Journal of Agricultural Science; Vol. 4, No. 7; 2012
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Response of Intercropping and Integrated Nutrition on Production Potential and Profitability on Rainfed Pigeonpea

Narendra Kumawat[1], Rajendra Prasad Singh[1], Rakesh Kumar[2], Anupma Kumari[3] & Pramod Kumar[4]

[1] Department of Agronomy, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, 221 005, Uttar Pradesh, India

[2] ICAR RC NEH Region, Nagaland Centre, Jharnapani, Medziphema- 797106, Nagaland, India

[3] Krishi Vigyan Kendra, Vaishali, Rajendra Agricultural University, Pusa, Samastipur 848 125, India

[4] Krishi Vigyan Kendra, Jagannathpur 833203, Birsa Agricultural University, Ranchi, India

Correspondence: Rakesh Kumar, Scientist (Agronomy), ICAR RC NEH Region, Nagaland Centre, Jharnapani, Medziphema 797106, Nagaland, India. E-mail: rakeshbhu08@gmail.com

Received: March 20, 2012 Accepted: April 5, 2012 Online Published: May 25, 2012

doi:10.5539/jas.v4n7p154 URL: http://dx.doi.org/10.5539/jas.v4n7p154

Abstract

A field experiment was conducted during *kharif* season 2008-09 and 2009 - 10 to evaluate the response of pigeonpea [*Cajanus cajan* (L.) Millsp.] + blackgram (*Vigna mungo* L.) intercropping system to integrated nutrient levels. Intercropping failed to influence the dry matter production /plant, CEC of roots, root N content, yield and quality parameters of both crops. Both the intercropping system gives significantly higher uptake of N, P and K when compared to sole pigeonpea. The available soil N, P, K after harvest of crop (s) was maximum observed under sole pigeonpea followed by normal intercropping and lowest inpaired intercropping. Application of 100% RDF+50% RDN+5 kg Zn/ha significantly increased the dry matter production /plant,CEC of roots, root N content, grain yield, protein content, protein harvest (kg/ha) and nutrient uptake (NPKS and Zn) in pigeonpea and black gram cropping system. Integrated use 100% RDF with 50% RDN and 5 kg Zn/ha also significantly improved the available N, P and K soil after harvest during both the years.The maximum net return (Rs. 117010) was obtained with combination of normal intercropping system + 100% RDF+50% RDN+5 kg Zn/ha followed by normal intercropping system + 50% RDF+100% RDN+5 kg Zn/ha (Rs. 115102).

Keywords: intercropping, rainfed pigeonpea, integrated nutrient management

1. Introduction

Grain legumes are important source of protein in the diets of a large section of vegetarian population in the developing countries in general and India in particular. Even though India has the largest area under pulses in the world, the average productivity is low and the production is not sufficient to meet the caput requirement. Pigeonpea (*Cajanus cajan*) is an important pulse crop of dry land agriculture because of its ability to produce economic yield under limited moisture condition. It occupies an area of about 3.86 m ha with a total production 2.9 mt with an average productivity of 751 kg/ha (Anonymous, 2011).

Pigeonpea has slow initial growth and is planted at wide spacing so a lot of space between rows remains utilized during the initial crop growth period. This space can be utilized for growing short duration intercrop. Growing of blackgram as intercrop helps to sustain the productivity of the system. Therefore, to increase the productivity of the pulses per unit area particularly in rainy (*kharif*) season, intercropping of short duration crops seems an alternative (Willey, 1979). When crops are intercropped by increasing the overall density, nutritional deficiency is likely to occur. The optimum dose of nutrients and their sources play important role in increasing the productivity of these crops. Since fertilizer nutrients constitute a major costly production inputs, exploitation of yield potentiality of this crop depend on how effectively and efficiently this input is managed. Moreover, high fertility levels not only put a heavy financial burden to the growers but gradually decrease the partial productivity and thereby, jeopardize the sustenance of the basic system of production. On the other hand, the large scale use of only chemical fertilizers as a source of nutrients has less use efficiency. Besides low, variable and generally unbalanced nutrient contents, it is difficult to provide the proper nutrientbalance to meet crop requirements with bulky organic manure (Kumar *et al*., 2009). Organic manures with recommended dose of fertilizers have been reported to be beneficial in augmenting the yield of pigeonpea (Singh, 2007). To combat this problem, intercropping system and use of chemical fertilizers along with organic manures and zinc is probably a nice way to keep up sustained food production. Keeping these facts in view the present investigation was carried out.

