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Production Potential and Economic Feasibility of Planting Pattern and Nutrient Management in Pigeonpea (*Cajanus cajan*) Based Intercropping System under Rainfed Condition

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ABSTRACT

Background: Pigeonpea grown as sole crop is not economically viable because of its slow initial growth rate, low productivity and longer duration. The initial slow growth rate, widely spaced, deep root system and longer duration of pigeonpea offers a good scope for intercropping with fast growing and early maturing compatible crops. Proper row arrangement of main as well as intercrops in appropriate proportion is the promising way to exploit the natural resources such as space, nutrient, sunlight, soil moisture to greater extent and boost up the system productivity.

Methods: The study was carried out for four consecutive years during kharif 2013-14 to 2016-17 at Tirhut College of Agriculture, Dholi, RPCAU, Pusa, Bihar. The treatment comprised 3 intercropping systems with two method of planting *viz*, pigeonpea (60 cm)+ urdbean (1:1), pigeonpea (60 cm) + sesame (1:1), pigeonpea (60 cm) + sorghum (1:1), pigeonpea paired (45 cm) + urdbean (2:2), pigeonpea paired (45 cm) + sesame (2:2), pigeonpea paired (45 cm) + sorghum (2:2) and 3 fertilizer levels of intercrop *viz*, 75% recommended dose of fertilizer (RDF), 100% RDF and 125% RDF along with sole crop of pigeonpea, urdbean, sesame and sorghum.

Result: Intercropping of urd bean [*Vigna mungo* (L.) Hepper], sesame (*Sesamum indicum* L.) and sorghum (*Sorghum bicolor* (L.) Moench] paired row planting of pigeonpea (45 cm) in 2:2 row ratio recorded significantly higher pigeonpea-equivalent yield, LER, water-use efficiency, production efficiency and net return than their intercropping with pigeonpea in normal planting pattern (60 cm) in 1:1 row ratio and sole pigeonpea. However, only pigeonpea + urdbean and pigeonpea + sesame in paired row planting recorded significantly higher B:C ratio than sole pigeonpea. Pigeonpea + urdbean in paired row planting recorded significantly higher pigeonpea equivalent yield (3.57 t/ha), LER (1.81), water-use efficiency (4.96 kg ha/mm), production efficiency (12.01 kg/ha/day), NPK-uptake by pigeonpea, net return (148.63 $\times$ 10^3 `/ha) and B:C ratio (4.84) than their intercropping in normal planting pattern, pigeonpea + sesame and pigeonpea + sorghum in both planting pattern. Pigeonpea + urdbean and pigeonpea + sesame in paired row recorded significantly higher number and dry weight of nodules/plant than sole pigeonpea. Pigeonpea equivalent yield in pigeonpea + urdbean intercropping system did not increased significantly with increasing levels of fertilizer. However, it increased significantly upto RDF and 125% RDF of sesame and sorghum in pigeonpea + sesame and pigeonpea + sorghum intercropping systems respectively in both the planting pattern. Pigeonpea + urdbean in both the planting pattern reduced bulk density of the soil and increased organic carbon, available N, P, K content of the soil than other intercropping systems and initial soil value but magnitude of improvement in physico-chemical properties of soil was higher in paired row planting.

Key words: Fruiting efficiency, NPK uptake, Paired row planting, Pigeonpea equivalent yield, Production efficiency, Water-use efficiency.

INTRODUCTION

In India, pigeonpea is grown in an area of about 4.24 mha and produce 3.68 mt of grain with productivity of 832 kg/ha. However, in Bihar it is grown in an area of 21.50 thousand hectare and produce 32.90 thousand tonnes of grain with productivity of 1532 kg/ha (Anonymous, 2019). Long duration pigeonpea is widely cultivated in Bihar mostly on marginal and sub-marginal land without any fertilizer under rainfed condition. Yield of the crop is unstable and at times uneconomical due to vagaries of monsoon under rainfed condition. Pigeonpea grown as sole crop is not economically viable because of its slow initial growth rate, low productivity and longer duration. Because of slow growth the crop face a lot of competition with weeds and the inter-row space was not utilized properly (Barod *et al*. 2017). The initial slow growth rate, widely spaced, deep root system and longer duration of pigeonpea offers a good scope for intercropping with fast growing and early maturing compatible crops to harness the potential of land, increase the productivity and

