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Effect of integrated nutrient management on productivity, nutrient uptake and economics of rainfed pigeonpea (*Cajanus cajan*) and blackgram (*Vigna mungo*) intercropping system

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ABSTRACT

Field experiments were carried out during *kharif* season of 2008-09 and 2009-10 to study the effect of integrated nutrition on productivity, nutrient uptake and economics of rainfed pigeonpea [*Cajanus cajan* (L.) Millsp.] and blackgram [*Vigna mungo* (L.) Hepper] intercropping system. Pooled data shows that intercropping systems did not influence significantly on the grain, stover, biological yield and harvest index of pigeonpea and blackgram. Total uptake of N, P, K, S and Zn by pigeonpea were highest recorded with the sole pigeonpea (S_1) which was comparable to normal intercropping system (S_2) and significantly superior over paired intercropping system (S_3). Further, pooled data revealed that normal intercropping system (S_2) gave maximum values of gross return (₹ 120 050), net return (₹ 99 396), B:C ratio (4.8), pigeonpea equivalent yield (21.75 q/ha), land equivalent ratio (1.70), production efficiency (7.98 kg/ha/day) and economic efficiency (364.83 ₹/ha/day) which was at par with paired intercropping system (S_3) and significantly superior to sole planting of pigeonpea (S_1). Application of 100% recommended dose of fertilizers + 50% recommended dose of nitrogen (through vermicompost) + 5 kg Zn/ha gave significantly higher grain yield (21.05 and 5.23 q/ha), stover yield (82.19 and 14.47 q/ha), biological yield (103.24 and 18.85 q/ha) and harvest index (20.23 and 26.40%) of pigeonpea and blackgram, respectively. This treatment (F_7) also gave the higher total uptake of N, P, K, S and Zn by pigeonpea and blackgram. Similarly, application of 100% RDF + 50% RDN + 5 kg Zn/ha (F_7) recorded highest gross return (₹ 130 735), net return (₹ 109 277), B:C ratio (5.11), PEY (24.24 q/ha), LER (1.57), production efficiency (8.9 kg/ha/day) and economic efficiency (401.07 ₹/ha/day) which was at par with 50% RDF + 100% RDN + 5 kg Zn/ha (F_8) and significantly superior to rest of the treatments.

Key words: Economics, Intercropping system, Integrated nutrition, Nutrient uptake, PEY, Yields

Pigeonpea [*Cajanus cajan* (L.) Millsp] is a multipurpose leguminous crop that can provide food, fuel, wood and fodder for the small-scale farmer in subsistence agriculture (Egbe and Kalu 2009). India accounts for 90% of world's pigeonpea growing area and 85 % of world's production of pigeonpea. In India, it is grown in an area of 3.47 mha with a production of 2.26 mt and productivity of 711 kg/ha (Anonymous 2009). The low productivity of pigeonpea has been attributed to the fact that large area is under rainfed situation grown in wider spacing. It is generally intercropped with sorghum, cotton and pulses. Under such situation, short duration pulse crop such as blackgram/greengram can be grown as an intercrop to increase the productivity of the system. When pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index; therefore, it is grown as intercrop, which helps in efficient utilization of available resources for enhancing the productivity and profit (Willey 1979). To raise production on a sustainable basis, increased use of organic manures, biofertilizers, vermicompost, management of nutrients through inter/mixed cropping is must both in rainfed and irrigated farming systems. Presently, organic sources of nutrients are preferred to synthetic chemicals but there is apprehension that the adequate quantity of organic material for the purpose may not be available. Therefore, there is a need for standardizing the mixed use of organic and inorganic sources of nutrition in order to increase the productivity and improving the soil health (Sharma and Chauhan 2011). The lack of information on these aspects under rainfed conditions made as impetus to undertake the present study.

