Indian Journal of Agronomy **62** (2): 155–159 (June 2017)

Research Paper

Effect of organic manure and biofertilizers on system productivity and profitability of potato (*Solanum tuberosum*)–French bean (*Phaseolus vulgaris*) cropping system

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Received : April 2016; Revised accepted : April 2017

ABSTRACT

A fixed plot field experiment was conducted during 2 consecutive summer and autumn seasons of 2013 and 2014 at the Shillong, Meghalaya, to evaluate the effect of organic manure and biofertilizers on system productivity and profitability of potato (*Solanum tuberosum* L.)–French bean (*Phaseolus vulgaris* L.) cropping sequence. The experiment was laid out in a randomized block design, having 3 replications. Application of the recommended dose of fertilizers to the each crops (140 N : 120 P_2O_5 : 60 K_2O kg/ha) through synthetic fertilizers resulted in 4.5% higher system productivity than FYM application @ 30 t/ha along with inoculation biofertilizers [*Azotobacter* + phosphate-solubilizing bacteria (PSB)]. However, the maximum economic efficiency (₹471/ha/day), net return (₹172.1 × 10^3/ha) and benefit: cost ratio (1.3) were noticed by application of 30 t FYM/ha along with inoculation of biofertilizers (*Azotobacter* + PSB). The increase in production efficiency due to application of biofertilizers was 14.0% over without biofertilizers with same level of FYM (30 t/ha). Either application 15 t FYM or 30 t FYM/ha with inoculation of biofertilizers generated more net returns than recommended dose of fertilizers due to premium on organic produce. Depending upon the availability as well as capability of farmers either application of 15 t FYM or 30 t FYM with inoculation of biofertilizers (*Azotobacter* + PSB) may be more profitable and sustainable potato-French bean cropping system in north-eastern hill region of India under rainfed condition.

Key words : Biofertilizers, Cropping system, French bean, FYM, Organic manure, Potato

Potato is traditionally grown during the summer season in the hilly tract of north-eastern region of India under rainfed situation. Majority of farmers grow only single crop either potato or French bean in a year. To meet the growing food demand of burgeoning population, the only possible approach is left to go for more crops per unit area/unit time with limited resources. French bean is one of the important crops in this region used as a green pod for vegetable. The green pod of French bean for vegetable purpose matures earlier at least by 20–30 days than grain crop. This early maturity of crop is crucial for adjusting in potato-based cropping sequence where the length of growing period for succeeding crop is limited due to terminal drought at the time of maturity accompanied by frosting due to low temperature in winter. Over the last few years, demand for healthier food and changing government policies on environmental security for productive and sustainable agricultural ecosystems have promoted a rapid expansion of organic cultivation (Patra *et al.,* 2016). There has been growing public concern about adverse impacts of pesticides and chemical fertilizers on environment and quality of produce. Imbalance uses of synthetic fertilizers not only reduces soil organic matter but adversely affects the human health especially in north-eastern hill region, where majority of farming community in the rural areas drinks flowing water. This situation warrants opting to organic nutrient management for sustaining productivity of potato-based cropping system (Sarkar *et al*., 2011). Organic manure influences soil productivity through rectification of secondary and micro-nutrient deficiency and their effect on soil physical, chemical and biological properties (Kalhapure *et al*., 2014). Biofertilizers are renewable source of plant nutrients which enhance the crop productivity levels at low input cost. Keeping these points in view, an investigation was undertaken to study the effect of organic source (FYM) and biofertilizers [*Azotobacter* +

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phosphate-solubilizing bacteria (PSB)] on system productivity and profitability of potato–French bean cropping system.

