Indian Journal of Agronomy **62** (4): 451–457 (December 2017)

Research Paper

Nutrient management for enhancing productivity of pigeonpea *(Cajanus cajan)*-based intercropping system under rainfed condition

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Received : May 2017; Revised accepted : October 2017

ABSTRACT

A field experiment was conducted during the rainy *(kharif)* season of 2011–12 and 2012–13 at Tirhut College of Agriculture, Dholi, Bihar, to study the effect of nutrient management for enhancing productivity of pigeonpea [*Cajanus cajan* (L.) Millsp.]-based intercropping systems. Pigeonpea + turmeric (*Curcuma longa* L.) intercropping system, recorded significantly higher pigeonpea yield (2.00 t/ha), pigeonpea-equivalent yield (4.79 t/ha), fruiting efficiency (18.8%), water-use efficiency (6.1 kg grain/ha/mm), production efficiency (18.0 kg/ha/day) and net returns (₹106.32 $\times 10^{3}$/ha) than pigeonpea + maize (*Zea mays* L.) intercropping and sole pigeonpea. However, pigeonpea + turmeric recorded lower benefit: cost (B: C) ratio than sole pigeonpea. Significantly higher B: C ratio was recorded under pigeonpea + sesame (*Sesamum indicum* L.) (2.32) and pigeonpea + urdbean [*Vigna mungo* (L.) Hepper] (2.31) intercropping systems than pigeonpea + maize, pigeonpea + turmeric and sole pigeonpea. Pigeonpea + maize recorded significantly lower NPK uptake by pigeonpea than sole pigeonpea and the other intercropping systems. Pigeonpea + mungbean [*Vigna radiata* (L.) R. Wilczek] and pigeonpea + urdbean recorded significantly higher number and dry weight of nodules /plant than pigeonpea + maize. Application of 125% recommended dose of fertilizer (RDF) recorded significantly higher number of branches and pods/plant, pigeonpea-equivalent yield (3.39 t/ha), land-equivalent ratio (1.87), production efficiency (12.8 kg/ha/day), net returns (₹80.83 $\times 10^{3}$/ha), benefit: cost ratio (2.17) and NPK uptake by pigeonpea than RDF and 75% RDF. Pigeonpea-equivalent yield in pigeonpea + urdbean, pigeonpea + mungbean and pigeonpea + sesame intercropping systems, increased significantly with the increasing levels of fertilizer up to RDF, and further increase in fertilizer level did not show significant effect on pigeonpea-equivalent yield. However, it increased significantly up to 125% RDF in pigeonpea + maize and pigeonpea + turmeric intercropping systems. Pigeonpea + urdbean and pigeonpea + mungbean increased organic carbon, available N, P, K content of the soil than the other intercropping systems and initial soil value.

Key words : Fruiting efficiency, Nutrient uptake, Pigeonpea, Pigeonpea equivalent yield, Production efficiency, Water-use efficiency

Pigeonpea is mostly grown in the rainy season on marginal land under rainfed conditions of Bihar and the yield of the crop is unstable and sometimes uneconomical due to vagaries of monsoon. To provide insurance against aberrant weather condition and to stabilize crop production, intercropping could be a viable agronomic means of risk minimizing, profitable, subsistence oriented, energy efficient and sustainable venture (Dubey and Vyas, 2010). Intercropping is an intensive land-use system with an objective to utilize the space left between the rows of main crop and provide more grain yield per unit area. Pigeonpea can be grown under wider range of ecological situations mainly owing to its deep rooting system and drought-tolerant characters. Slow growth of pigeonpea up to 45–60 days with wider row spacing makes it especially suitable crop for intercropping with short-duration crops. In intercropping systems, the component crops are able to use resources differently when grown together and make the better total use of resources than when grown separately. However, in intercropping system, it has still not been understood adequately as compared to sole cropping in terms of system efficiency, more so regarding the concept of nutrient management where both crop have different growth habit and nutrient requirement (Ansari *et al.*,

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2011). The duration of component crop, their growth rate, planting density, the differences in the depth of rooting, lateral root spread and root densities are some of the factors that affect competition between component crops in intercropping system for moisture and nutrients and hence input-use efficiency. The magnitude of competition varies with the types of intercrops grown with pigeonpea due to their differential nutrient absorption behaviour. Hence it is necessary to maintain soil fertility between both sole and intercropped stand through judicious use of nutrients. It is also hypothesized that nutrient application could also influence competition ability of component crops and the yield of the intercropping system. In order to generate location-specific nutrient management in pigeonpea- based intercropping system, the present study was carried out to find out the most productive and remunerative intercropping system and nutrient-management strategy for boosting system production of pigeonpea-based intercropping system under rainfed condition of Bihar.