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MATERIALS AND METHODS

A field experiment was conducted during rainy seasons of 2008-09 and 2009-10 at Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi in sandy clay loam soil. The experimental soil was poor in organic carbon (0.35%), available nitrogen (190.5 kg/ha) and sulphur (18.6 kg/ha) and medium in available phosphorus (19.3 kg/ha) and available potassium (210.15 kg/ha). The zinc was below the critical limit (0.51 ppm). The rainfall received during the growing period of crop was 528.6 mm in 2008-09 and 420.11 mm in 2009-10. The experiment was laid-out in split plot design with three replications. The treatment combinations comprised three cropping systems [sole pigeonpea (60 cm) (S_1), normal intercropping (60 × 20 cm) + blackgram [*Vigna mungo* (L.) Hepper] (1 row) (S_2) and paired intercropping (80+40 cm × 20 cm) + blackgram (2 row) (S_3) in main plots; and nine integrated nutrition combinations, i.e. control (F_0), 100% RDF (F_1), 50% RDF + 50% RDN (F_2), 100% RDF + 50% RDN (F_3), 50% RDF + 100% RDN (F_4), 100% RDF + 5 kg Zn/ha (F_5), 50% RDF + 50% RDN + 5 kg Zn/ha (F_6), 100% RDF + 50% RDN +5 kg Zn/ha (F_7), 50% RDF + 100% RDN + 5 kg Zn/ha (F_8) in sub plots. Where, RDF represents recommended dose of N, P, K, and S (20-40-20-20 kg/ha) through inorganic fertilizers and RDN represents recommended dose of N (20 kg/ha) through vermicompost. The gross and net plot size were 30 m^2 (6.0 × 5.0 m^2) and 14.4 m^2 (3.6 × 4.0 m^2), respectively. N, P, K, S and Zn fertilizers were applied just before sowing according to the treatment using urea, DAP, MOP, elemental sulphur and zinc oxide. Fertilizers were drilled in band 5-7 cm below the surface. The required amount of RDN (vermicompost) containing N (1.5%), P (0.90%), K (1.12%), S (0.56) and Zn (58 ppm) as per the treatment were incorporated in plots after preparing layout as per treatment into the soil. Bahar and T 9 varieties of pigeonpea and blackgram respectively were used for experimental purpose. The crops were sown on 18 July 2008 and 10 July 2009. The pigeonpea and blackgram seeds were sown @ 15 kg/ha and 12 kg/ha, respectively with the help of spade. The other cultural operations were done as per recommendation and crop requirement. Seed yield was computed by threshing pods from net plot, cleaned and the seeds weight was recorded. From this seed yield per hectare was computed. Net returns (₹/ha) was calculated by deducting cost of cultivation (₹/ha) from gross returns, while B: C ratio were worked out as ratio of gross returns (₹/ha) to cost of cultivation (₹/ha). The data for two seasons was pooled for final statistical analysis as per the method suggested by (Gomez and Gomez 1984). Nutrient uptake in grain and stover of pigeonpea/blackgram crop were calculated in kg/ha in relation to dry matter production/ha by using the formula.

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%)} \times \text{yield (grain/stover in kg/ha)}}{100}$$

Pigeonpea equivalent yield (kg/ha): Pigeonpea equivalent yield (PEY) was calculated as follows:

$$\text{PEY (kg/ha)} = \frac{\text{Economic yield of a crop} \times \text{per kg price of respective crop}}{\text{Price per kg of pigeonpea}}$$

Land equivalent ratio (LER): It is the relative land area of pure crops required to produce the yield obtained from intercropping system. It can be calculated by the formula suggested by Mead and Willey (1980).

$$\text{LER} = \text{LA} + L_B = \left[\frac{Y_a}{S_a} + \frac{Y_b}{S_b} \right]$$

Where L_A and L_B are partial LER to individual crops, Y_a and Y_b are the individual crop yields in intercropping and S_a and S_b are their yields as sole crops.