MATERIALS AND METHODS

A fixed field experiment was conducted during 2 consecutive summer and autumn seasons of 2013 and 2014 at ICAR-Central Potato Research Station, Shillong (25°54' N and 91°84' E, 1,738 m above mean sea-level), Meghalaya. The soil was sandy loam with *p*H 5.10, moderately fertile, being high in organic carbon (1.56%), medium in available nitrogen (314.5 kg/ha), low in available phosphorus (9.5 kg/ha) and high in available potassium (310.0 kg/ha). There is no assured irrigation facility available in this lock hill region. Hence rainfed cultivation is only option for growing of crops. Generally, rainfall used to start from the last week of February and continues till mid of October. More than 80% total (Apprx. 2,500 mm/year) rainfall received during pre-monsoon to monsoon season during crop-growing period. The experiment consisting of 10 treatments, viz. control (no application of any nutrient); 100% recommended dose of fertilizers through synthetic fertilizers (140 N : 120 P_2O_5 : 60 K_2O kg/ha) were taken separately for potato and French bean; FYM @ 15 t/ha; FYM @ 15 t/ha along with inoculation of *Azotobacter*; FYM @ 15 t/ha along with inoculation of phosphate-solubilizing bacteria (PSB); FYM @ 15 t/ha along with inoculation of *Azotobacter* and PSB; FYM @ 30 t/ha; FYM @ 30 t/ha with inoculation of *Azotobacter*; FYM @ 30 t/ha along with inoculation of PSB; and FYM @ 30 t/ha along with inoculation with *Azotobacter* and PSB, were applied to both crop potato and French bean separately in each season as per treatment. With a view to avoid the mixing of soil among different treatments, individual plots were thoroughly prepared by power tiller and manual labour. The farmyard manure contained, viz. 0.5% 0.3% and 0.5% N, P and K respectively. Details of nutrient applied in each season to each crop in potato-French bean cropping sequence are given in Table 1.

Cultivation practices were followed as per standard recommendation for each crop. Planting of potato was done in the last week of February and harvesting in the last week of June, while French bean was planted immediately after harvesting of potato in the same field and harvested through picking in October. Variety 'Kufri Jyoti' of potato and 'Contender' of French bean were used in this experiment. Properly decomposed organic manure was applied 15 days before planting each crop as per treatment. The seed was inoculated with biofertilizers (*Azotobacter* + PSB) and sown as per treatment. Two solutions of each biofertilizers, i.e. *Azotobacter* and PSB, were prepared by dissolving 500 g biofertilizers in 80 litres of water. Molasses slurry was prepared by boiling 2 kg molasses per liter of water. After cooling, 2 liters of molasses slurry was added to each solution of biofertilizers. Potato and French bean tubers/ seed were dipped in the biofertilizers solution for 30 minutes as per the treatment followed by dried in shade.

Recommended package and practices for disease and insect management for potato crop was followed. Earthing up was done 50 days after planting for proper growth and development of tubers. Weeding was also done during earthing up with the help of a small spade and *khurpi*. All the plants from net plot area were harvested manually in case of potato, while picking was done at maturity in French bean. The tuber yield of potato and pod yield of French bean of different plots were estimated and converted into tonnes (t) per hectare basis. Potato-equivalent yield and economics were calculated considering the prevailing market price of inorganic potato (₹7.5/kg) and

Table 1. Quantity of nutrient applied in potato–French bean cropping sequence (kg/ha)

Sources of nutrient	Potato			French bean		
	N	P	K	N	P	K
Control	–	–	–	–	–	–
Fertilizer (RDF)	140	120	60	140	120	60
15 t (FYM)	75	45	75	75	45	75
15 t FYM + *Azotobacter*	75+	45	75	75+	45	75
15 t FYM + (PSB)	75	45+	75	75	45+	75
15 t FYM + *Azotobacter* + PSB	75+	45+	75	75+	45+	75
30 t (FYM)	150	90	150	150	90	150
30 t FYM + *Azotobacter*	150+	90	150	150+	90	150
30 t FYM + PSB	150	90+	150	150	90+	150
30 t FYM + *Azotobacter* + PSB	150+	90+	150	150+	90+	150

+Indicate the biofertilizers contribution in addition to applied nutrient to crop
RDF, Recommended dose of fertilizer; PSB, phosphate solubilizing bacteria

French bean (₹12.5/kg) and for organic potato (₹10/kg), and French bean (₹15/kg). The system productivity (kg/ha/day) was calculated by dividing the potato-equivalent yield of the system by 365 days. Economic efficiency in / ha/day was worked out by dividing the average net return over years by 365. All observations for each character were subjected to statistical analysis according to the standard method. The calculated values of the treatments and error variance ratio were compared with Fisher and Yates F table at 5% level of significance. The differences between significant treatments means were tested against CD at 5% probability.