MATERIALS AND METHODS

The field experiment was conducted at Tirhut College of Agriculture, Dholi (25°98' N 85°76' E and of 51.3 m above mean sea-level) of the Dr Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar, during the rainy season of 2011–12 and 2012–13. The soil was sandy loam, low in organic carbon (0.35%), available nitrogen (155.2 kg/ha), phosphorus (12.43 kg /ha) and potassium (55.8 kg/ha) with the *p*H 8.1. Treatments comprised 5 intercropping systems, viz. pigeonpea + maize, pigeonpea + urdbean, pigeonpea + mungbean, pigeonpea + turmeric and pigeonpea + sesame, along with sole cropping of pigeonpea, maize, urdbean, mungbean, turmeric and sesame and 3 fertilizer levels, viz. 75% recommended dose of fertilizer (RDF), 100% RDF and 125% RDF.The experiment was laid out in a randomized block design (factorial) and replicated thrice. Pigeonpea variety 'Bahar', maize 'Laxmi', urdbean 'Pant U 31', mungbean 'SML 668', turmeric 'Rajendra Sonia' and seamum 'Krishna' were sown in the last week of July. Pigeonpea was harvested in the third week of April, maize in the first week of November, urdbean, mungbean and sesame in the third week of October and turmeric in the third week of January in both the years. Pigeonpea was sown in rows distance of 75 cm and 1 row of maize and 2 rows of other intercrops, i.e. urdbean, mungbean, turmeric and sesame, were accommodated between 2 rows of pigeonpea as per intercropping treatment. Sole crop of pigeonpea was sownin row spacing of 75 cm, maize 60 cm and urdbean, mungbean, turmeric and sesame were sown 30 cm. The plant-to-plant distance of 20 cm was maintained in pigeonpea and maize, and 10 cm in urdbean, mungbean, turmeric and sesame in sole as well as in intercropping. The recommended dose of fertilizers, i.e. pigeonpea (20:40:20 kg N : P : K/ha), maize (100 : 50 : 25 kg N : P : K/ha), urdbean and mungbean (15:40:20 kg N: P: K/ha), turmeric (150 : 60 : 120 kg N: P: K/ha) and sesame (40 : 20 : 20 kg N : P : K/ha) were given in sole crop. In intercropping systems, fertilizers of intercrops were applied as per treatment along with RDF of pigeonpea. Full dose of nitrogen, phosphorus and potassium in pigeonpea, urdbean, mungbean and sesame were applied at the time of sowing. However, in maize half dose of nitrogen, full dose of phosphorus and potassium were applied at the time of sowing and remaining nitrogen was top-dressed 30 days after sowing, while in turmeric one-third nitrogen and full dose of phosphorus and potassium were applied at sowing and remaining nitrogen was applied in 2 equal splits – 60 and 70 days after sowing in sole as well as in intercropping. Earthing up in turmeric was done at 75 days after sowing. One hand-weeding was uniformly done in all the sole and intercropping systems 30 days after sowing. The crop received 829.8 and 664.9 mm rainfall during the crop-growth period in the first and second year of experimentation respectively. The initial and final (after harvesting of the second year crop) *p*H, organic carbon, N, P and K content of soil were analyzed by glass electrode *p*H meter, Walkley and Black, alkaline per magnate, olsen's and flame photometric method respectively. For comparison between treatments, the yields of crops were converted into pigeonpea-equivalent yield on prevailing market price.

For measuring the fruiting efficiency, 3 sample plants per experimental unit were randomly selected and covered with net at flower-initiation stage. After completition of fruiting net was removed and total number of dropped flowers in net along with total number of pods/plant were counted and average was taken. Fruiting efficiency was worked out by dividing the flower-bearing pods by total number of flowers (dropped flower + pods) multiplied by 100. Plant height was measured from 3 randomly selected plants per experimental unit at maturity stage and average was taken. However, yield indices were measured after harvesting of 3 sampled plants from experimental unit and average was taken. Nodule study was done 75 days after sowing and for this purpose 5 randomly selected plants from each plot were uprooted carefully by digging around the plants. The soil was washed off by dipping root portion in water to remove all traces of soil after thorough washing nodules were removed from root. Nodules were secured in paper bags for air drying. Later, they were transferred to a dry oven at 60°C temperature and kept for 48 hr and dry to constant weight then average were taken.