Production efficiency and economic efficiency was calculated as following formula suggested by Goud and Kale (2010).

$$\text{Production efficiency (kg/ha/day)} = \frac{\text{Grain yield (kg/ha)}}{\text{Total duration taken crop (days)}}$$

$$\text{Economic efficiency (₹/ha/day)} = \frac{\text{Net return (₹/ha)}}{\text{Total duration taken crop (days)}}$$

RESULTS AND DISCUSSION

Effect of weather

The meteorological data depicted in Fig 1 showed marked variation in weather condition during two years of experimentation. Rainfall received during 2008-09 (529 mm) was quite high as compared to 2009-10 (420 mm). Further, the temperature particularly at reproductive phases of both the crops was more conducive during second year. This resulted in slightly better performance of the crops during 2008-09 than 2009-10.

Effect of intercropping system

Yields (q/ha) and harvest index (%): Data presented in Table 1 revealed that intercropping systems did not affect the seed, stover, biological yield and harvest index of both crops, i.e. pigeonpea and blackgram (Table 1). Blackgram being a shallow rooted/fibrous root system it harvests the nutrients from upper soil. However, pigeonpea is deep rooted crop which harvest the nutrient from deeper soil. The grand growth stage of both the crops did not coincide. The results were in close conformity with the work done by Kumar *et al*. (2012) and Singh *et al*. (2013).

Total nutrient uptake (kg/ha): Total uptake of N, P, K, S and Zn by pigeonpea was significantly influenced by different intercropping systems (Table 2). Sole planting of pigeonpea (S_1) was recorded significantly higher uptake of N (119.92 kg/ha), P (17.33 kg/ha), K (83.62 kg/ha), S (14.21 kg/ha) and Zn (0.151 kg/ha) which was comparable to normal intercropping system (S_2) and significantly superior to paired intercropping system (S_3). However, total

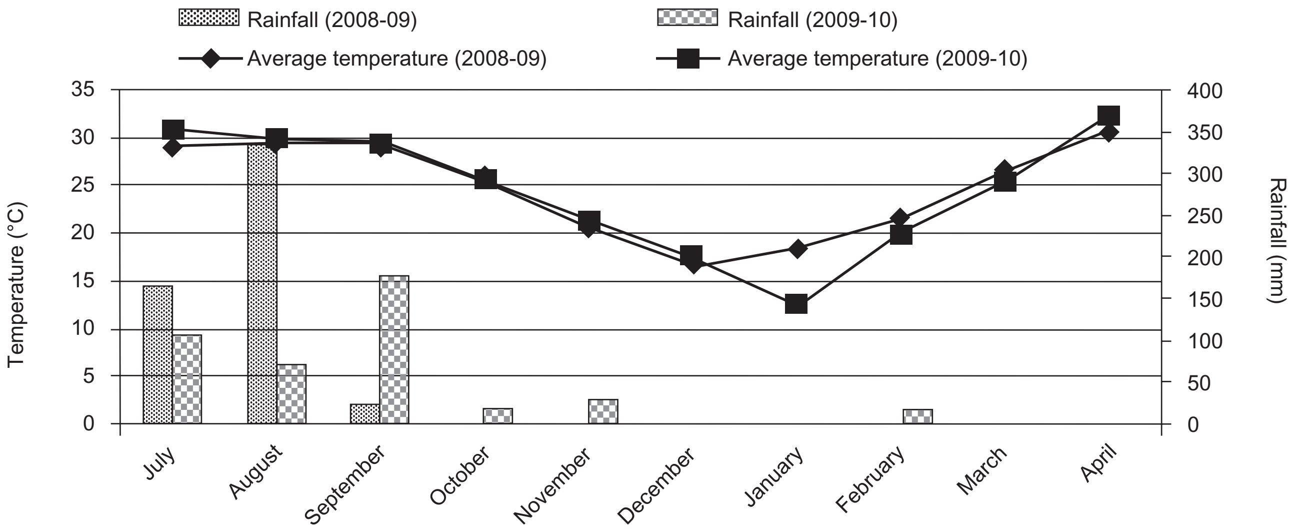

Fig. 1 Monthly rainfall and mean temperature during the two growing seasons of the experimentation

