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Research Paper

Integrated nutrient management for sustaining the productivity of pigeonpea (*Cajanus cajan*) based intercropping systems under rainfed condition

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ABSTRACT

A field experiment to study the effect of integrated nutrient management for sustaining the productivity of pigeonpea [*Cajanus cajan* (L.) Millsp.] based intercropping systems was conducted for six consecutive years during 2005-06 to 2010-11 at Tirhut College of Agriculture, Dholi, Bihar. Pigeonpea+urdbean [*Vigna mungo* (L.) Hepper] intercropping system, recorded higher yield of pigeonpea (1.85 t/ha), pigeonpea equivalent yield (2.17 t/ha), LER (2.29), production efficiency (8.56 Kg/ha/day), water use efficiency (2.96 Kg grain/ha/mm), fruiting efficiency (17.16%) net return (₹67.3×10^3/ha) and net return per rupee investment (3.05) as compared to pigeonpea + maize (*Zea mays* L.) intercropping and sole pigeonpea. Pigeonpea + urdbean intercropping enhanced total nitrogen uptake and reduced total potassium uptake by the system, than pigeonpea + maize intercropping. Integration of FYM 5.0 tonnes or vermicompost 2.5 tonnes together with RDF proved effective and recorded significantly higher yields of pigeonpea, pigeonpea equivalent yield, LER, production efficiency, fruiting efficiency, water use efficiency, net returns and total NPK uptake by the system than RDF alone. However, higher net returns per rupee investment was recorded in combined application of FYM 5.0 t/ha and RDF (3.01). Seed inoculation with PSB exerted significant effect only on net return (₹64.4×10^3/ha) than un inoculated seed (₹60.2×10^3/ha). Lower value of aggressivity was recorded under combined application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnes/ha and RDF. Pigeonpea + Urdbean intercropping and combined application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonne/ha and RDF improved bulk density and organic carbon and increased available N,P, K content of the soil over initial soil value.

Key words: Intercropping, Integrated nutrient management, Pigeonpea, Rainfed, Seed inoculation, Water use efficiency.

Pigeonpea of long duration is widely grown in NEPZ of the country under rainfed conditions and its yield is unstable and uneconomic due to vagaries of monsoon. To stabilize crop production and to provide insurance against aberrant weather situation, intercropping could be a viable agronomic means of risk minimizing, more profit and subsistence oriented, energy efficient and sustainable venture (Faroda *et al.* 2007). Pigeonpea being a deep rooted crop and initial slow rate of growth for 45-60 days offers good scope for intercropping with short duration crops. Fertilizer use is considered a barometer of agricultural production, no doubt it played a key role in agricultural production and changed country from a region of food scarcity to food sufficiency. But, in spite of liberal application of chemical fertilizers a declining or stagnating yield trend was found which might be attributed to multiple nutrient deficiencies and imbalance of nutrients. With short in supply and escalating prices of chemical fertilizers there is an increasing awareness in favour of adopting biological routes of soil fertility management so as to prevent soil degradation and improving the efficiency of applied fertilizers and thus maintaining crop production. The interactive advantage of combining organic and inorganic sources of nutrients together with biofertilizer have proved superior to use of each component separately (Palaniappan and Annadurai, 2007). Organic manure on the other side, provide a good substrate for the growth of the micro-organism and maintain a favourable nutrient supply environment to the crop. The use of phosphate solubilizing micro-organism with organic manure may prove a viable option for sustaining crop production. Thus, integrated approach of nutrient supply by chemical fertilizers along with organic manures and bio -fertilizers is gaining importance but their importance in modern input intensive crop pro-

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duction technologies needs to be further evaluated, especially in pigeonpea based intercropping systems under rain fed conditions. Hence, the present experiment was conducted to find out suitable management strategies for sustaining productivity of pigeonpea.