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net profit per unit area/unit time through crop intensification. Agronomic practice like plant geometry is known to affect crop environment, which influence the yield and yield components. Proper row arrangement of main as well as intercrops in appropriate proportion is the promising way to exploit the natural resources such as space, nutrient, sunlight, soil moisture to greater extent and boost up the system productivity (Kasbe *et al*. 2010). 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 when both crop have different growth habit and nutrient requirement (Ansari *et al*., 2011). The duration of component crop, their growth rate, planting density, the differences in the depth of rooting, lateral root movement and root densities are some of the factors that affect competition between component crops in intercropping system for nutrient, moisture and space and hence input-use efficiency. The magnitude of competition varies with the types of planting pattern and nature of intercrops grown with pigeonpea due to their differential growth habit and nutrient absorption behavior. Hence, it is necessary to maintain soil fertility among intercropped stand through judicious use of nutrients. In order to generate location specific nutrient management in appropriate planting pattern of pigeonpea based intercropping system, the present study was carried out to find out production potential and economic feasibility of planting pattern and nutrient management in 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 an altitude of 51.3 m above mean sea-level) of the Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar during the *Kharif* season for four consecutive years 2013-14 to 2016-17. The soil of the experimental plot was sandy loam in texture, low in organic carbon (0.33%), low in available nitrogen (163.8 kg/ha), low in available phosphorus (12.2 kg/ha) and medium in available potassium (152.8 kg/ha) with pH 8.1. The treatment comprised 3 intercropping systems with two method of planting *viz*, pigeonpea (60 cm)+ urdbean (1:1), pigeonpea (60 cm) + sesame (1:1), pigeonpea (60 cm) + sorghum (1:1), pigeonpea paired (45 cm) + urdbean (2:2), pigeonpea paired (45 cm) + sesame (2:2), pigeonpea paired (45 cm) + sorghum (2:2) and 3 fertilizer levels of intercrop *viz*, 75% recommended dose of fertilizer (RDF), 100% RDF and 125% RDF along with sole crop of pigeonpea, urdbean, sesame and sorghum. The experiment was laid out in randomized block design (Factorial) and replicated thrice. Pigeonpea variety, 'Bahar', urdbean 'PantU-31', sesame 'Pragati' and sorghum 'Swarna' were sown in last week of July. Pigeonpea was harvested in third week of April, sorghum in last week of November, urdbean and sesame in second week of October in all the experimental years. Sole crop of pigeonpea and sorghum were sown in row 60 cm apart and urdbean, sesame 30 cm apart. The plant-to-plant distance of 20 and 15 cm was maintained in pigeonpea and sorghum respectively and 10 cm in urdbean and sesame in sole as well as in intercropping. The recommended dose of fertilizer *i.e.,* pigeonpea (20:40:20:20 kg N:P:K:S/ha), sorghum (100:50:25 kg N:P:K/ha), urdbean (15:40:20 kg N:P:K/ha) and sesame (40:20:20 kg N:P:K/ha) were given to sole crop. In intercropping systems, fertilizers of intercrops were applied as per treatment along with RDF of pigeonpea. Full dose of nitrogen, phosphorus, potassium and sulphure were applied at the time of sowing in pigeonpea, urdbean and sesame. However, in sorghum half dose of nitrogen, full dose of phosphorus and potassium were applied at the time of sowing and remaining nitrogen was top-dressed 45 days after sowing in sole as well as intercropping systems. One hand-weeding was uniformly done in all the sole and intercropping system at 30 days after sowing. The crop received 582.6, 792.6, 676.0 and 440.4 mm rainfall during the crop growth period in first, second, third and fourth year of experimentation respectively. The initial and final (after harvesting of last year crop), pH, organic carbon, N, P and K content of soil were analyzed by glass electrode *pH* meter, walkley and Black, alkaline per magnate, Olsen's and flam photometric method respectively. For comparison between the treatments, the yields of crops were converted in to pigeonpea-equivalent yield on prevailing market price. Nodule study was done at 75 days after sowing, 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 hrs and dry to constant weight then average was taken. Fruiting efficiency was worked out by dividing the flower-bearing pods by total number of flowers multiplied by 100.