In an experiment conducted at Hisar, it was reported that pigeonpea (75 cm) + green gram (1:2) ratio gave the highest total yield (2,352 kg ha^{-1}), net return and benefit: cost ratio (2.09) over the other different cropping systems (Kumar *et al*., 2003). Similar results have also been reported by Kantwa *et al*. (2005). Kumar and Rana (2007) reported that significantly increased the total uptake of P and S with the sole pigeonpea over pigeonpea + green gram intercropping, however cropping systems had no marked influence on P and S uptake by gain and stalk of pigeonpea. Kantwa *et al*. (2005) reported that the phosphorus uptake by pigeonpea sole and pigeonpea + urd bean intercropping system was significantly more in 40 kg P_2O_5 ha^{-1} over unfertilized crop.

Sharma *et al*. (2010) revealed that application of RDF + 15 kg $ZnSo_4$ significantly higher number of pods per plant, number of seeds per pod, 100-seed weight and seed yield of pigeonpea (13.78 q ha^{-1}) followed by RDF + 25 kg $ZnSo_4$ (13.53 q ha^{-1}) and RDF + seed treatment with sodium molybdenum @ 4 g kg^{-1} (12.42 q ha^{-1}) as compared to control (7.78 q ha^{-1}). Ramesh *et al.* (2006) conducted a field experiment at Bhopal applying different organic manures (cattle dung 4 t ha^{-1}, vermicompost 3 t ha^{-1} and poultry manure 2 t ha^{-1}) to pigeonpea and reported that the highest protein content in seed was recorded with the application of cattle dung (21.25%) followed by vermicompost (20.90%) and poultry manure (20.87%).

2. Materials and Methods

A field experiment was conducted during *kharif* season of 2008-09 and 2009-10 at Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, situated at $25^0$18' N latitude, $83^0$03' E longitude and at an altitude of 128.9 m above means sea level. The total rainfall received during crop growing season 2008-09 and 2009-10 was 528.60 mm and 420.41 mm, respectively. However, the rainfall was well distributed in 2008-09 than 2009-10. The soil was slight alkaline (pH 7.3), poor organic carbon (0.35%), available nitrogen (190.50 kg) and sulphur (18.6 kg); medium in available phosphorus (19.30) and available potassium (210.15 kg). The zinc (0.51 ppm) was below the critical limit. The field capacity and wilting point were 19.82 and 5.61 per cent, respectively. The treatment combinations comprised three cropping systems [pigeonpea sole (60 cm), normal planting (60 × 20 cm) + black gram (1 row) and paired planting (80+40 cm and 20 cm) + blackgram (2 row) in main plots; and nine integrated nutrient levels (control, 100% RDF, 50% RDF + 50% RDN, 100% RDF + 50% RDN, 50% RDF + 100% RDN, 100% RDF + 5 kg Zn/ha, 50% RDF + 50% RDN + 5 kg Zn/ha, 100% RDF + 50% RDN +5 kg Zn/ha, 50% RDF + 100% RDN + 5 kg Zn/ha in sub plots repeated thrice in a split plot design. RDF represents recommended dose of N, P_2O_5, K_2O, 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 m × 5.0 m) and 14.4 m^2 (3.6 × 4.0 m^2), respectively. All the doses of nitrogen, phosphorus, potassium, sulphur and zinc fertilizers as per treatment were applied just before sowing using urea, DAP, murate of potash, elemental sulphur and zinc oxide, respectively as basal. The required amount of RDN through vermicompost containing N (1.5%), P (0.90%), K (1.12%), S (0.56) and Zinc (58 ppm) as per treatment was incorporated in the soil after preparing the layout and demarcating the plots during both the years. 'Bahar' and 'T-9' varieties of pigeonpea and blackgram respectively were used as test crop. The seed rate of both the crops @ 15 kg ha^{-1} (pigeonpea) and 12 kg ha^{-1} (black gram) were sown in rows opened by kudal. The optimum plant population was maintained by thinning and gap filling 10 days after germination to ensure the uniform plant population.

2.1 Dry Matter Production/Plant (g)

Dry matter production/plant was recorded at the time of harvesting.

2.2 CEC of Roots (meq/100 Dry Roots) and Root N Content (%)

Treatment wise, plant samples were uprooted at maturity, tops were cut off close to the ground and roots were washed gently first in tap water and then in mineralized water. Then the roots were dried at 80^0 C for 48 hrs and then after proper grinding, it was stored in labelled polythene bags. The CEC of the plant root was determined by the method suggested by Chamuah and Dey (1982). Nitrogen content in roots were analyzed by the method proposed by Linder (1944).

2.3 Protein Content (%) and Protein Harvest (kg/ha)

Protein content in grain was worked out by multiplying the nitrogen content in grain with the factor by (A.O.A.C, 1970). Protein harvest (kg/ha) was determined by multiplying the protein content in grain with their respective yields.