Net return was calculated by subtracting cost of cultivation from gross return. Benefit: cost ratio was calculated by dividing the net returns with cost of cultivation. Production efficiency in term of kg/ha/day was obtained by pigeonpea-equivalent yield of the treatments divided by total duration of the crop in that treatment. For economic analysis the prevailing prices of the inputs and produce during the period of experiment were considered. Data pertaining to each characters were analyzed statistically by applying the standard procedure of randomized block design (factorial) to test the level of significance among the treatment mean of intercropping systems and fertilizer levels. The critical difference (CD) values were worked out at 5% level of probability. Separate CD was calculated to test the significance level between sole pigeonpea and intercropping systems (sole vs rest).

RESULTS AND DISCUSSION

Growth and yield attributes of pigeonpea

Plant height of pigeonpea was significantly higher in pigeonpea + turmeric than pigeonpea + maize and pigeonpea + sesame intercropping systems as well as in sole pigeonpea (Table 1). Application of 125% recommended dose of fertilizers significantly enhanced the plant height than 100% RDF and 75% RDF. Yield indices such as number of branches/plant and pods/plant were significantly higher under pigeonpea + turmeric intercropping than sole pigeonpea, pigeonpea + maize and pigeonpea + sesame intercroppings (Table 1). Significant reduction in the value of these yield indices as compared to sole pigeonpea were recorded only in pigeonpea + maize intercropping. However, pod length, grains/pod and 100-seed weight of pigeonpea did not vary significantly among the intercropping systems and sole pigeonpea. The higher value of yield indices and plant height in pigeonpea + turmeric intercropping might be owing to absence of competition between main and intercrop for growth resources such as nutrient and solar radiation; besides use of interculture operation in turmeric provides congenial physical environment for growth and development of crop plant resulting in expression of higher values of these yield indices. Tiwari *et al.* (2011) also recorded higher yield indices of pigeonpea in pigeonpea + urdbean intercropping system than pigeonpea + maize. Kumawat *et al.* (2013) reported that pigeonpea + blackgram did not affect the growth, yield attributes and yield of pigeonpea as compared to sole pigeonpea. These yield indices were also significantly higher at 125% RDF than 100 and 75% RDF. This might be because of addition of additional quantity of nutrients in the soil which reduce the state of competition for nutrients among the crop plants and make their availability in appropriate amount to the crop plants resulting in favourable increase in growth and development of crop

Table 1. Plant height, yield attributes, fruiting efficiency, nodules number and dry weight of pigeonpea as influenced by intercropping systems and fertilizer levels (pooled mean of 2 years)

Treatment	Plant height (cm)	Branches/ plant	Pod length (cm)	Pods/ plant	Grains/ pod	100-seed weight (g)	Fruiting efficiency (%)	Nodules/ plant	Dry weight of nodule (mg)
Intercropping									
sole crop	217.5	16.3	4.7	213	4.0	11.0	14.1	14.6	23.4
Pigeonpea + maize	219.9	14.1	4.5	192	3.8	10.7	13.2	14.0	22.3
Pigeonpea + urdbean	224.5	17.6	5.0	225	4.0	11.4	18.3	15.2	24.3
Pigeonpea + mungbean	225.7	18.1	5.0	230	4.3	11.5	18.6	15.4	24.6
Pigeonpea + turmeric	226.9	18.5	5.2	234	4.4	11.6	18.8	14.0	22.7
Pigeonpea + sesame	222.5	17.0	4.9	220	4.2	11.3	17.7	14.8	23.7
SEm±	1.1	0.6	0.5	3	0.3	0.4	0.9	0.4	0.6
CD (P=0.05)	2.4	1.1	NS	5	NS	NS	1.8	0.9	1.4
Sole vs Rest									
SEm±	1.6	0.7	0.6	4	0.4	0.6	1.2	0.6	1.0
CD (P=0.05)	3.2	1.4	NS	8	NS	NS	2.3	NS	NS
Fertilizer level									
75% RDF	220.1	15.4	4.6	211	4.0	11.0	16.0	15.1	24.3
RDF	223.1	17.0	4.9	220	4.2	11.3	17.0	14.6	23.4
125% RDF	225.2	18.3	5.1	226	4.2	11.5	17.4	14.2	22.8
SEm±	0.9	0.5	0.4	2	0.2	0.3	0.7	0.4	0.6
CD(P=0.05)	1.9	1.1	NS	4	NS	NS	1.4	NS	NS

RDF, Recommended dose of fertilizer

plant which lead toward an increase in plant height and yield indices.

