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Research Paper

Integrated nutrient management in pigeonpea-based intercropping systems

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ABSTRACT

A field experiment was conducted during the rainy (*kharif*) seasons of 2013-14 and 2014-15 at Faizabad, Uttar Pradesh, on silty loam soils, to study the effect integrated nutrient management practices on pigeonpea [*Cajanus cajan* (L.) Millsp.]-based intercropping systems. The treatments comprised 3 intercropping systems of pigeonpea sole, pigeonpea + urdbean [*Vigna mungo* (L.) Hepper] and pigeonpea + maize (*Zea mays* L.) with different integrated nutrient management levels. On the basis of 2 year results, pigeonpea + urdbean intercropping system recorded significantly higher pigeonpea seed yield (1.72 t/ha), root nodules, N, P and K uptake by grain and straw/ stover over sole pigeonpea and pigeonpea + maize intercropping system. An intercropping of urdbean with pigeonpea recorded significantly higher value of organic carbon, available N, P, K and S contents, net returns (69.5 × 10^3 ₹/ha) over other the other cropping systems at harvest. Among the INM practices, application of recommended dose of fertilizer (RDF) + PSB + *Rhizobium* + FYM @ 3 t/ha + 'Harit-vardan' @ 5 kg/ha recorded significantly higher pigeonpea yield (1.69 t/ha), root nodules, N, P and K uptake by grain and straw/ stover, organic carbon, available N, P, K and S contents, net returns (56.8 × 10^3 ₹/ha) over RDF.

Key words : Harit-vardan, Integrated nutrient management, Pigeonpea-based intercropping systems, Phosphate-solubilizing bacteria, Rainfed, *Rhizobium*

The major pigeonpea-producing countries include India (63.7% of global production), Myanmar (19.0%), Malawi (6.1%), Tanzania (4.4%) and Uganda 2.0%). India grows the largest variety of pulses in the world, accounting for about 32% of the area under cultivation and 25% of the world production. The important pulse crops are chickpea with a 49% share, pigeonpea with a 16% share and urdbean with 4%. The major pulse-producing states are Madhya Pradesh with a 27% share and Uttar Pradesh with an 8% share which together accounted for 63% of the total production (IIPR, 2014).

In India, pigeonpea cultivated over an area of about 3.88 million ha with production and productivity of 3.17 million tonnes and 1,188 kg/ha, respectively, during 2013–14. In Uttar Pradesh, it is grown on 0.64 million ha area with production of 0.79 million tonnes and productivity of 1,234 kg/ha (IIPR, 2014). The basic principle of integrated nutrient management is the maintenance of soil fertility, sustainable agriculture and improving farmer's profitability through the judicious and efficient use of mineral fertilizers, organic manures, green manures and crop residue etc. Continuous use of only chemical fertilizers in intensive cropping system is leading to imbalance of nutrients in soil, which has an adverse effect on soil health and also on crop yields. On the other hand, continuous use of organics helps buildup soil humus and beneficial microbes, besides improving the soil physical properties. But use of organics alone does not result in spectacular increase in crop yields due to their low nutrient content and also availability. '*Harit-vardan*' is a biofertltzer supports the crop plants under water-stress conditions by making regular supply of moisture and nutrient throughout the crop season and increase water and fertilizer-use efficiency. Therefore, effect of judicious combination of organic and inorganic fertilizers on performance and nutrient uptake as well as soil chemical properties of pigeonpea-based intercropping systems.

MATERIALS AND METHODS

A field experiment was conducted during rainy (*kharif*) seasons of 2013–14 and 2014–15 at Agronomy Research