Net return was calculated by subtracting cost of cultivation from gross return. Benefit:cost ratio was calculated by dividing the net returns by cost of cultivation. Production efficiency in term of kg/ha/day was obtained by pigeonpea-equivalent yield of the treatments divided by the total duration of the crop in that treatment. Data pertaining to each character were analyzed statistically by applying the standard procedure of randomized block design (Cochran and Cox, 1977).

RESULTS AND DISCUSSION

Growth and yield attributes of pigeonpea

Plant height of pigeonpea was significantly higher in pigeonpea + urdbean and pigeonpea + sesame in both paired and normal planting than sole pigeonpea (Table 1).

Table 1: Effect of planting pattern and nutrient management on plant height, yield indices, number and dry weight of nodule and pigeonpea equivalent yield of pigeonpea based intercropping system (Pooled mean of 4 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)	Grain yield (t/ha)				Pigeonpea-equivalent yield (t/ha)
										Pigeon pea	urd bean	Sesame	Sorghum	
Intercropping														
Sole crop	221.6	17.6	4.7	222.8	4.2	10.9	12.8	15.3	28.3	2.01	0.87	0.65	2.10	2.37
Pigeonpea (60 cm) + urdbean (1:1)	230.3	19.9	5.3	233.4	4.5	11.2	16.0	16.9	31.4	2.12	0.34	-	-	3.01
Pigeonpea (60 cm) + sesame (1:1)	227.8	19.0	5.0	228.5	4.4	11.0	15.6	16.4	30.7	2.00	-	0.27	-	2.78
Pigeonpea (60 cm) + sorghum (1:1)	224.7	14.2	4.4	213.7	4.0	10.8	11.6	15.0	26.6	1.85	-	-	0.95	2.59
Pigeonpea paired (45 cm) + urdbean (2:2)	231.9	21.3	5.4	241.4	4.6	11.3	18.6	17.3	34.1	2.30	0.58	-	-	3.59
Pigeonpea paired (45 cm) + sesame (2:2)	228.4	20.2	5.2	237.6	4.4	11.2	16.4	16.6	32.3	2.18	-	0.37	-	3.17
Pigeonpea paired (45 cm) + sorghum (2:2)	225.8	15.4	4.6	220.1	4.1	10.9	13.1	15.5	27.4	1.97	-	-	1.27	2.88
SEm±	2.3	0.8	0.6	3.5	0.4	0.5	1.2	0.5	1.0	0.04	-	-	-	0.07
CD (P=0.05)	4.7	1.6	NS	7.1	NS	NS	2.4	1.0	2.0	0.09	-	-	-	0.13
(Sole Vs Rest) SEm±	3.0	1.0	0.7	4.4	0.6	0.6	1.5	0.7	1.3	0.05	-	-	-	0.08
CD (P=0.05)	6.1	2.0	NS	9.0	NS	NS	3.0	1.4	2.6	0.10	-	-	-	0.17
Fertilizer levels														
75% RDF	224.4	16.5	4.7	222.2	4.1	10.9	14.0	16.7	32.3	1.96	0.37	0.26	0.94	2.78
RDF	228.5	18.6	5.1	231.1	4.4	11.1	15.5	16.2	31.2	2.08	0.46	0.32	1.14	3.02
125% RDF	231.4	19.8	5.3	237.0	4.5	11.2	16.2	15.9	30.8	2.16	0.54	0.37	1.27	3.21
SEm±	1.8	0.6	0.4	2.4	0.3	0.4	0.8	0.4	0.8	0.03	-	-	-	0.05
CD (P=0.05)	3.7	1.1	NS	4.9	NS	NS	1.6	NS	NS	0.06	-	-	-	0.09

RDF: Recommended dose of fertilizer.