MATERIALS AND METHODS

Field experiment was conducted for six consecutive years (2005-06 to 2010-11) on sandy loam soil which was low in organic carbon (0.36%), available nitrogen (162.4 Kg/ha), phosphorous (12.16 Kg/ha) and potassium (56.2 Kg/ha) with pH 8.1. The treatment comprised two intercropping systems (pigeonpea+urdbean and pigeonpea+maize), three fertilizer management practices (RDF alone, RDF + 2.5 tonnes vermicompost/ha and RDF + 5.0 tonnes FYM/ha) and two bio fertilizer (no PSB and seed inoculation with PSB) along with sole cropping of pigeonpea, maize and urdbean. The experiment was laid out in randomized block design with 3 replications. Pigeonpea variety 'Bahar', Maize 'Laxmi' and urdbean 'Pant U-31' were sown in first week of August and pigeonpea was harvested in third week of April next year while the maize and urdbean were harvested in first week of November and third week of October respectively in all the years of experimentation. Pigeonpea was sown in rows 60 cm apart and one row of maize and urdbean were accommodated between two rows of Pigeonpea under pigeonpea + maize and pigeonpea + urdbean intercropping systems. Sole crop of pigeonpea, maize and urdbean were sown on the same distance as in intercropping system at recommended package of practices. The plant to plant distance of 20 cm in pigeonpea and maize and 10 cm in urd bean in sole as well as in intercropping system were maintained by thinning at 14 days after sowing. The recommended dose of fertilizers i.e. pigeonpea (20:40:20 NPK Kg/ha), urd bean (15:40:20 NPK Kg/ha) and Maize (100:50:25 NPK Kg/ha) were given individually. Full dose of nitrogen, phosphorous and potassium in pigeonpea and urdbean were applied at the time of sowing. However, in maize, half of nitrogen, full dose of phosphorous and potassium were applied at the time of sowing and remaining nitrogen was top dressed in two equal splits i.e. $1/4^{th}$ at high and $1/4^{th}$ at tasseling stage of the crop. One hand weeding was done at 30 day of sowing. The crop received 612.8 mm of mean annual rainfall during the crop growth period. The initial and final (after harvest of second year crop), bulk density, organic carbon, N, P and K content of soil were analyzed as per standard methods. For comparison between treatments, the yields of crops were converted into pigeonpea equivalent yield on prevailing market price (Tomar and Tiwari, 1990). Production efficiency values in term of Kg/ha/day were obtained by pigeonpea equivalent yield of the treatments divided by total duration of the crop in that treatment. Aggresivity and water use efficiency were calculated using standard method explained by Palaniappan and Sivaraman (1996).

RESULTS AND DISCUSSION

Growth and yield attributes of pigeonpea

Taller plant of pigeonpea was observed in pigeonpea + urdbean intercropping as compared to pigeonpea + maize intercropping including sole pigeonpea (Table 1). Combined application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnes/ha and recommended dose of inorganic fertilizers significantly enhanced plant height than the recommended dose of inorganic fertilizer alone. Inoculation has no effect on plant height.

Yield indices such as number of branches/plant, pods/plant and 100 seed weight were significantly higher under pigeonpea+urdbean intercropping (Table 1). This might be due to amount of nitrogen fixed by the component crop was fully utilized by the main crop for better growth and development resulted in expression of higher values of these yield indices. These yield indices were significantly higher under combined application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnnes/ha and RDF than alone application of RDF. The yield indices recorded under inoculated and un inoculated were on par with each other.

Grain yield of pigeonpea

Intercropping of pigeonpea+urdbean significantly enhanced grain yield (1.85 tonnes/ha) of pigeonpea as compared to pigeonpea+maize intercropping (1.63 tonnes/ha) and sole pigeonpea (1.51 tonnes/ha) (Table 1). Inclusion of urdbean as intercrop with pigeonpea attributed to less exhaustion of soil fertility, reduced early stage of crop weed competition due to their smothering effects on weeds as compared to sole pigeonpea and pigeonpea+maize intercropping, thereby increase the yield indices and finally the grain equivalent yield of pigeonpea However, in pigeonpea+maize intercropping, maize plants approached above the height of pigeonpea, thus produce shading effect on pigeonpea and reduced penetration of light to the pigeonpea leaves. The leaves export higher proportion of their assimilates to the root at early stage, hence there is more active and prolonged root system and more efficient uptake of water and nutrients to shoot. This provide the reason for reduction in pigeonpea yield. Pandey *et al.* (2003) also reported similar result. Application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnes/ha with RDF proved equally effective for enhancing the grain yield of pigeonpea and both produced significantly higher grain yield than RDF alone (1.55 tonnes and 7.10 tonnes/ha). The increase in grain yield might be due to adequate

quantities and balance proportions of plant nutrients supplied to the crop as per need during the growth period resulting in favourable increase in yield indices which ultimately leads towards an increase in grain yield. Improved physico-chemical properties of the soil through the application of organic manures might be the other possible reason for their higher productivity. Kumawat (2010) also reported 18.2% higher black gram yield by combined application of 2.5 tonnes FYM/ha and 25% RDF than RDF alone.