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Farm, Narendra Deva University of Agriculture and Technology, Kumarganj, Faizabad (26< 47' N, 82< 12' E and 113 m above the mean sea-level) Uttar Pradesh, in the Indo-Gangetic alluvial soil belt of Eastern Uttar Pradesh. The soil of the experimental field was silty loam having slight alkaline (*p*H 7.8), electrical conductivity 0.33 dS/m, poor in organic carbon (0.29%), available nitrogen (164.2 kg) medium in available phosphorus (16.7 kg) and potassium (250.6 kg). The treatment combinations comprised 3 intercropping systems (pigeonpea sole, pigeonpea + urdbean and pigeonpea + maize) and 4 nutrient management levels recommended dose of fertilizer (RDF), RDF + phosphate solubilizing bacteria (PSB) + *Rhizobium*, RDF + PSB + *Rhizobium* + FYM @ 3 t/ha and RDF + PSB + *Rhizobium* + FYM @ 3 t/ha + 'Harit-vardan' @ 5 kg/ha]. The experiment was laid out in a factorial randomized block design with 3 replications. The required quantity of various organic manures, viz. FYM and 'Harit-vardan biofertilizer, were applied in moist soil as per treatment about 1 week before sowing of crop and at the time of sowing respectively. Seeds of pigeonpea and urdbean were inoculated with *Rhizobium* and PSB before sowing as per treatments. The recommended dose of fertilizers was given for (pigeonpea 20 : 40 : 00, urdbean 20 : 40 : 00 and maize 80 : 60 : 40 kg N : P_2O_5 : K_2O/ha) in the form of urea, diammonium phosphate and muriate of potash were applied basal. In case of intercropping treatments, fertilizers were applied in proportionate to the sole optimum population for main crop and intercrop, separately. Weeding and plant-protection measures were undertaken as per their need and the required plant population was maintained. 'Narendra Arhar 1', 'Narendra Urd 1' and 'MM 1107' varieties of pigeonpea, urdbean and maize, respectively, were used. The seed rate of the crops @ 16 kg/ha (pigeonpea), 20 kg/ha (urdbean) and 25 kg/ha (maize) was used and the crops were raised on 15 June 2013 and 20 June 2014, respectively, under rainfed condition. The optimum plant population was maintained by thinning and gap filling 10 days after germination to ensure the uniform plant population. Weeding and plant-protection measures were undertaken as per the need. The crops were harvested at their physiological maturity. The nodules/plant were counted from the roots of 5 sampled plants at flowering stage at 90 DAS in pigeonpea and 45 days after sowing (DAS) in urdbean.

Post-harvest soil samples were drawn 15 cm soil depth and analyzed for organic carbon by wet digestion method (Walkley and Black, 1934), available N by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus (P) by 0.5 M $NaHCO_3$. extractable Olsen's Colorimetric method (Olsen's, 1965), available potassium (K) by neutral normal ammonium acetate method (Jackson, 1973) and S by Turbidimetric method (Chesnin and Yien, 1950). The plant samples (grain and straw samples separately) of both the seasons were collected after the harvesting of crop and analyzed for uptake of nitrogen, phosphorus and potassium content by following standard methods, and plant uptake of nutrients was calibrated using grain and straw yields data. The data collected from the experimental field and laboratory analysis were subjected to statistical analysis by adopting Fischer's method of analysis of variance. The level of significance used in 'F' and 't' test was P=0.05. Critical difference was calculated wherever 'F' test was significant.

RESULTS AND DISCUSSION

Nodulation study

In pigeonpea, significantly higher number of nodules, fresh and dry weight of nodules/plant were recorded under pigeonpea + urdbean intercropping system than pigeonpea sole and pigeonpea + maize intercropping (Table 1). The legumes to attain its potential growth through biological nitrogen fixation, the symbiosis between the plant and *Rhizobium* in nodules must be working properly. The healthy nodules and their number depend on the manufacture of carbohydrate in the leaf and their downward translocation to the nodules, which must be adequate for better symbiosis. Thus, the better nodulation and more fresh and dry weight occurred in pigeonpea + urdbean intercrop of might be attributed to better photosynthesis and translocation of photosynthetic to root nodules, because of adequate light and space. These results confirm the findings of Singh and Faroda (1986).