Among the intercropping systems, pigeonpea + urdbean in both planting pattern recorded significantly higher plant height than pigeonpea + sorghum. Application of 75 % RDF recorded significantly lower plant height than 100% and 125% RDF. Yield indices such as number of branches/ plant and pods/plant were significantly higher in pigeonpea + urdbean in both planting pattern and pigeonpea + sesame in paired row planting than sole pigeonpea (Table 1). Significant reduction in these yield indices were recorded in pigeonpea + sorghum in both planting pattern than sole pigeonpea. Among the planting pattern, paired row planting of pigeonpea + urdbean (2:2) row ratio recorded significantly higher value of these yield indices which was at par with pigeonpea + sesame in same planting patten and significantly higher over intercropping system in normal planting pattern (1:1) row ratio. However, pod length, grains/pod and 100-seed weight did not varied significantly among the row ratios of intercropping systems and sole pigeonpea.

The higher value of yield indices and plant height in paired row planting of pigeonpea + urdbean and pigeonpea + sesame might be owing to absence of competition between main and intercrops for growth resources such as nutrient and solar radiation, besides wider spacing between two paired row provides congenial environment for better 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 + black gram did not affect the growth and yield attributes 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 due to addition of additional quantities of nutrient 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 plant resulting in favorable increase in plant height and yield indices. Pandey *et al*. (2015) also obtained higher plant height and yield attributes of pigeonpea at RDF over 50% RDF.

Fruiting efficiency of pigeonpea enhanced significantly under both planting pattern of pigeonpea + urdbean and paired row planting of pigeonpea + sesame than pigeonpea + sorghum in both planting pattern and sole pigeonpea (Table 1). Among the planting pattern, paired row planting of pigeonpea + urdbean in 2:2 row ratio recorded significantly higher fruiting efficiency (18.6%) than their intercropping in normal planting pattern (16.0%) and pigeonpea + sorghum in both the planting pattern. Fruiting efficiency increased significantly only upto 100% RDF (15.5%), further increase in fertilizer level fail to produce significant effect on fruiting efficiency. Higher fruiting efficiency in these treatments might be owing to compatible nature of component crops initially more thoroughly cover the soil surface, suppressed weed, conserve soil moisture and facilitating the uptake of adequate quantity of nutrients to the main crop plant resulting in reduced rate of flower dropping and enhanced pod-bearing capacity of the plant.

Nodulation

Number and dry weight of nodules were significantly higher in pigeonpea + urdbean intercropping system in both planting pattern than sole pigeonpea (Table 1). Among the intercropping systems, number and dry weight of nodules reduced significantly in pigeonpea + sorghum intercropping system than pigeonpea + urdbean and pigeonpea + sesame in both planting pattern. Higher number and dry weight of nodules in pigeonpea + urdbean might be due to contribution of legumes towards an increase in plant nutrition. Fertilizer levels had 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 in both the planting pattern than sole pigeonpea (Table 2). Paired row planting recorded significantly higher values of these indices in all intercropping systems than normal planting pattern. Among the intercropping systems, significantly higher production (12.04 kg/ha/day) and water-use efficiency (4.96 kg/ha/mm) were registered in paired row planting of pigeonpea + urdbean than pigeonpea + sesame and pigeonpea + sorghum. Application of 125% RDF recorded significantly higher production (10.76 kg/ha/day) and water-use efficiency (4.43 kg/ha/mm) than RDF and 75% RDF. The increase in water-use efficiency under these treatment was achieved owing to increase in grain yield per unit of water used.