Fruiting efficiency of pigeonpea significantly enhanced in all the pigeonpea-based intercropping systems compared with the sole pigeonpea except pigeonpea + maize (Table 1). Among the intercropping systems, highest fruiting efficiency was recorded under pigeonpea + turmeric intercropping system which was found at par with other intercroppings and significantly higher than pigeonpea + maize. Among the fertilizer levels, fruiting efficiency of pigeonpea was significantly higher at 125% RDF than 75% RDF. Higher fruiting efficiency in these treatments might be owing to compatible nature of component crops initially suppressed weed and facilitating the uptake of adequate quantity of nutrients to the main crop plant which resulted in reduced rate of flower dropping and increased pod-bearing capacity of the plant.

Nodulation

Number of nodules/plant and dry weight of nodules were not significantly influenced by intercropping systems as compared to sole pigeonpea (Table 1). Among the intercropping systems, number and dry weight of nodules reduced significantly in pigeonpea + maize and pigeonpea + turmeric than pigeonpea + urdbean and pigeonpea + mungbean intercroppings systems. Higher number and dry weight of nodules in pigeonpea + urdbean and pigeonpea + mungbean intercropping system might be due to contribution of legumes towards an increase in plant nutrition. Fertilizer levels exerted non significant effect on number and dry weight of nodules.

Production and water-use efficiency

Production and water-use efficiency were significantly higher in intercropping systems than sole pigeonpea except pigeonpea + maize intercropping (Table 2). Among the intercroppings, significantly higher production (18.0 kg/ha/day) and water-use efficiency (6.1 kg grain/ha/mm) were obtained under pigeonpea + turmeric intercropping than rest of the intercropping systems. Application of 125% RDF recorded significantly higher water-use efficiency than 75% RDF but was at par with RDF. However, production efficiency increased significantly with increasing fertilizer levels and recorded higher value at 125% RDF (12.8 kg/ha/day).The increase in water-use efficiency under these treatments was achived owing to increase in grain yield

Table 2. Pigeonpea-equivalent yield, water-use efficiency, production efficiency and economics as influenced by intercropping systems and fertilizer levels (pooled mean of 2 years)

Treatment	Grain yield (t/ha)						Pigeonpea-equivalent yield (t/ha)	LER	Harvest index (%)	WUE (kg grain/ ha/mm)	Production efficiency (kg/ha/day)	Net returns (×10³ ₹/ha)	Benefit: cost ratio
	Pigeonpea	Maize	Urdbean	Mungbean	Turmeric	Sesame							
Intercropping													
Sole crop	1.78	1.62	0.65	0.40	20.52	0.54	2.23	1.00	18.8	2.8	8.4	82.58	2.09
Pigeonpea + maize	1.54	0					2.32	1.56	18.6	2.9	8.7	48.18	1.47
Pigeonpea + urdbean	1.92						2.91	1.75	19.0	3.7	11.1	71.52	2.31
Pigeonpea + mungbean	1.95						2.64	1.61	18.6	3.4	9.9	61.10	1.95
Pigeonpea + turmeric	2.00						4.79	1.77	19.2	6.1	18.0	106.32	1.74
Pigeonpea + sesame	1.85						2.85	1.75	18.9	3.5	10.7	68.65	2.32
SEm±	0.06						0.06	0.07	0.1	0.1	0.3	1.49	0.06
CD (P=0.05)	0.11						0.16	0.15	0.2	0.3	0.6	3.06	0.14
Sole vs Rest													
SEm±	0.08						0.09	0.10	0.1	0.2	0.4	1.88	0.08
CD (P=0.05)	0.16						0.19	0.21	0.2	0.4	0.8	3.85	0.18
Fertilizer level													
75% RDF	1.71	0.86	0.33	0.15	11.06	0.31	2.79	1.48	18.9	3.5	10.5	60.10	1.70
RDF	1.88	1.13	0.44	0.20	13.68	0.39	3.15	1.71	19.0	4.0	11.8	72.55	2.00
125% RDF	1.97	1.28	0.50	0.23	15.78	0.44	3.39	1.87	19.1	4.2	12.8	80.83	2.17
SEm±	0.05	-	-	-	-	-	0.05	0.05	0.1	0.1	0.2	1.13	0.05
CD (P=0.05)	0.10	-	-	-	-	-	0.12	0.12	0.2	0.2	0.5	2.32	0.12