RESULTS AND DISCUSSION

Growth and yield attributes of potato

Growth and yield attributes of potato presented in Table 2 revealed that the highest plant height and numbers of tubers/plant were recorded with application of 100% recommended dose of fertilizers through inorganic sources, followed by FYM @ 30 t/ha along with inoculation of *Azotobacter* and PSB. No significant variation was found between recommended dose of fertilizers and application of FYM @ 30 t/ha either with inoculation of biofertilizers or without biofertilizers but higher values were found where biofertilizers, applied along with organic sources through FYM than same dose of organic sources alone. Plant height was 59% higher by application of synthetic fertilizers through inorganic sources over the control. However, the highest weight of tubers per plant was noted with application of 30 t FYM along with inoculation of *Azotobacter* + PSB which was statistically at par with recommended dose of fertilizers through synthetic fertilizers. It was observed that biofertilizers inoculation brought out 10% higher weight of tubers/plant over without inoculated treatment with same level of application (30 t FYM/ha). The effect on weight of tubers/plant through inoculation of PSB was more pronounced than *Azotobacter* with same level of FYM application. This was might be due to increased availability of phosphorus to the plant (Kumar *et al*., 2013).

Growth and yield attributes of French bean

Growth and yield attributes showed that application of recommended dose of fertilizers through synthetic fertilizers recorded the highest plant height of French bean (Table 2). All the nutrient treatments resulted in significantly higher plant height, number of pod and their weight/plant than the control treatment. Weight of pod/plant was more affected by different treatments than number of pod/plant. Highest pod weight/plant was recorded with application of recommended dose of fertilizers and the lowest with the control treatment. Application of biofertilizers along with FYM significantly improved the weight of pod/plant over application of FYM alone (Singh and Choudhary, 2016). Although no significant variation was found with application of the highest dose, i.e. 30 t FYM /ha either with PSB or both *Azotobacter* + PSB. Weight of pod/plant was higher (11%) with inoculation of PSB than *Azotobacter* with application of 30 t FYM/ha. Phosphorus fixation in north-eastern hill region soils due to highly acidic condition, might have resulted in poor availability while inoculation of PSB might increased the availability of phosphorus through entire duration of crop. Similar were also reported by Sud and Jatav (2007).

Table 2. Effect of organic manure and biofertilizer treatments on growth and yield attributes of potato and French bean (data pooled over 2 years)

Treatment	Potato			French bean		
	Plant height (cm)	Tuber/ plant (Nos.)	Tubers weight/ plant (g)	Plant height (cm)	Pods/plant (Nos.)	Pod weight/ plant (g)
Control	26.2	6.3	160.6	24.0	7.7	15.5
Fertilizer (RDF)	41.7	9.3	215.9	46.7	13.0	91.0
15 t FYM	31.0	7.4	186.0	28.7	10.3	26.3
15 t FYM + *Azotobacter*	33.3	7.9	195.3	31.0	12.3	37.5
15 t FYM + PSB	34.7	8.1	200.0	32.0	12.7	41.6
15 t FYM + *Azotobacter* + PSB	35.0	8.4	205.3	33.7	12.7	47.8
30 t FYM	36.0	8.2	207.3	39.0	11.7	62.8
30 t FYM + *Azotobacter*	37.3	8.3	212.1	40.0	13.3	71.3
30 t FYM + PSB	38.3	8.5	221.8	40.3	13.5	79.3
30 t FYM + *Azotobacter* + PSB	40.3	8.6	227.7	43.0	13.7	89.3
SEm±	1.9	0.4	12.3	2.0	0.7	5.5
CD (P=0.05)	5.5	1.1	36.4	5.9	2.1	16.4

RDF, Recommended dose of fertilizers; PSB, phosphate-solubilizing bacteria

Productivity of potato–French bean

Productivity of potato and French bean differ significantly due to different treatments (Table 3). Application of 30 t FYM/ha + biofertilizers (*Azotobacter* + PSB) recorded the highest productivity of potato during both the years. Productivity of potato was higher with application of recommended dose of fertilizers through synthetic fertilizers during previous year than subsequent year, whereas application of FYM with biofertilizers or without biofertilizers enhanced the productivity of potato during subsequent year better than the recommended dose of fertilizers. Residual fertility owing to application FYM might be major reason for higher productivity during succeeding year. Yadav *et al*. (2013) also reported similar results.

In contrast to potato, French bean was found to be more responsive to application of synthetic fertilizers than organic source of nutrient during both the years. Data presented in Table 3 revealed that the highest productivity of French bean was noticed through application of recommended dose of fertilizers through synthetic fertilizers over other treatments. Application of FYM @ 30 t/ha along with inoculation of biofertilizers resulted in the highest productivity among organic sources of nutrients. The lowest productivity of French bean was recorded under control plot. The enhancement in productivity of French bean was higher during succeeding year than previous one. This might be owing to build of soil fertility, resulted in higher productivity. Soil fertility build up through addition of organic manure was also reported by Meena *et al*. (2013).