Grain yield

Intercropping of pigeonpea + urdbean in both planting pattern and pigeonpea + sesame in paired row planting significantly enhanced grain yield of pigeonpea than pigeonpea + sorghum and sole pigeonpea (2.01 t/ha) (Table 1). Pigeonpea yield was significantly higher in all the intercroppings under paired row planting in 2:2 row ratio than their intercropping in normal planting pattern in 1:1 row ratio. Among the intercropping systems, pigeonpea + urdbean in paired row planting recorded significantly higher pigeonpea yield (2.30 t/ha.) than pigeonpea + sesame and pigeonpea + sorghum in both the planting pattern and pigeonpea + urdbean in normal planting pattern. Kumar *et al*. (2005) also reported that inclusion of two rows of green gram proved superior as compared to single row of green gram irrespective to row ratio in pigeonpea. Kumar and Kushwaha (2018) also reported higher grain yield of pigeonpea and economic returns under pigeonpea + sesame (2:2) row ratio. Inclusion of urdbean with pigeonpea attributed to less exhaustion of soil fertility, reduced early stage of crop-weed competition due to their smothering effects on weed and also improved physical properties of the soil to some extent as compared to sole pigeonpea and other intercroppings, thereby increase the yield indices and finally the grain yield of pigeonpea.

Table 2: Effect of planting pattern and nutrient management on water-use efficiency, production efficiency, economics and NPK uptake by pigeonpea of pigeonpea based intercropping system (Pooled mean of 4 years).

Treatment	LER	Harvest index (%)	WUE (kg grain/ ha/mm)	Production efficiency (kg/ha/day)	Net return ($\times 10^3$ \`/ha)	Benefit: cost ratio	N uptake by pigeon pea (kg/ha)	P uptake by pigeon pea (kg/ha)	K uptake by pigeon pea (kg/ha)
Intercropping									
Sole crop	1.00	18.2	3.27	7.95	92.74	3.60	158.4	43.6	109.6
Pigeonpea (60 cm) + urdbean (1:1)	1.44	18.5	4.17	10.12	120.04	3.91	166.5	45.1	115.3
Pigeonpea (60 cm) + sesame (1:1)	1.40	18.5	3.82	9.34	109.34	3.66	154.9	42.1	106.6
Pigeonpea (60 cm) + sorghum (1:1)	1.38	18.1	3.58	8.69	95.25	2.33	143.2	39.7	98.4
Pigeonpea paired (45 cm) + urdbean (2:2)	1.81	18.6	4.96	12.04	148.63	4.84	176.8	48.3	121.6
Pigeonpeapaired (45 cm) + sesame (2:2)	1.65	18.5	4.38	10.63	128.45	4.30	166.8	45.8	114.3
Pigeonpeapaired (45 cm) + sorghum (2:2)	1.59	18.2	3.98	9.66	109.66	3.20	150.1	41.9	102.1
SEm±	0.03	0.1	0.09	0.22	3.23	0.22	3.2	1.1	2.1
CD (P=0.05)	0.07	0.2	0.19	0.44	6.56	0.45	6.6	2.1	4.3
(Sole Vs Rest) SEm±	0.04	0.2	0.12	0.27	4.07	0.31	4.0	1.4	2.7
CD (P=0.05)	0.09	0.4	0.24	0.55	8.26	0.63	8.2	2.9	5.4
Fertilizer levels									
75% RDF	1.40	18.3	3.83	9.34	107.89	3.48	149.6	41.3	102.0
RDF	1.55	18.4	4.18	10.15	119.60	3.82	155.6	44.1	110.8
125% RDF	1.68	18.5	4.43	10.76	128.21	4.04	168.4	45.9	116.3
SEm±	0.02	0.1	0.07	0.15	2.29	0.16	2.2	0.17	1.5
CD (P=0.05)	0.05	NS	0.14	0.31	4.65	0.33	4.6	1.6	3.1

WUE: Water-use efficiency; LER: Land equivalent ratio.