WUE, Water-use efficiency; LER, land-equivalent ratio per unit of water used.

Grain yield

An intercropping of pigeonpea + turmeric significantly enhanced the grain yield of pigeonpea (2.00 t/ha) and harvest index (19.2%) as compared to pigeonpea + maize (1.54 t/ha,) and sole pigeonpea (1.78 t/ha) (Table 2). Split application of high quantity of nitrogenous fertilizer at different growth stages and earthing-up operation in turmeric provide congenial environment and adequate quantity of plant nutrients to the main crop as per need resulting in favourable increase in yield indices and finally the grain yield of pigeonpea. However, in case of pigeonpea + maize intercropping, maize crop being a heavy feeder competes with pigeonpea for nutrients and also approaches above the height of pigeonpea, thus produces shading effect on pigeonpea and reduces penetration of light to the pigeonpea leaves. Since, leaves export higher proportion of their assimilates to the root at early stage, there is more active and prolonged root-system and more efficient uptake of water and nutrients to shoot. These provides the reason for reduction in pigeonpea yield. Application of 125% RDF to intercrops resulted in significantly higher grain yield (1.97 t/ha) over 75% RDF (1.71 t/ha). The increase in grain yield might be owing to adequate quantities and balanced proportion of plant nutrients supplied to the intercrops reduced the state of competition for nutrients among main and intercrops, resulting in favourable increase in yield indices which ultimately led towards an increase in grain yield. Pandey *et al.* (2015) also recorded higher pigeonpea yield at recommended dose of fertilizer over 50% RDF. Application of 125% RDF recorded significantly higher harvest index (19.1%) than 75% RDF (18.9%).

Pigeonpea-equivalent yield

All the intercropping systems except pigeonpea + maize (2.32 t/ha) recorded significantly higher pigeonpea-equivalent yield than sole pigeonpea (2.23 t/ha). Among the intercropping systems, pigeonpea + turmeric recorded significantly higher pigeonpea-equivalent yield (4.79 t/ha) over rest of the intercropping systems. The higher pigeonpea-equivalent yield in pigeonpea + turmeric intercropping was owing to better production of component crop without affecting the yield of main crop. Pandey *at el.* (2013) also obtained higher pigeonpea-equivalent yield in pigeonpea + urdbean intercropping than pigeonpea + maize and sole pigeonpea. Similarly, pigeonpea-equivalent yield also increased significantly with increasing levels of fertilizer and recorded the maximum pigeonpea-equivalent yield at 125% RDF. The higher pigeonpea-equivalent yield at higher level of fertilizers might be owing to adequate quantity of plant nutrients supplied to the crops resulting in favourable increase in yield of the crops and finally the equivalent yield. Ansari *et al*. (2011) also recorded higher pigeonpea-equivalent yield at 50:17.2 kg N and P/ha in pearl millet and pigeonpea intercropping than its lower level.

Interaction between intercropping systems and fertilizer levels was found to be significant with respect to pigeonpea-equivalent yield (Table 3). In pigeonpea + maize and pigeonpea + turmeric, pigeonpea-equivalent yield increased significantly with increasing levels of fertilizers and recorded maximum pigeonpea-equivalent yield at 125% RDF. However, in pigeonpea + urdbean, pigeonpea + mungbean and pigeonpea + sesame significant increase in pigeonpea-equivalent yield was recorded only up to 100% RDF, and further increase in the fertilizer level fail to produce significant effect on pigeonpea-equivalent yield. Urdbean and mungbean, being legumes crops, are likely to make liberal use of atmospheric nitrogen by symbiotic process and thus, may add in fertility status of soil and less exhaustion of soil nutrients by sesame might fulfil the nutrient requirement of main as well as component crops at lower level of fertilizer. Contrary on other hand, being a heavy feeder, maize and turmeric crops make use of higher quantity of nutrients thus respond to higher dose of fertilizer.

