et al.*, 12). The System total water productivity for the cropping system ranged between 1.42 to 1.79 kg/m^3 under rice-faba bean + maize (cob) - green gram and rice-faba bean + lentil- green gram in irrigated condition; and similar trend was also recorded under partial rainfed conditions. Overall, the lowest system water productivity (1.22 kg/m^3) was found for rice-faba bean – lady'sies finger under partial rainfed condition (Singh, 11).

As developed technology, of course should be sound on technical footing, easy to execute and environmentally friendly. But in addition to these, it should also be economically viable too. Economics of developed technology was worked out and reported in Table 5. Regarding cost of cultivation, it was observed that under partial rainfed condition it was marginally low as compared to irrigated ecology among all the tested cropping systems. The highest cost of cultivation of Rs 0.98 lakh/ha was recorded

Table 5. Economics of Developed Technology.

Cropping System	Cost of Cultivation (Rs)	Gross Return (Rs)	Net Return (Rs)	B:C Ratio
Irrigated System				
Rice-Faba Bean - Lady's Finger (CS_1)	71000	177660	106660	2.50
Rice-Faba Bean- Green Gram (CS_2)	64000	191620	127620	2.99
Rice-Faba Bean+ Potato -Cowpea (P) (CS_3)	98000	173660	75660	1.77
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	88000	200060	112060	2.27
Rice-Faba Bean + Lentil- Green Gram (CS_5)	65500	153500	88000	2.34
CD (P=0.05)	2872	4831	4171	0.11
*Rainfed during Rabi only				
Rice-Faba Bean - Lady's Finger (CS_1)	66000	132780	66780	2.01
Rice-Faba Bean- Green Gram (CS_2)	60000	146520	86520	2.44
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3)	95000	145600	50600	1.53
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_4)	85000	155360	70360	1.83
Rice-Faba Bean + Lentil- Green Gram (CS_5)	63500	130350	66850	2.05
CD (P=0.05)	2981	5172	4247	0.09

under Rice-Faba Bean+ Potato - Cowpea cropping system; however, the corresponding lowest cost of cultivation of Rs. 0.64 lakh /ha was computed for the cropping system involving rice-faba bean + lentil-green gram. The selling price of rice, faba bean, green gram, cowpea (Green pod), potato, maize (Cob), Lentil and lady's finger was fixed Rs.8000, 22000, 25000, 4000, 5000, 4000, 25000 and 4000 per ton respectively. In case of gross returns, the maximum Rs. 2.0 lakh /ha was obtained with the cropping system involving rice-faba bean + maize (cob) - green gram crops in a sequence under irrigated ecology, and the corresponding minimum gross return of Rs.1.3 lakh/ha was computed in case of cropping system Rice-Faba Bean + Lentil- green gram, under partial rainfed ecology. However in case of net return, it was varied from Rs 0.55 lakh/ha for rice-faba bean+ potato –cowpea under partial rainfed situation to Rs 1.28 lakh /ha for Rice-Faba Bean- Green Gram cropping system under irrigated ecosystem. Again, as the benefit cost ratio (B: C Ratio) is a good indicator for the profit per rupee investment, the results indicates that the maximum B: C ratio of 2.99 was obtained when rice-faba bean- green gram were taken under irrigated ecosystem; whereas, the minimum of 1.53 was recorded when rice-faba bean+ potato -cowpea (GP) were taken under partial rainfed ecosystem (Singh *et al.*, 12).

For sustainability of any developed technology the first and formost requirement is that it should not be detrimental to the inherent physicochemical properties of soil in longer run. For the very much purpose, the soil samples were collected analysed at the onset of field experimentation and after the completion of each cycle and at the end of experimentations as per the procedure and guidelines described in materials and method section. Results were summarized in Table 6. It shows that all the tested parameters were within the range of initial value. Some numerical deviation was recorded with all parameters under examination, but no significant deterioration or build was reported (Singh, 11). The Soil pH has been increased from initial value of 6.93 in all the experimental plots and it ranged between 6.98 to 7.05. The Organic Carbon was also maintained or increased marginally, and it ranged from 0.66 to 0.68. Nitrogen content gradually improved in all the cases of maize and potato, being a heavy feeder has been taken in to account in the cropping system. Phosphorus contents were increased in all the cropping systems under experiment. Other parameters were intact since no significant difference was observed across the tested soil parameters (Singh *et al.*, 12).

Based on results and discussion for the evaluated diversified faba bean based cropping system technology, it is concluded that faba bean based cropping system could improve not only their absolute crop production returns but also the soil fertility status of soil. Developed diversified cropping system is also sustainable for current climatic changes scenario and the small and marginal farmers of Eastern India could be benefitted by faba bean based diversified cropping system, therefore the impact of climate change in terms of erratic rainfall could be minimized.

Table 6. Dynamics in soil fertility status due to cropping system.

Cropping System	pH	EC (ds/m)	TOC (%)	N (ppm)	Olsen P (ppm)	K (ppm)	Suphur (ppm)	Average Zn (ppm)
Initial Value	6.93	0.18	0.66	114.8	13.54	87.4	3.41	0.37
Rice-Faba Bean - Lady's Finger (CS_1a)	7.03	0.18	0.67	115.5	13.69	86.7	3.41	0.36
Rice-Faba Bean - Lady's Finger (CS_1b)	7.01	0.17	0.67	116.2	13.89	86.9	3.42	0.36
Rice-Faba Bean- Green Gram (CS_2a)	6.98	0.17	0.68	118.7	15.11	88.1	3.32	0.37
Rice-Faba Bean- Green Gram (CS_2b)	7.05	0.18	0.68	119.4	15.29	88.9	3.37	0.36
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3a)	7.02	0.17	0.66	115.7	13.71	85.4	3.42	0.35
Rice-Faba Bean+ Potato -Cowpea (GP) (CS_3b)	7.04	0.18	0.66	115.9	13.84	86.3	3.45	0.35
Rice-Faba Bean + Maize (Cob) - Green Gram (CS_{4a})	7.01	0.17	0.66	115.4	13.97	86.4	3.40	0.35
Rice-Faba Bean Maize (Cob) - Green Gram (CS_4b)	7.02	0.18	0.66	115.9	14.09	87.9	3.39	0.36
Rice-Faba Bean + Lentil- Green Gram (CS_5a)	7.02	0.17	0.67	117.6	14.84	87.9	3.31	0.37
Rice-Faba Bean + Lentil- Green Gram (CS_5b)	7.05	0.17	0.67	118.2	14.09	88.1	3.32	0.36
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

a= rainfed, b=irrigated

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Received : October, 2019; Revised : November, 2019;
Accepted : November, 2019