Pigeonpea equivalent yield

Pigeonpea+urdbean intercropping system recorded maximum and significantly higher pigeonpea equivalent yield (2.17 tonnes/ha) as compared to pigeonpea+maize intercropping (1.96 tonnes/ha) and sole pigeonpea (1.80 tonnes/ha) (Table 1). The higher pigeonpea equivalent yield (PEY) in pigeonpea+urdbean intercropping was owing to better production of component crop without affecting the yield of main crop. Similarly, pigeonpea equivalent yield at FYM 5.0 tonnes/ha or 2.5 tonnes vermicompost/ha and RDF was on par with each other and significantly higher than RDF alone. Higher pigeonpea equivalent yield under combined application of organic sources of fertilizer and RDF might be due to adequate quantity of plant nutrients supplied to the crops resulting in favourable increase in yield of crops and finally the equivalent yield. These results corroborate with the findings of Meena *et al.* (2009).

Land equivalent ratio

In intercropping systems land equivalent ratio (LER) was greater than 1, indicating more biological efficiency of intercroppings. The LER value of 2.29 and 2.15 was observed in pigeonpea + urdbean and pigeonpea + maize intercropping. LER value 2.15 in pigeonpea + maize intercropping, meaning 1.15% more land would be required as sole pigeonpea to produce same yield as obtained in intercropping system. Higher LER values was observed with 5 tonnes/ha FYM or 2.5 tonnes/ha vermicompost with RDF as compared to RDF alone, indicating yield advantage over RDF alone. Seed inoculation with PSB did not exerted significant effect on LER.

Aggressivity

Aggressivity values were positive in pigeonpea under fertilizer and biofertilizer management practices in both the cropping systems, indicating dominance of pigeonpea over urdbean and maize (Table 2). The pigeonpea was more aggressive at RDF in both intercropping systems, the degree of aggressivity was reduced under combined application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnes/ha and RDF, indicating less competition effect of pigeonpea on urdbean and maize. Aggressivity values

Table 1. Growth and yield attributes, yield and economics as influenced by INM and intercrop in pigeonpea (Data pooled over 5 years)

Treatment	Plant height (cm)	Branches/ plant	Pod/ plant	100 seed weight (g)	Grain yield (t/ha)			Pigeonpea equivalent yield (t/ha)	LER	Net Return (× 10^3 ₹/ha)	B:C ratio
					Pigeonpea	Maize	Urdbean				
Intercropping											
Sole crop	206	13.5	189	10.2	1.51	1.35	0.33	1.80	1.00	45.96	2.66
Pigeonpea+maize	209	16.3	196	11.1	1.63	–	–	1.96	2.15	57.30	2.32
Pigeonpea+urdbean	216	20.2	220	11.9	1.85	–	–	2.17	2.29	67.56	3.05
SEm±	1	0.6	4	0.3	0.05			0.06	0.12	0.80	0.10
CD (P=0.05)	3	1.8	8	0.7	0.10	–	–	0.12	NS	1.66	0.21
(Sole vs Rest) Sem±	3	1.6	7	0.6	0.09			0.10	0.21	1.44	0.17
CD (P=0.05)	6	3.3	14	1.3	0.19	–	–	0.21	0.43	2.98	0.36
Fertilizer Management											
RDF	209	16.6	193	10.8	1.55	1.01	0.29	1.83	1.83	54.71	2.59
RDF+vermicompost (2.5t/ha)	214	18.9	214	11.7	1.82	1.32	0.38	2.18	2.28	64.05	2.45
RDF + FYM (5.0 t/ha)	215	19.4	216	12.2	1.83	1.34	0.40	2.19	2.56	68.06	3.01
SEm±	2	1.1	4	0.4	0.06			0.06	0.14	1.00	0.13
CD (P=0.05)	4	2.2	9	0.9	0.13	–	–	0.14	0.29	2.50	0.26
Bio fertilizer											
No PSB	212	17.7	206	11.4	1.70	1.18	0.31	2.01	2.06	60.19	2.60
PSB	213	18.9	210	11.6	1.78	1.26	0.35	2.12	2.22	64.35	2.77
SEm±	1	0.6	4	0.3	0.05			0.06	0.12	0.80	0.10
CD (P=0.05)	NS	NS	NS	NS	NS	–	–	NS	NS	1.66	NS

RDF = Recommended dose of fertilizer

were greater than zero in both the intercropping systems indicating yield advantage over sole pigeonpea.