Total number of nodules per plant, fresh and dry weight of nodules in pigeonpea/ urdbean crop were found significantly maximum under RDF + PSB + *Rhizobium* + FYM @ 3 t/ha + 'Harit vardan' @ 5 kg/ha as compared to RDF alone during both the years. Inoculation of PSB with *Rhizobium* and FYM could bring more phosphorus to soil solution, ultimately increased phosphorus uptake which enhances root growth. Phosphorus has a specific role in nodule initiation, growth and function in addition to its role in host plant growth (Singh and Yadav, 2008). Microorganisms with phosphate-solubilizing bacteria, potentially increase the availability of soluble phosphate and enhance the plant growth by improving biological nitrogen fixation (Ponmurugan and Gopi, 2006). Singh *et al.*, (2008) also reported beneficial effect on number of nodules/ plant, fresh and dry weight of urdbean.

Yield of components crop and pigeonpea

Grain yields were found significantly higher under pigeonpea + urdbean intercropping system than pigeonpea sole and intercropping of pigeonpea + maize (Table 2). In pigeonpea + urdbean or pigeonpea + maize intercropping system, the grain yield of pigeonpea was increased 10.2% and 24.3% over pigeonpea sole respectively. Similarly, the pigeonpea + urdbean intercropping system increased the grain yield of pigeonpea was 31.4% over pigeonpea + maize intercropping system. Inclusion of urdbean as intercrop with pigeonpea attributed to less exhaustion of soil fertility, reduced early stage of crop-weed competition due to their smoothing effect on weeds as compared to sole pigeonpea and pigeonpea + maize intercropping, thereby increased the yield indices and finally the grain-equivalent yield of pigeonpea. However, in pigeonpea + maize intercropping, maize plants approved above the height of pigeonpea, thus produces 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 shoots. Similar results were also reported by Singh *et al*. (1998) and Pandey *et al.* (2003).

Amongst integrated nutrient management application of RDF + PSB + *Rhizobium* + FYM @ 3 t/ha + 'Harit-vardan' @ 5 kg/ha recorded the maximum grain yield over all the nutrient management system, which was statisti-

Table 1. Effect of intercrop and nutrient management on nodulation in pigeonpea and urdbean (pooled mean of 2 years)

Treatment	Pigeonpea			Urdbean		
	Number of nodules/ plant	Fresh weight of nodules (mg/plant)	Dry weight of nodules (mg/plant)	Number of nodules/ plant	Fresh weight of nodules (mg/plant)	Dry weight of nodules (mg/plant)
Intercropping system						
Pigeonpea sole	9.1	97.9	11.5	–	–	–
Pigeonpea + urdbean	10.7	129.0	15.7	70.3	278.6	74.0
Pigeonpea + maize	4.0	69.8	8.0	–	–	–
SEm±	0.2	2.6	0.4	–	–	–
CD (P=0.05)	0.5	7.7	0.9	–	–	–
Integrated nutrient management system						
RDF	7.1	81.6	9.8	58.1	245.5	65.5
RDF + PSB + *Rhizobium*	7.7	93.9	11.1	67.9	273.4	72.8
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha	8.4	107.9	12.7	76.3	285.6	78.2
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha + 'Harit-vardan' @ 5 kg/ha	8.6	112.2	13.4	78.7	301.0	79.7
SEm±	0.2	2.9	0.3	2.2	5.8	1.1
CD (P=0.05)	0.6	8.7	1.1	7.4	20.2	3.8

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

Table 2. Effect of integrated nutrient treatments on yield of crops in pigeonpea-based intecropping systems (pooled mean of 2 years)

Treatment	Grain yield (t/ha)		
	Pigeonpea	Urdbean	Maize
Intercropping system			
Pigeonpea sole	1.56	-	-
Pigeonpea + urdbean	1.72	0.71	-
Pigeonpea + maize	1.18	-	2.59
SEm±	0.04	-	-
CD (P=0.05)	0.11	-	-
Integrated nutrient management system			
RDF	1.25	0.54	2.19
RDF + PSB + *Rhizobium*	1.41	0.67	2.42
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha	1.6	0.78	2.84
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha 'Harit-vardan' @ 5 kg/ha	1.69	0.83	2.89
SEm±	0.04	0.03	0.09
CD (P=0.05)	0.12	0.10	0.32

RDF, Recommended dose of fertilizer; PSB phosphate-solubilizing bacteria cally at par with RDF + PSB + *Rhizobium* + FYM @ 3 t/ha during both the years of study (Table 2). The increase in yield might be owing to the beneficial effect of combined use of organics with balanced inorganic fertilization to the extent of with FYM @ 3 t/ha with 'Harit-vardan' @ 5 kg/ha + RDF + seed inoculation of biofertilizer over RDF alone. These results corroborated the findings of Kumar and Gautam (2004) and Saritha *et al.* (2012).