However, in case of pigeonpea + sorghum, sorghum being a heavy feeder competes with pigeonpea for nutrients, moisture, space and also approaches above the height of pigeonpea, thus produces shading effect on pigeonpea and reduced 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 provide a reason for reduction in pigeonpea yield. Pandey and Tiwari (2017) also recorded significantly lower pigeonpea yield in pigeonpea + maize intercropping system than pigeonpea + urdbean/mungbean and sole pigeonpea. Grain yield of pigeonpea increased significantly with increasing levels of fertilizer and recorded higher grain yield at 125% RDF (2.16 t/ha). The increase in grain yield might be owing to adequate quantities of plant nutrients supplied to the intercrops reduced the state of competition for nutrients among main and intercrops, resulting in favorable increase in yield attributes which led towards an increase in grain yield. Pandey *at al.* (2015) also recorded higher pigeonpea yield at recommended dose of fertilizer over 50% RDF. Paired row planting of pigeonpea + urdbean recorded significantly higher harvest index (18.6%) than sole pigeonpea (18.2%) and pigeonpea + sorghum in both planting pattern. Harvest index did not varied significantly among the fertilizer levels.

Pigeonpea-equivalent yield

All the intercropping systems in both planting pattern recorded significantly higher pigeonpea-equivalent yield than sole pieonpea (2.37 t/ha) (Table 1). Among the planting pattern, all the intercroppings in paired row planting recorded significantly higher pigeonpea equivalent yield than their intercropping innormal planting pattern. Among the intercropping systems, pigeonpea + urdbean in paired row planting recorded significantly higher pigeonpeaequivalent yield (3.59 t/ha) than pigeonpea + urdbean in normal planting pattern (3.01 t/ha) as well as pigeonpea + sesame and pigeonpea + sorghum in both planting pattern. Significantly lower pigeonpea-equivalent yield was registered in pigeonpea + sorghum in both planting pattern. The higher pigeonpea-equivalent yield in paired row planting of pigeonpea + urdbean was owing to better production of main as well as component crop. Kumar *et al.* (2012) reported that intercropping in paired row planting of pigeonpea enhanced the pigeonpea equivalent yield by 11.1% over flat row planting. Kumar *et al*. (2018) also obtained significantly higher biological seed yield in paired sowing of pigeonpea + urdbean than other intercropping systems. Similarly, pigeonpea-equivalent yield also increased significantly with increasing levels of fertilizer and recorded maximum pigeonpea-equivalent yield at 125% RDF (3.21 t/ha). The higher pigeonpea-equivalent yield at higher levels of fertilizer might be owing to adequate quantity of plant nutrients supplied to the crops resulting in favorable increase in yield of 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. Sekhon (2018) too reported higher pigeonpea equivalent yield at 100% RDF to intercrops.

Interaction between intercropping systems and fertilizer levels with respect to pigeonpea-equivalent yield was found to be significant (Table 3). In pigeonpea + urdbean intercropping system, pigeonpea-equivalent yield did not increased significantly with increasing levels of fertilizer in both planting pattern. However, in pigeopea + sesame significant increase in pigeopea-equivalent yield was recorded upto 100% RDF, further increase in fertilizer level fail to produce significant effect on pigeonpea-equivalent yield, while, in pigeonpea + sorghum, it increased significantly with increasing levels of fertilizer and recorded significantly higher value at 125% RDF in both planting pattern. Urdbean, being legume crop, is likely to make liberal use of atmospheric nitrogen through 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, sorghum make use of high quantity of nutrients thus respond to higher dose of fertilizer.

Land-equivalent ratio

In intercropping systems, land-equivalent ratio (LER) was greater than 1 in both planting pattern, indicating more biological efficiency in intercropping systems (Table 2). LER was significantly higher in paired row intercropping systems than their normal planting pattern. Among the intercropping

Table 3: Interaction effect of planting pattern and fertilizer levels on pigeonpea-equivalent yield (t/ha) in pigeonpea based intercropping system (Pooled mean of 4 years).