System productivity of potato–French bean

The highest potato-equivalent yield of French bean and system productivity were recorded with application of recommended dose of fertilizers through synthetic fertilizers over the other treatments (Table 3). However, no significant variation was found between application of recommended dose of fertilizers through synthetic fertilizers and 30 t FYM/ha along with inoculation of biofertilizers (*Azotobacter* and PSB). Application of recommended dose of fertilizers through synthetic fertilizers brought out about 4.5% higher system productivity than FYM application @ 30 t/ha along with biofertilizers. The control plot recorded the lowest potato-equivalent yield and system productivity. System productivity was found higher by 14.0% with inoculation of biofertilizers than without biofertilizers with same level of FYM application (30 t/ha). This was might be owing to that application of biofertilizers enhanced the nutrient availability in the rhizosphere. Das *et al.* (2008) and Narayan *et al*. (2014) also reported similar trend.

System-efficiency indicators and net return

Production efficiency and profitability are the two major factors for deciding the viability of a sustainable cropping system. Data presented in Table 3 revealed that potato–French bean cropping system recorded the significantly higher production efficiency (88.5 kg/ha/day) with the application of recommended dose of fertilizers through synthetic fertilizers, followed by application of 30 t FYM/ha along with inoculation of biofertilizers but both were found to at par with each other but significantly superior

Table 3. Effect of organic manure and biofertilizer treatments on productivity and economic viability of potato–French bean cropping system (pooled data over 2 years)

Treatment	Potato tuber yield (t/ha)	French bean pod yield (t/ha)	Potato EY of French bean (t/ha)	System productivity (t/ha)	Production efficiency (kg/ha/day)	Profitability (₹/ha/day)	Cost of cultivation ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Control	9.8	0.9	1.2	11.0	30.3	44	94.4	16.0	0.2
Fertilizer (RDF)	22.1	6.2	10.3	32.3	88.5	330	121.8	120.3	1.0
15 t FYM	17.1	1.5	2.3	19.3	52.9	216	114.0	78.9	0.7
15 t FYM + *Azotobacter*	18.7	2.2	3.2	21.8	59.8	282	115.4	103.0	0.9
15 t FYM + PSB	20.0	2.4	3.6	23.6	64.6	329	115.6	120.2	1.0
15 t FYM + *Azotobacter* + PSB	21.1	2.8	4.3	25.3	69.2	372	117.0	135.7	1.2
30 t FYM	21.7	3.6	5.4	27.1	74.2	376	133.6	137.3	1.0
30 t FYM + *Azotobacter*	22.4	4.2	6.3	28.7	78.6	416	135.0	151.8	1.1
30 t FYM + PSB	23.4	4.3	6.4	29.7	81.4	444	135.2	162.1	1.2
30 t FYM + *Azotobacter* + PSB	24.2	4.5	6.7	30.9	84.6	471	136.6	172.1	1.3
SEm±	0.6	0.2	0.3	0.6	1.6				
CD (P=0.05)	1.7	0.6	0.9	1.7	4.6				

RDF, Recommended dose of fertilizers; PSB, phosphate-solubilizing bacteria; EY, equivalent yield

to the other treatments (Chitale *et al*., 2015).

Similarly, the lowest production efficiency was noticed under the control treatment. The enhancement in production efficiency with the application of biofertilizers was 14.0% over without biofertilizers with application of same level, i.e. 30 t FYM/ha. However, the maximum economic efficiency (471/ha/day), net return (172.1×10^3) and B:C ratio (1.3) were noticed with application of 30 t FYM/ha along with inoculation of biofertilizers (*Azotobacter* + PSB). This was mainly owing to more enhancements in productivity of both crops through inoculation of biofertilizers without proportionate increase in cost of cultivation accompanied by the higher price of organic produce in the market. Both the treatments either 15 t or 30 t FYM/ha application with inoculation of biofertilizers generated more net returns than recommended dose of fertilizers due to higher market prices of organic produce as compared to product obtained through synthetic fertilizers.

Based on the economic efficiency and net returns it may be concluded that application of either 15 t FYM or 30 t FYM depending on the availability of FYM with inoculation of biofertilizers (*Azotobacter* + PSB) are more profitable than application of the recommended dose of fertilizers through synthetic fertilizers under organic mode of potato–French bean cultivation in north-eastern hill region of India under rainfed condition.

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