Nutrient uptake

The pooled data on N, P and K uptake of pigeonpea, urdbean and maize (Table 3) indicated significantly higher uptake of N, P and K of pigeonpea under pigeonpea + urdbean inter cropping system as compared to pigeonpea sole and pigeonpea + maize inter cropping. Application of RDF + PSB + *Rhizobium* + FYM @ 3 t/ha + 'Harit-vardan' @ 5 kg/ha, being at par with RDF + PSB + *Rhizobium* + FYM @ 3 t/ha, recorded significantly higher uptake of N, P and K than RDF alone. This was mainly owing to higher biological production and developed root system with enhanced root activity (Sasode, 2006; Patil and Padmani, 2007; Jain *et al*., 2007). It was also evident that yields were deciding factors for the uptake of nutrient by crop. Moreover, soil organic matter (SOM) is store house of nitrogen, phosphorus and sulphur and thereby contributed significantly to supply of these nutrients to crop plants. All these are conducive to availability of nutrients and thereby more uptake by crop (Vasanthi and Subramaniam, 2004). The value of total uptake of N, P, K and S has positive and significant correlation with grain yield. All of which have a strong bearing on the grain yield, as they are the yield-determining components (Goud and Kale, 2010).

Soil chemical properties

At harvesting stage of crop, organic carbon (%), available N,P, K and S content in the soil after harvesting of pigeonpea recorded in pigeonpea + urdbean intercropping system were significantly higher than pigeonpea sole, but were at par with pigeon sole + maize (Table 4). The application of RDF + PSB + *Rhizobium* + FYM @ 3 t/ha + 'Harit-vardan' @ 5 kg/ha resulted in significantly maximum organic carbon (0.35%) over RDF alone which might be due to use of only inorganic fertilizers which can also lead to decline in soil organic matter by enhancing its decomposition (Narde *et al*., 2004).

The improved organic matter content of soil in the treatments receiving organic materials with chemical fertilizers might be owing to direct addition of organic substances in soil, better root growth and more plant residues recycled in soil (Sharma *et al.*, 2000). The subsequent decomposition of these roots might have resulted in increase organic

Table 3. Uptake of nitrogen, phosphorus and potassium as influenced by pigeonpea-based intercropping system and integrated nutrient management (pooled mean of 2 years)

Treatment	Pigeonpea (kg/ha)						Urdbean (kg/ha)						Maize (kg/ha)					
	N uptake		P uptake		K uptake		N uptake		P uptake		K uptake		N uptake		P uptake		K uptake	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
Intercropping system																		
Pigeonpea sole	48.5	49.3	3.6	9.1	7.6	46.2	–	–	–	–	–	–	–	–	–	–	–	–
Pigeonpea + urdbean	56.0	55.3	4.4	10.7	8.8	54.2	24.4	11.8	3.4	2.1	5.4	19.7						
Pigeonpea + maize	34.5	38.2	2.5	7.0	5.5	39.8	–	–	–	–	–	–	40.5	38.0	12.0	3.1	15.7	38.8
SEm±	1.3	1.6	0.1	0.2	0.2	1.6	–	–	–	–	–	–	–	–	–	–	–	–
CD (P=0.05)	3.8	4.6	0.3	0.7	0.6	4.7	–	–	–	–	–	–	–	–	–	–	–	–
Integrated nutrient management																		
RDF	37.1	34.8	2.6	6.3	5.8	34.9	17.7	8.3	2.4	1.3	3.9	14.8	31.2	29.8	9.6	2.3	13.1	32.3
RDF + PSB + *Rhizobium*	42.8	43.0	3.1	8.0	6.7	42.6	22.9	11.0	3.1	2.0	5.0	18.7	36.2	34.6	10.9	2.8	14.5	36.3
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha	50.8	54.0	4.0	10.2	8.1	52.4	27.5	13.3	3.8	2.5	6.0	21.8	46.7	43.4	13.6	3.7	17.5	42.8
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha 'Harit-vardan' @ 5 kg/ha	54.5	58.7	4.4	11.2	8.7	57.0	29.6	14.4	4.1	2.7	6.5	23.3	48.0	44.1	13.9	3.7	17.8	43.6
SEm±	1.5	1.5	0.1	0.3	02	1.9	1.2	0.45	0.1	0.1	0.2	0.7	1.8	1.3	0.5	0.1	0.6	2.4
CD (P=0.05)	4.5	5.4	0.4	0.8	0.6	5.4	4.1	1.57	0.4	0.4	0.6	2.3	6.2	4.7	1.8	0.4	1.7	8.4