2.4 Nutrient Uptake (kg/ha)

Nutrient uptake was calculated by multiplying the nitrogen, phosphorus and potassium content of pigeonpea/black gram (system) grain and stalk with their respective yield.

2.5 Estimation of Available Nitrogen of Soil (kg/ha)

Available nitrogen of the soil was estimated by Alkaline Permanganate method (Subbaiah & Asija, 1973).

2.6 Estimation of Available Phosphorus of Soil (kg/ha)

Available nitrogen of the soil was estimated by 0.5 M $NaHCO_3$ Extractable Olsen's Colorimetric Method (Olsen's *et al*., 1954).

2.7 Estimation of Available Potassium of Soil (kg/ha)

Available potassium was estimated by Flame photometric method (Ammonium acetate extract) (Jackson, 1973).

2.8 Production Efficiency

Production efficiency was calculated by grain yield and net return divided by total duration taken crop.

2.9 Economics (Rs.)

Economics analysis was done based on prevailing market price the output.

2.10 Statistical Analysis of Data

All the data pertaining to the present investigation were statically analyzed as per the methods described by Gomez and Gomez (1984). The statically significance of various effects was tested at 5 per cent level of probability. The data recorded were analyzed as per analysis of variance technique for split plot design.

3. Result and Discussion

3.1 Performance of Pigeonpea

3.1.1 Effect of Cropping System

The intercropping system of pigeonpea with blackgram did not affect the dry matter production /plant, CEC of roots, root N content, grain yield, protein content, protein harvest during both the years. However, maximum values of these parameters were recorded under sole pigeonpea. This might be ascribed to differential growth habit of pigeonpea and black gram, and both crops grow in a non-competitive environment. Kumar and Rana (2007) also observed that pigeonpea growth and development was not affected by green gram intercropping.

3.1.2 Integrated Nutrient Levels

Data of two crop season revealed that integrated use of recommended dose of fertilizers plus vermicompost along with zinc significantly increased that the dry matter production /plant, CEC of roots, root N content, grain yield, protein content and protein harvest of pigeonpea during both the years. Over the 9 integrated nutrient levels, application of 100% RDF + 50% RDN +5 kg Zn/ha being on par with 50% RDF + 100% RDN +5 kg Zn/ha and 50% RDF + 50% RDN +5 kg Zn/ha and significantly increased the dry matter/plant, CEC of roots, root N content, grain yield, protein content and protein harvest over rest of the integrated nutrient levels (Table 1). The yield increment in pigeonpea due to application of 100% RDF + 50% RDN +5 kg Zn/ha, 50% RDF + 100% RDN +5 kg Zn/ha and 50% RDF + 50% RDN +5 kg Zn/ha being 71.37, 68.68 and 62.90 percent in 2008 and 79.73, 77.11 and 73.04 in 2009, respectively when compared with control. Improvement in yield might be have resulted, there ideal condition for soil micro flora, due to application of vermicompost along with zinc and increased the availability of nutrient with 100% RDF, there was improvement in both growth and yield attributes, which turn might have increased the yield of pigeonpea. Similar findings were also reported by Singh *et al*. (2008).

CEC of roots and root N content was higher with the application of 100% RDF + 50% RDN +5 kg Zn/ha among the integrated nutrient levels it was found statistically on par with 50% RDF + 100% RDN +5 kg Zn/ha and 50% RDF + 50% RDN +5 kg Zn/ha. This might be due to favorable effect of vermicompost on root proliferation and development. It may be inferred that the increase in CEC of roots may be indicated better crop response to the applied nutrients under study (Helmy & Egalaby, 1985). Increase in CEC of roots with the increase in nitrogen content resulting into an increased over all surface area available for cation exchange.

Application of 100% RDF + 50% RDN +5 kg Zn/ha recorded maximum protein content and protein harvest which was on par with 50% RDF + 100% RDN +5 kg Zn/ha and 50% RDF + 50% RDN +5 kg Zn/ha during both the years the lowest protein content and protein harvest were recorded under control. This might be due to adoption integrated nutrient management practices. Protein harvest is the end product of a complex series of biochemical and physiological process. It seems that balanced recommend dose of fertilizers fortified with vermicompost might have helped in more efficient translocation of nitrogen from vegetative part to developing seeds as well as synthesis of protein from the reduced nitrogen compound with the seeds as coenzyme pyridoxal phosphate is involved in the transamination reaction and amino acids are activated for protein synthesis in presence of activity of enzyme and ATP (Patil & Padmani, 2007).