Fruiting efficiency

Fruiting efficiency of pigeonpea enhanced significantly in pigeonpea + urdbean intercropping (17.16%) as compared to pigeonpea + maize intercropping (13.03%) and sole pigeonpea (12.26%) (Table 2). Similarly fruiting efficiency of pigeonpea was also significantly higher at integration of nutrients compared to RDF alone. The higher fruiting efficiency in pigeonpea+urdbean intercropping and integration of nutrients might be due to improved physico-chemical properties of soil which provide adequate quantities of plant nutrients and water to the crop plant leading to reduced flower dropping and enhanced fruiting of the plant.

Water-use efficiency

The water-use efficiency was higher in intercropping systems than sole pigeonpea but significant difference in water-use efficiency was observed in pigeonpea+urdbean intercropping (Table 2). Water-use efficiency also increased in integration of nutrients through inorganic and organic than inorganic alone. The increase in water-use efficiency (WUE) in these treatment was achieved due to increase in total grain production per unit of water used. The water use efficiency was marginally increased under seed inoculation with PSB.

Total NPK uptake

Intercropping systems significantly enhanced total NPK uptake by the crops than sole pigeonpea (Table 2). Pigeonpea + urdbean registered maximum total N uptake (159 kg/ha) while total K uptake (57 kg/ha) was associated with pigeonpea + maize intercropping. Higher nitrogen uptake in pigeonpea + urdbean intercropping might be due to higher nitrogen content in grain and straw of urdbean accompanied by higher total biomass production of pigeonpea. However, higher total K uptake in pigeonpea+maize intercroping might be due to total higher crops biomass production. The total NPK uptake in integration was significantly higher than RDF alone. The higher total NPK uptake in these treatments might be due to

Table 2. Aggressivity, fruiting efficiency, WUE and nutrient uptake as influenced by INM and intercropping system (Data pooled over 5 years)

Treatment	Aggressivity				Fruiting efficiency of PP (%)	WUE (kg grain/ ha/mm)	Production efficiency (kg/ha /day)	N uptake (kg/ha)				P uptake (kg/ha)				K uptake (kg/ha)			
	PP	Maize	PP	Urdbean				Pigeonpea	Maize	Urdbean	Total	Pigeonpea	Maize	Urdbean	Total	Pigeon pea	Maize	Urdbean	Total
Intercropping																			
Sole Crop	-	-		-	12.26	2.46	7.10	102	-	-	102	30	-	-	30	25	-	-	25
Pigeonpea+maize	-	-		-	13.03	2.67	7.71	114	-	-	145	33	-	-	43	27	-	-	57
Pigeonpea+urdbean	-	-		-	17.16	2.96	8.56	135	-	-	159	38	-	-	41	31	-	-	43
SEm±					0.54	0.06	0.26	4			4	1			1	1			1
CD (P=0.05)	-	-		-	1.13	0.12	0.54	7	-	-	8	2	-	-	2	2	-	-	3
Sole vs Rest SEm±					0.97	0.11	0.46	6			7	2			2	2			2
CD (P=0.05)	-	-		-	2.03	0.22	0.97	13	-	-	15	4	-	-	4	3	-	-	5
Fertilizer																			
RDF	0.22	-.22	.24	-0.24	12.69	2.49	7.19	107	26	19	130	31	3	2	37	25	25	9	43
RDF+VC (2.5t/ha)	0.14	-.14	.15	-0.15	16	2.97	8.62	132	33	26	162	38	11	3	45	30	32	13	53
RDF+FYM(5.0 t/ha)	0.17	-.17	.07	-0.07	16.61	2.99	8.64	133	34	27	164	38	11	3	45	31	32	13	54
SEm±					0.66	0.07	0.29	4	-	-	5	1	-	-	1	1	-	-	2
CD (P=0.05)					1.37	0.15	0.61	9	-		10	3	“		3	2	-	-	3
Biofertilizer																			
No PSB	0.18	-0.18	.19	-0.19	14.83	2.74	7.92	122	30	22	148	35	10	3	41	28	28	11	48
PSB	0.16	-0.16	.11	-0.11	15.37	2.89	8.35	127	31	26	156	37	10	3	43	30	30	12	51
SEm±					0.54	0.66	0.26	4			4	1			1	1			1
CD (P=0.05)	-	-		-	NS	NS	NS	NS	“	“	NS	NS	“	“	NS	NS	“	“	NS