Table 3. Interaction effect of intercropping system and fertilizer levels on pigeonpea-equivalent yield (t/ha) (pooled mean of 2 years)

Fertilizer level	Intercropping system				
	Pigeonpea + maize	Pigeonpea + urdbean	Pigeonpea + mungbean	Pigeonpea + turmeric	Pigeonpea + sesame
75% RDF	2.00	2.69	2.43	4.24	2.59
100% RDF	2.33	2.99	2.68	4.86	2.89
125% RDF	2.62	3.19	2.82	5.27	3.07
SEm±	–	–	0.13	–	–
CD (P=0.05)	–	–	0.27	–	–

RDF, Recommended dose of fertilizer

Land-equivalent ratio

In the intercropping systems, land-equivalent ratio (LER) was greater than l, indicating more biological efficiency of intercroppings (Table 2). Among the intercropping systems, highest LER value was recorded in pigeonpea + turmeric (1.77) intercropping, being significantly higher than pigeonpea + maize and also with pigeonpea + mungbean. The LER value of 1.77 in pigeonpea + turmeric intercropping, meaning 0.77% more land would be required as sole pigeonpea to give same yield as obtained in intercropping system. The LER value also increased significantly with increasing levels of fertilizer and recorded the maximum value at 125% RDF (1.87), indicating yield advantage over 100% and 75% RDF.

NPK uptake

Uptake of NPK by pigeonpea significantly reduced in pigeonpea + maize intercropping as compared to sole pigeonpea and the other intercropping systems (Table 4). Among the intercropping systems, the maximum NPK uptake were registered in pigeonpea + turmeric intercropping system which was significantly higher than pigeonpea + maize and pigeonpea + sesame intercroppings system, but was at par with pigeonpea + urdbean and pigeonpea + mungbean except K uptake in pigeonpea + urdbean. The K uptake was also significantly lower in pigeonpea + urdbean intercropping system than pigeonpea + turmeric. Higher NPK uptake in pigeonpea + turmeric and pigeonpea + urdbean might be due to enhanced availability of these nutrients to the plant which raised their content in seed and stalk accompanied by higher total biomass production of pigeonpea. Pandey *et al.* (2013) also recorded higher NPK uptake by pigeonpea in pigeonpea + urdbean intercropping system than pigeonpea + maize and sole pigeonpea. Application of 125% RDF recorded significantly higher NPK uptake by pigeonpea which decreased significantly at lower doses of fertilizers. This could be attributed to the fact that added fertilizers enhanced the availability of these nutrients to plant. This might has resulted in profuse shoot and root growth, and thereby activating greater absorption of these nutrients from the soil. Umesh *et al.* (2013) also recorded significantly higher uptake of NPKS and Zn by pigeonpea at graded levels of fertilizer application.

Economics

The intercropping systems recorded significantly higher net return than sole pigeonpea except pigeonpea + maize (Table 2). Pigeonpea + turmeric fetched significantly higher net return (106.32×10₹/ha) than the other intercropping systems. However, significantly higher benefit: cost (B: C) ratio was obtained in pigeonpea + sesame (2.32) and pigeonpea + urdbean (2.31) intercropping among the intercropping systems. The lower B:C ratio in pigeonpea + turmeric, pigeonpea + maize and pigeonpea

Table 4. Effect of intercropping system and fertilizer levels on NPK uptake by pigeonpea and physico-chemical properties of soil