Table 1　Yields and harvest index of pigeonpea and blackgram as influenced by integrated nutrition and intercropping systems (Pooled data of 2 years)

Treatment	Pigeonpea (q/ha)			Harvest index (%)	Blackgram (q/ha)			Harvest index (%)
	Grain yield	Stalk yield	Biological yield		Grain yield	Stalk yield	Biological yield	
Intercropping systems								
S_1	18.49	76.48	94.97	19.22				
S_2	17.79	74.70	92.48	18.98	4.33	13.21	16.95	24.41
S_3	17.44	74.51	91.94	18.65	3.96	12.54	15.90	23.71
SEm ±	0.35	1.20	1.47	0.30	0.10	0.22	0.31	0.47
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Integrated nutrient management								
F_0	12.05	60.61	72.67	16.44	2.70	10.18	12.51	20.89
F_1	16.74	72.66	89.41	18.56	3.69	12.30	15.50	22.94
F_2	17.30	73.26	90.56	18.89	3.80	12.60	15.86	23.09
F_3	18.98	77.12	96.10	19.52	4.38	13.06	16.81	24.93
F_4	17.28	75.68	92.96	18.42	3.92	12.82	16.22	23.35
F_5	16.87	74.63	91.51	18.27	3.86	12.70	16.00	23.22
F_6	20.12	79.63	99.75	20.01	4.73	13.67	17.77	25.59
F_7	21.05	82.19	103.24	20.23	5.23	14.47	18.85	26.40
F_8	20.73	81.27	102.00	20.16	5.00	14.06	18.36	26.14
SEm ±	0.31	1.05	1.32	0.25	0.08	0.21	0.28	0.46
CD (*P*=0.05)	0.97	2.99	3.73	0.70	0.24	0.61	0.79	1.34

nutrients uptake by blackgram did not influence significantly due to both intercropping systems. This might be due to compound effect of grain and stalk yield of their content. Other possible reasons are absorption of nutrients are more in sole planting system due to better utilization of nutrient, more space and less competition for nutrient uptake than the intercropping systems. Similar results were reported in pigeonpea + greengram intercropping system by Kantwa *et al*. (2005), Kumar and Rana (2007) and Singh *et al*. (2013).

Land equivalent ratio (LER) and pigeonpea equivalent yield (PEY q/ha): Normal planting (60 cm × 20 cm) + blackgram (1 row) recorded significantly higher PEY during both the years which was at par with paired row planting (40/80 cm × 20 cm) + blackgram (2 rows). Whereas, lowest PEY and LER were noted under sole pigeonpea (Table 3). Additional grain yield of blackgram along with pigeonpea grain yield in intercropping system produced significantly higher pigeonpea equivalent yield over sole pigeonpea as well as sole blackgram. Kumar and Rana (2007) reported pigeonpea intercropped with greengram recorded significantly higher PEY and LER than sole pigeonpea. Similar findings were also reported by Singh *et al.* (2013).

Economics: Both intercropping systems were more remunerative with higher gross returns, net return, B: C ratio, production efficiency and economic efficiency as compared with sole pigeonpea (Table 3). Normal

Table 2 Total nutrient uptake of pigeonpea and blackgram as influenced by integrated nutrition and intercropping systems (Pooled data of 2 years)