Fertilizer level	Intercropping system					
	Pigeonpea (60 cm) + urdbean (1:1)	Pigeonpea (60 cm) + sesame (1:1)	Pigeonpea (60 cm) + sorghum (1:1)	Pigeonpea paired (45 cm) + urdbean (2:2)	Pigeonpea paired (45 cm) + sesame (2:2)	Pigeonpea paired (45 cm) + sorghum (2:2)
75% RDF	2.90	2.51	2.31	3.44	2.92	2.60
RDF	3.03	2.81	2.60	3.62	3.19	2.89
125% RDF	3.11	3.01	2.86	3.70	3.40	3.15
SEm±	0.11	-	-	-	-	-
CD (P=0.05)	0.23	-	-	-	-	-

systems, significantly higher LER 1.81 was recorded in pigeonpea + urdbean in paired row planting, being significantly higher than pigeonpea + sesame and pigeonpea + sorghum in both planting pattern and pigeonpea + urdbean in normal planting. The LER values of 1.81 in pigeonpea + urdbean in paired row planting system meaning 0.81% more land would be required as sole pigeonpea to give same yield as obtained in intercropping system under paired row planting. The LER value also increased significantly with increasing levels of fertilizer and recorded the maximum value at 125% RDF (1.68), indicating yield advantage over 100 and 75% RDF.

NPK uptake

Uptake of NPK by pigeonpea significantly reduced in pigeonpea + sorghum in both planting pattern as compared to sole pigeonpea and other intercropping systems (Table 2). Paired row intercropping recorded significantly higher NPK uptake by pigeonpea than their normal row planting. Among the intercropping systems, pigeonpea + urdbean registered significantly higher NPK uptake than pigeonpea + sesame and pigeonpea + sorghum in both planting pattern. The higher NPK uptake in 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 significantly enhanced NPK uptake by pigeonpea which decreased significantly with decreasing levels of fertilizer. This could be attributed to fact that added fertilizers enhanced the availability of these nutrients to the 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

Intercroppings in both the planting pattern except pigeonpea + sorghum in normal planting pattern recorded significantly higher net return than sole pigeonpea (Table 2). However, pigeonpea + urdbean and pigeonpea + sesame in paired row planting fetched significantly higher B:C ratio than sole pigeonpea. Intercropping of urdbean, sesame and sorghum in paired row planting recorded significantly higher net return and B:C ratio than their intercropping in normal planting pattern. Among the intercropping systems, pigeonpea + urdbean in paired row planting recorded significantly higher net return (148.63×10^3 `/ha)and B:C ratio (4.84) than pigeonpea + sesame and pigeonpea + sorghum in both planting pattern and pigeonpea + urdbean in normal planting pattern.

The higher net return and B:C ratio in paired row planting of pigeonpea + urdbean was obviously due to better yield of main as well as component crops. Kumar *et al.* (2012) also recorded 13.8% higher net return in paired row intercropping of pigeonpea over flat row planting. Singh *et al.* (2013) recorded higher net return and B:C ratio in pigeonpea + mungbean intercropping system than sole pigeonpea. Application of 125% RDF significantly enhanced net return (128.21×10^3 `/ha) than 100% ($119.60 \times 10^3$ `/ha) and 75% RDF (107.89×10^3 `/ha). However, B:C ratio increased significantly onlyupto 100% RDF (3.82). Higher biological yield of main and component crop at higher fertilizer level was in fact the reasons for higher net return and B:C ratio in this treatment. Pandey and Tiwari (2017) also recorded higher monetary returns at 125% RDF in pigeonpea based intercropping system.

Soil physico-chemical properties

Bulk density, organic carbon, available nitrogen, phosphorus and potassium content of soil after harvest of pigeonpea were affected by intercropping in planting pattern and fertilizer levels (Table 4). Bulk density decreased in intercropping system in both planting pattern and fertilizer levels over initial soil value (1.36 g/cc). The lower bulk density was recorded in pigeonpea + urdbean (1.32 and 1.31 g/cc in paired and normal planting pattern respectively) in both planting pattern over other intercropping systems and sole

Table 4: Effect of planting pattern in pigeonpea based intercropping system and fertilizer levels on physico-chemical properties of soil.