Treatment	N uptake by pigeonpea (kg/ha)	P uptake by pigeonpea (kg/ha)	K uptake by pigeonpea (kg/ha)	*p*H	Bulk density (g/cc)	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Intercropping									
Initial	-	-	-	8.1	1.39	0.34	155.2	12.4	55.8
Pigeonpea sole	134.7	34.7	91.4	8.1	1.36	0.37	163.1	14.2	58.0
Pigeonpea + maize	114.8	30.1	71.4	8.1	1.36	0.36	158.6	13.0	56.8
Pigeonpea + urdbean	144.5	37.1	97.2	8.1	1.34	0.38	165.6	15.5	60.2
Pigeonpea + mungbean	145.3	37.3	99.4	8.1	1.33	0.39	166.9	15.9	60.9
Pigeonpea + turmeric	144.7	38.5	103.5	8.1	1.35	0.37	164.9	15.9	59.4
Pigeonpea + sesamum	135.1	35.4	92.3	8.1	1.35	0.37	164.2	15.1	58.6
SEm±	4.4	1.1	2.9	–	–	–	–	–	–
CD (P=0.05)	9.1	2.3	5.9	–	–	–	–	–	–
Sole vs Rest									
SEm±	5.6	1.4	3.7	–	–	–	–	–	–
CD(P=0.05)	11.4	2.9	7.6	–	–	–	–	–	–
Fertilizer level									
75% RDF	124.6	32.8	84.7	8.1	1.36	0.36	136.2	14.6	56.4
100% RDF	138.7	36.1	93.8	8.1	1.35	0.37	164.1	15.0	58.8
125% RDF	147.7	38.2	99.9	8.1	1.34	0.39	164.8	15.6	59.4
SEm±	3.4	0.9	2.3	–	–	–	–	–	–
CD (P=0.05)	6.9	1.9	4.7	–	–	–	–	–	–

+ mungbean was obviously due to increase in cost of production with no commensurate increase in crop yields. Singh *et al.* (2013) recorded higher net return and B:C ratio in pigeonpea + mungbean intercropping system over sole pigeonpea. Application of 125% RDF significantly enhanced net return (80.83×10^3₹/ha) and B: C ratio (2.17) over lower levels of fertilizer. Higher grain and stalk yields at higher fertilizer level were in fact the reasons for higher net return and B: C ratio in this treatment. Kumar and Rana (2007) recorded higher momentary returns at higher fertility level in pigeonpea + greengram intercropping system.

Soil physico-chemical properties

Bulk density, organic carbon, available nitrogen, phosphorus and potassium content of the soil after harvesting of pigeonpea were influenced by intercropping systems and fertilizer levels over initial soil status (Table 4). Bulk density showed decreasing trend in intercropping systems and sole pigeonpea from the initial soil value (1.39 g/cc). Lower bulk density was recorded in pigeonpea + mungbean (1.33 g/cc) and pigeonpea + urdbean (1.34 g/cc) intercroppings than pigeonpea + maize and sole pigeonpea. However, organic carbon, available N,P and K content of soil substantially increased in the intercropping systems and sole pigeonpea over initial soil value. Maximum increase in organic carbon (0.39%), available N (166.9 kg/ha), P (15.9 kg/ha) and K (60.9 kg/ha) contents of soil was recorded in pigeonpea + mungbean intercropping, closely followed by pigeonpea + urdbean and higher over pigeonpea + maize (0.36%, 158.6,13.0 and 56.8 kg/ha, organic carbon, available N, P and K content respectively) and sole pigeonpea (0.37%, 163.1, 14.2 and 58.0 kg/ha, organic carbon, available N, P and K content respectively). The lower bulk density and higher nutrient content of soil under these intercroppings might be because of 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. Pandey *at el.* (2013) also recorded lower bulk density and higher content of organic carbon, available N,P,K in pigeonpea + urdbean intercropping compared with pigeonpea + maize and initial soil value. Application of 125% RDF reduced the bulk density (1.34 g/cc) and enhanced available N (164.8 kg/ha), P (15.6 kg/ha) and K (58.8 kg/ha) content of the soil over 75% RDF and initial soil value. The improvement in nutrient status of the soil at higher fertilizer level may be ascribed to more biomass (leaves, roots etc.) added by crops. Goud *et al.* (2012) also recorded the similar result. Soil *p*H was unaffected by the intercropping systems and fertilizer levels.

It can be concluded that, pigeonpea + turmeric was found more productive and remunerative intercropping system than pigeonpea + mungbean, pigeonpea + urdebean and pigeonpea + sesame intercropping systems under rainfed condition of Bihar, as it recorded the highest pigeonpea-equivalent yield and net return. For obtaining higher pigeonpea-equivalent yield from pigeonpea + urdbean, pigeonpea + mungbean and pgeonpea + sesame intercropping systems, recommended dose of fertilizer (RDF) of intercrops should be applied along with RDF of pigeonpea. However, in pigeonpea + turmeric and pigeonpea + maize intercropping, 125% RDF of intercrops should be applied together with RDF of pigeonpea.

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