Treatment	Pigeonpea (kg/ha)					Blackgram (kg/ha)				
	N uptake	P uptake	K uptake	S uptake	Zn uptake	N uptake	P uptake	K uptake	S uptake	Zn uptake
Intercropping systems										
S_1	119.72	17.33	83.62	14.21	0.151					
S_2	112.87	16.20	79.42	13.22	0.142	28.23	3.34	27.00	2.300	0.065
S_3	108.84	15.39	77.25	12.69	0.137	25.52	3.02	25.22	2.090	0.059
SEm ±	2.00	0.30	1.41	0.24	0.002	0.59	0.07	0.86	0.050	0.001
CD (*P*=0.05)	7.86	1.13	5.51	0.93	0.010	NS	NS	NS	NS	NS
Integrated nutrient management										
F_0	70.70	9.64	49.60	7.24	0.098	16.49	2.04	19.16	1.450	0.039
F_1	103.46	14.20	76.55	11.95	0.128	23.98	2.82	24.12	1.930	0.054
F_2	106.59	14.70	77.98	12.43	0.133	24.99	2.94	24.82	2.005	0.056
F_3	121.20	17.13	84.19	14.40	0.143	28.10	3.31	26.68	2.285	0.062
F_4	110.23	15.29	81.01	13.09	0.137	26.02	3.07	25.58	2.105	0.059
F_5	107.10	14.87	79.40	12.65	0.147	25.49	3.03	25.15	2.070	0.062
F_6	130.45	19.65	88.08	15.55	0.165	30.13	3.54	28.35	2.435	0.071
F_7	139.45	21.27	93.32	16.78	0.176	34.42	4.06	31.35	2.840	0.078
F_8	135.14	20.41	90.76	16.27	0.171	32.51	3.81	29.77	2.655	0.075
SEm ±	1.72	0.27	1.21	0.21	0.002	0.53	0.06	0.68	0.040	0.001
CD (*P*=0.05)	4.89	0.75	3.44	0.58	0.006	1.53	0.18	1.96	0.120	0.003

intercropping system (S_2) fetched higher gross return (₹ 120 050), net return (₹ 99 396), B:C ratio (4.8), production efficiency (7.98 kg/ha/day) and economic efficiency (364.83 ₹/ha/day) which was at par with paired intercropping system (S_3) and significantly superior to sole pigeonpea. This might be due to marginal difference in pigeonpea yield and additional yield of blackgram, which resulted in higher net returns in pigeonpea + blackgram cropping system than sole pigeonpea. Similar findings were also reported by Kumar and Rana (2007) and Singh *et al.* (2013).

Soil health: Pooled data presented in Table 4 revealed cropping system did not influence significantly on organic carbon available N, P, K, S and Zn. Whereas, maximum values were noted under sole cropping system followed by normal planted intercropping system and the lowest were under paired planting system.

Effect of integrated nutrition

Yields (q/ha) and harvest index (%): The various combinations of integrated nutrition significantly affect the seed, stover, biological yield and harvest index of pigeonpea and blackgram (Table 1). Among integrated nutrition treatments, application of 100% RDF + 50% RDN +5 kg Zn/ha (F_7) remained statistically at par with 50% RDF + 100% RDN +5 kg Zn/ha (F_8) and 50% RDF + 50% RDN +5 kg Zn/ha (F_6) significantly increased grain yield, stalk yield and biological yield of pigeonpea over control. The grain, stalk and biological yield increases in pigeonpea due to application of 100% RDF + 50% RDN +5 kg Zn/ha being 74.69, 35.60 and 42.07%, respectively compared to control. The corresponding values in blackgram were 85.18, 38.11 and 46.76 percent, respectively. Harvest index was also found to be significantly higher in 100% RDF + 50% RDN +5 kg Zn/ha and at par with 50% RDF + 100% RDN +5 kg Zn/ha and 50% RDF + 50% RDN +5 kg Zn/ha. Whereas, blackgram grain, straw, biological yield and harvest index statistically at par with only 50% RDF + 100% RDN +5 kg Zn/ha. On the other hand, lowest yields (grain stalk and biological) and harvest index were recorded in control plots. Kene *et al*. (1990) also reported that the application of 37.5 kg N + 75 kg P_2O_5 + 20 kg K_2O + 10 kg $ZnSO_4$/ha admirably enhanced the grain yield of pigeonpea. This might be due to combined application of organic manures and inorganic fertilizers were more effective due to complimentary in their response. It can facilitate the retention of added mineral fertilizers and the timing of their availability. Increase in growth and development characters with application of vermicompost along with chemical fertilizers, which resulted into higher yield of both crops. Application of fertilizers significantly influenced the growth and yield attributes. This could be attributed to the fact that added fertilizers enhanced the availability of these nutrients to plants. This might have resulted in profuse shoot and root growth, and thereby activating greater absorption of these nutrients from soil, and improved grain yield (Goud and Kale 2010). Similar results were reported by Sharma *et al*. (2010) and Kumari *et al*. (2012).