Table 3. Physico-chemical property of soil as influenced by INM and intercropping system after harvest of the crop

Treatment	Soil fertility				
	Bulk density (g/cc)	Organic carbon (g/kg)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Initial	1.32	3.6	162.4	12.2	56.2
Pigeonpea Sole	1.28	4.2	176.5	13.8	60.2
Pigeonpea+maize	1.29	4.0	172.0	13.2	59.5
Pigeonpea+urdbean	1.23	4.4	179.6	14.6	63.1
RDF	1.30	3.9	171.8	12.6	58.6
RDF+vermicompost 2.5 tonnes/ha	1.25	4.3	176.2	14.2	61.8
RDF + FYM 5.0 tonnes/ha	1.24	4.4	178.6	14.9	63.4
No PSB	1.27	4.1	174.6	13.1	60.4
PSB	1.25	4.3	176.4	14.7	62.0

higher biomass production of the crops (grain+stalk/stover). Ansari *et al.* (2011) also recorded higher NP uptake in pearlmillet+pigeonpea intercropping system.

Economics

Intercropping system gained significantly higher net return than sole pigeonpea (Table 2). Pigeonpea+urdbean was more remunerative with higher net return (₹67.3×10^3/ha) and net return per rupee investment (3.05) as compared to pigeonpea+maize and sole pigeonpea. The lower net return per rupee investment in pigeonpea+maize intercropping was obviously due to increase in the cost of production with no commensurate increase in crop yields. Application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnes/ha with RDF significantly enhanced net return over RDF alone (₹54.7×10^3/ha). The magnitude of increase was higher in combined application of FYM 5.0 tonnes/ha and RDF (₹68.1×10^3/ha). However, significant increase in net returns per rupee investment was observed in integration of FYM 5.0 tonnes/ha and RDF (3.01) than RDF alone (2.59).

Production efficiency

Pigeonpea + urdbean intercropping seemed to be more productive (8.56 kg/ha/day) than pigeonpea + maize (7.71 kg/ha/day) than sole pigeonpea (7.10 kg/ha/day) (Table 2). The production efficiency recorded in pigeonpea + maize intercropping and sole pigeonpea was statistically at par. Production efficiency increased under combined application of organic sources of fertilizers with RDF. Application of FYM 5 tonnes/ha or vermicompost 2.5 tonnes/ha and RDF was equally effective (8.64 and 8.62 kg/ha/day) respectively and recorded significantly higher value than RDF alone (7.19 kg/ha/day).

Physico-chemical properties of the soil

The values of bulk density and organic carbon, available nitrogen, phosphorous and potassium before and after experimentation are presented in Table 3. There was substantial decrease in bulk density and increase in nutrient content of the soil in pigeonpea+urdbean intercropping as compared to pigeonpea+maize and sole pigeonpea. The lower bulk density and higher nutrient content of the soil in this intercropping might be due to addition of sufficient quantity of plant leaf and stubble and their decomposition make the soil more porous and productive on one hand and less utilization of these nutrients from the soil by leguminous crop on the other. Application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnes/ha with RDF also reduced bulk density and increased organic carbon, available N,P,K content of the soil over RDF alone. Application of FYM 5.0 tonnes/ha or vermicompost 2.5 tonnes/ha with RDF proved equally effective for improving physico-chemical properties of the soil. This might be due to addition of these organic manures directly resulted in an increase in organic carbon content of the soil while increase in N content as a result of organically bound nitrogen converted to mineralizable form of nitrogen, available P as a result that organic material reducing phosphate fixing capacity of the soil and available K due to release of non exchangeable K from the soil. This release of K and also applied K not only met crop requirement but also build up available K content of the soil. The results are in close conformity with Marathe *et.al.* (2009).

Thus Pigeonpea+urdbean intercropping and fertilized with FYM 5.0 tonnes/ha and RDF was found most remunerative system for sustaining the soil fertility under rainfed conditions of Bihar.

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