Treatment	pH	Bulk density (g/cc)	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)
Initial	8.1	1.36	0.33	163.8	12.2	152.8
Pigeonpea sole	8.1	1.34	0.36	172.6	14.6	156.3
Pigeonpea (60 cm) + urdbean (1:1)	8.1	1.32	0.38	174.2	16.3	158.4
Pigeonpea (60 cm) + sesame (1:1)	8.1	1.33	0.37	173.4	15.8	157.6
Pigeonpea (60 cm) + sorghum (1:1)	8.1	1.34	0.35	166.7	13.9	154.3
Pigeonpea paired (45 cm) + urdbean (2:2)	8.1	1.31	0.39	176.1	17.1	159.6
Pigeonpea paired (45 cm) + sesame (2:2)	8.1	1.32	0.38	174.6	16.7	158.7
Pigeonpea paired (45 cm) + sorghum (2:2)	8.1	1.33	0.35	167.3	14.6	155.1
75% RDF	8.1	1.34	0.36	167.3	14.2	154.8
100% RDF	8.1	1.33	0.37	173.1	15.7	157.5
125% RDF	8.1	1.32	0.38	176.0	16.8	159.1

pigeonpea. However, organic carbon, available N, P and K content of soil substantially increase in intercropping systems in both planting pattern and sole pigeonpea than initial soil value. Maximum increase in organic carbon (0.39%), available N (176.1 kg/ha), P (17.1 kg/ha) and K (159.6 kg/ha) contents of soil were recorded in pigeonpea + urdbeanin paired row planting. However, minimum increase in organic carbon (0.35%), available N (166.7 kg/ha), P (13.9 kg/ha) and K (154.3 kg/ha) contents over initial soil value were recorded in pigeonpea + sorghum in normal planting pattern. Intercroppings in paired row planting registered higher content of organic carbon, available nitrogen, phosphorus and potassium in soil than their intercropping in normal planting pattern. The lower bulk density and higher nutrient content under paired row planting and pigeonpea + urdbean intercropping 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 and Tiwari (2017) also recorded lower bulk density and higher content of organic carbon, available N, P and K in pigeonpea + mungbean intercropping system compared to pigeonpea + maize and initial soil value. Application of 125% RDF reduced the bulk density (1.32 g/cc) and enhanced organic carbon (0.38%) available N (176.0 kg/ha), P (16.8 kg/ha) and K (159.1 kg/ha) content of soil than lower levels of fertilizer and initial soil value. The reduction in bulk density and improvement in nutrient status of the soil at higher fertilizer level may be ascribed to more biomass (leaves, roots *etc*.) by the crops. Gound *et al.* (2012) also recorded similar result. Soil pH was unaffected by intercropping system in both planting pattern and fertilizer levels. It can be concluded that intercropping of urdbean, sesame and sorghum in paired row planting of pigeonpea was found more productive and remunerative than their intercropping in normal planting pattern. Pigeonpea + urdbean in paired row planting in 2:2 row ratio proved most productive and economical as it recorded highest pigeonpea equivalent yield, net return and B:C ratio than intercropping of sesame and sorghum in paired and normal planting pattern and sole pigeonpea. For obtaining better yield from pigeonpea + urdbean, 75% recommended dose of fertilizer (RDF) of urdbean should be applied along with RDF of pigeonpea. However, in pigeonpea + sesame and pigeonpea + sorghum, 100 and 125% RDF of sesame and sorghum respectively should be applied together with RDF of pigeonpea.

CONCLUSION

Paired row planting of pigeonpea +urdbean (45 cm) in 2:2 row ratio recorded higher pigeonpea-equivalent yield, net return and B:C ratio than their normal planting pattern and sole pigeonpea. It also reduced bulk density of the soil and enhanced available N, P, K content of soil than initial soil value. In pigeonpea +urdbean intercropping only 75% RDF of urdbean to be applied with RDF of pigeonpea. However, in pigeonpea + sesame, 100% RDF of sesame and pigeonpea + sorghum, 125% RDF of sorghum to be applied with RDF of pigeonpea.

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