Total nutrient uptake (kg/ha)

The pooled data on total N, P, K, S and Zn uptake of pigeonpea are provided in Table 3. Integrated nutrition combinations significantly improved the total uptake of N, P, K, S and Zn in pigeonpea and blackgram as compared to control. Application of 100% RDF + 50% RDN + 5 kg Zn/ha (F_7), being at par with 50% RDF + 100% RDN + 5 kg Zn/ha (F_8), recorded significantly higher total uptake of N,

Table 3 Economics and production efficiency and economic efficiency as influenced by integrated nutrition and intercropping systems (Pooled data of 2 years)

Treatment	Cost of cultivation (₹/ha^{-1})	Gross return (×10^3 ₹/ha)	Net return (×10^3 ₹/ha)	B:C ratio	PEY (q/ha)	LER	Production efficiency (kg/ha/day)*	Economic efficiency (₹/ha/day)**
Intercropping systems								
S_1	17956	102.93	82.28	3.98	18.49	1.00	6.79	302.02
S_2	17956	120.05	99.40	4.80	21.75	1.70	7.98	364.83
S_3	17956	117.20	96.55	4.66	21.06	1.62	7.73	354.38
SEm ±		1.85	1.85	0.09	0.34	0.02	0.13	5.65
CD (*P*=0.05)		7.28	7.28	0.36	1.35	0.09	0.49	22.16
Integrated nutrient management								
F_0	17956	81.62	63.67	3.55	13.70	1.22	5.03	233.67
F_1	19491	106.88	87.39	4.49	18.99	1.39	6.97	320.78
F_2	20524	109.46	88.94	4.34	19.61	1.39	7.20	326.50
F_3	21291	118.70	97.41	4.58	21.66	1.50	7.95	357.57
F_4	22324	110.94	88.61	3.97	19.67	1.40	7.22	325.27
F_5	19658	108.84	89.18	4.54	19.23	1.40	7.06	327.33
F_6	20690	124.86	104.17	5.02	23.00	1.49	8.45	382.31
F_7	21458	130.74	109.28	5.11	24.24	1.57	8.90	401.07
F_8	22490	128.53	106.03	4.72	23.78	1.57	8.73	389.17
SEm ±		1.56	1.56	0.08	0.31	0.02	0.11	4.93
CD (*P*=0.05)		4.44	4.44	0.22	0.86	0.06	0.31	14.01

*Based upon pigeonpea equivalent yield, **Based upon net return

Table 4 Soil health as influenced by integrated nutrition and intercropping systems (Pooled data of 2 years)