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

Table 4. Available nitrogen, phosphorus, potassium and sulphur as influenced by pigeonpea-based intercropping system and integrated nutrient-management system

Treatment	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha)	S (ppm)
Intercropping system					
Pigeonpea sole	0.32	158.6	17.3	238.5	10.7
Pigeonpea + urdbean	0.35	163.6	19.0	244.6	11.1
Pigeonpea + maize	0.32	15.3	16.7	232.1	10.1
SEm±	0.01	1.0	0.5	2.1	0.7
CD (P=0.05)	0.03	2.8	1.8	6.2	NS
Integrated nutrient management system					
RDF	0.30	152.3	15.6	236.8	9.3
RDF + PSB + *Rhizobium*	0.32	156.1	17.2	238.1	10.3
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha	0.34	160.9	18.6	240.8	11.3
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha 'Harit-vardan' @ 5 kg/ha	0.35	161.3	19.0	241.3	11.8
SEm±	0.01	1.3	0.5	0.6	0.4
CD (P=0.05)	0.03	3.8	1.4	1.7	1.1

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

Table 5. Economical yield of pigeonpea as influenced by pigeonpea-based intercropping and integrated nutrient management (pooled mean of 2 years)

Treatment	Net returns (× 10^3 ₹/ha)	Benefit: cost ratio
Intercropping system		
Pigeonpea sole	38.8	1.5
Pigeonpea + urdbean	69.5	2.2
Pigeonpea + maize	45.8	1.4
Integrated nutrient management system		
RDF	38.8	1.4
RDF + PSB + *Rhizobium*	47.9	1.7
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha	57.4	1.9
RDF + PSB + *Rhizobium* + FYM @ 3 t/ha 'Harit-vardan' @ 5 kg/ha	56.8	2.0

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

carbon content of the soil (Tolanur and Badanur, 2003). The improvement in nutrient status of the soil may be ascribed to more biomass (leaves and root etc.) added by the pigeonpea. Shivran and Ahlawat (2000) also reported improvement in status of the soil through addition of fertilizers. Application of 3 t FYM/ha with 5 kg/ha. Harit-vardan reduced the bulk density, and *p*H of the soil, and increase in the organic carbon and available NPKS content of the soil over RDF. This might be owing too addition of FYM that directly resulted in increases of organic carbon content of the soil, while increases in nitrogen content as a result of organically bond nitrogen converted to mineralizable from nitrogen, phosphorus as a result of organic materials reducing phosphorus fixing capacity of the soil and available K due to release non-exchangeable K from the soil. This released K and also applied K not only met crop requirement but also build up available K content of the soil.

Economics

The intercropping system of pigeonpea + urdbean recorded significantly higher net return than sole crop of pigeonpea and pigeonpea + maize (Table 5). The same trend in benefit: cost ratio was observed under intercropping system (2.2). Kumar and Rana (2007) reported higher monetary returns at higher fertility level in pigeonpea + greengram intercropping system. Goyal *et al.* (1991) and Bajpai and Singh (1992) also reported similar findings in intercropping of pigeonpea with greengram. Combined application of RDF + PSB + *Rhizobium* + FYM @ 3 t/ha 'Harit-vardan' @ 5 kg/ha significant higher net returns and benefit cast ratio over RDF alone. Similar findings were also reported by Vyas *et al*. (2006).

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