Treat-ment	OC (%)	N (kg/ha)	P (kg/ha)	K (kg/ha$^-$)	S (kg/ha)	Zn (ppm)
Intercropping systems						
S_1	0.407	207.27	20.19	217.20	20.37	0.65
S_2	0.393	203.28	19.47	214.58	19.91	0.64
S_3	0.392	201.80	18.91	212.60	19.63	0.64
SEm±	0.008	2.29	0.35	2.45	0.36	0.01
CD (*P*=0.05)	NS	NS	NS	NS	NS	NS
Integrated nutrient management						
F_0	0.338	187.55	17.63	198.17	17.45	0.50
F_1	0.381	202.06	18.98	212.75	19.31	0.62
F_2	0.387	203.10	19.15	213.50	19.42	0.63
F_3	0.397	205.37	19.76	216.25	20.13	0.64
F_4	0.409	204.84	19.46	215.42	19.91	0.64
F_5	0.386	204.04	19.33	214.03	19.64	0.68
F_6	0.422	208.71	19.97	219.58	20.76	0.69
F_7	0.435	211.35	21.11	222.46	21.86	0.71
F_8	0.425	210.02	20.29	220.98	21.27	0.70
SEm±	0.006	1.82	0.26	2.01	0.28	0.01
CD (*P*=0.05)	0.017	5.18	0.74	5.73	0.80	0.03

P, K, S and Zn as compared to rest of the treatments. The total uptake of N, P, K, S and Zn by blackgram also significantly higher reported with the application of 100% RDF + 50% RDN + 5 kg Zn/ha. This was mainly due to higher biological production and developed root system with enhanced root activity Soil organic matter is store house of nitrogen, phosphorus, potassium and sulphur and thereby contributed significantly by supplying these nutrients to crop plants. It improved various other chemical properties of soil. For example, increased cation exchange capacity helps in trapping nutrient cations like potassium and zinc etc. Apart from nutrient supply, SOM also helps in release of nutrients from the soil. 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 to grain yield. All of which have a strong bearing on the grain yield as they are the yield determining components (Goud and Kale 2010).

Land equivalent ratio (LER) and pigeonpea equivalent yield (PEY q/ha): Application of 100% RDF + 50% RDN + 5 kg Zn/ha (F_7) produced maximum pigeonpea equivalent yield (24.24 q/ha) and land equivalent ratio (1.57) which was comparable to 50% RDF + 100% RDN +5 kg Zn/ha (F_8) and significantly higher than rest of the nutrition treatments. This treatment (F_7) registered 76.93% higher PEY than control. The fertilizer application (100% RDF + 50% RDN + 5 kg Zn/ha) to component crop improved the equivalent yield of system due to proper nourishment and less competition for nutrients and attributed to increase in economic yield of the component crop. The contributing effect of various yield attributes and yield fetched the maximum pigeonpea equivalent yield with integrated nutrient levels. The results of Rathod *et al.* (2004) and Sharma *et al.* (2010) pigeonpea supported the above findings.

Economics: Pooled data presented in Table 3 shows that maximum gross return of ₹ 130 735, net return of ₹ 109 277, B:C ratio of 5.11, production efficiency of 8.90 kg/ha/day and economic efficiency of 401.07 ₹/ha/day were found with 100% RDF + 50% RDN +5 kg Zn/ha (F_7). It was closely followed by 50% RDF + 100% RDN +5 kg Zn/ha (F_8) and minimum were under control.

Soil health: On the basis of pooled data of two years, application of 100% RDF + 50% RDN + 5 kg Zn/ha gave maximum organic carbon available N, P, K, S and Zn which was found at par with 50% RDF + 100% RDN + 5 kg Zn/ha and 50% RDF + 50% RDN + 5 kg/Zn ha, whereas, in respect of phosphorus it was at par with only 50% RDF + 100% RDN + 5 kg/Zn/ha. The lowest values of these parameters were under control. This might be due to increased supply of nutrient sources to the crop, as well as due to the indirect effect resulting from reduced loss of nutrients from organic sources. It was probably due to the fact that application of vermicompost increased apparent availability of native and added B from soil to crops and higher biomass production. Similar findings were also reported by Chaturvedi *et al*. (2010).

The present study clearly suggests that intercropping systems and integrated nutrient management affected the yield and economics of crop under rainfed conditions. Hence, normal planting (60 × 20 cm) + blackgram (1 row) and fertilized with 100% RDF + 50% RDN + 5 kg Zn/ha was most productive and profitable.

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