Table 1. Growth, root parameters, yield and qualityof pigeonpea as influenced by intercropping system and integrated nutrient management

Treatments	Dry matter/plant (g)		CEC of roots (meq 100 g^{-1} dry roots)		Root N content (%)		Grain yield (kg/ha)		Protein content (%)		Protein harvest (kg/ha)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
A. Cropping system												
S_1	223.08	199.94	65.36	62.46	2.72	2.45	2201	1496	20.68	20.50	457.31	309.22
S_2	217.21	191.90	62.83	61.30	2.54	2.37	2119	1439	20.31	20.00	431.68	289.53
S_3	210.40	187.80	61.94	61.18	2.44	2.35	2070	1417	19.75	19.67	413.01	280.62
SEm±	3.83	3.81	0.93	0.71	0.08	0.07	42	28	0.35	0.34	16.21	10.44
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B. Integrated nutrient management												
F_0	198.64	174.97	56.68	54.67	1.97	1.95	1453	957	18.54	18.22	270.47	174.72
F_1	206.38	185.02	60.27	59.44	2.27	2.13	1996	1352	19.85	19.62	397.37	265.86
F_2	208.68	186.41	61.10	59.81	2.34	2.19	2090	1369	19.96	19.76	417.99	270.59
F_3	219.05	195.70	64.88	63.36	2.74	2.46	2274	1522	20.37	20.18	464.77	307.81
F_4	213.96	191.19	62.12	61.25	2.48	2.30	2044	1411	20.25	20.08	414.71	283.72
F_5	212.31	189.44	61.42	60.59	2.41	2.24	2003	1371	20.00	19.94	401.45	273.82
F_6	226.91	200.04	67.42	64.35	2.86	2.69	2367	1656	20.79	20.67	492.84	343.44
F_7	237.37	210.46	68.79	66.14	3.03	2.80	2490	1720	21.31	21.11	531.49	364.01
F_8	228.76	205.67	67.72	65.23	2.96	2.74	2451	1695	20.98	20.88	514.89	354.13
SEm±	3.74	3.75	0.67	0.65	0.07	0.07	40	22	0.31	0.29	13.60	8.60
CD(P=0.05)	10.63	10.65	1.91	1.83	0.20	0.19	124	69	0.89	0.84	38.66	24.45

3.2 Performance of Black Gram

3.2.1 Effect of Cropping System

The cropping system did not show any marked influenced on dry matter production /plant, CEC of roots, root N content and grain yield of black gram during both the years. This might be due to absence of competition between main crop and intercrop for growth sources because of shorter duration and non-spreading nature. Similar results were reported by Kumar and Rana (2007).

3.2.2 Effect of Cropping System

Application of 100% RDF + 50% RDN + 5 kg Zn/ha recorded maximum dry matter/plant and grain yield which was statistically at par with 50% RDF + 100% RDN + 5 kg Zn/ha during both the years of study and both the treatments were significantly superior to 50% RDF + 50% RDN + 5 kg Zn/ha, 100% RDF + 50% RDN, 50% RDF + 100% RDN, 100% RDF + 5 kg Zn/ha, 50% RDF + 50% RDN, 100% RDF and control. The magnitude of grain yield increases with 100% RDF + 50% RDN + 5 kg Zn/ha 99.66 and 86.50 per cent over control during 2008 and 2009, respectively. This might be due to growth and yield contributing characters were concordant to the yield of crop. Obviously, the trend observed for the yield attributes perpetuated to build up the final outcome in terms of yield.

Application of inorganic fertilizers with vermicompost and zinc had significantly influenced the CEC of roots and root N content during both the years of study (Table 2). Among the integrated nutrient levels, application of 100% RDF + 50% RDN + 5 kg Zn/ha gave maximum CEC of roots and root N content which was statistically at par with

50% RDF + 100% RDN + 5 kg Zn/ha and 50% RDF + 100% RDN + 5 kg Zn /ha. These two treatments were found significantly superior to rest of the nutritional treatments. This might be due to better utilization of macro and micronutrients which helped in improvement of roots developments (Goud & Kale, 2010).

The integrated nutrient levels had significant influence on protein content and protein harvest. The protein content and protein harvest were higher with the application of 100% RDF + 50% RDN + 5 kg Zn/ha which was on par with 50% RDF + 100% RDN + 5 kg Zn/ha and significantly superior over rest of the treatments. The absolute control recorded lowest protein content and protein harvest during both the years. The higher nitrogen content might be due to increased activity nitrate reductase in synthesis of protein in seeds because it is a primary component of amino acids which are the building blocks of protein molecules.Similar results were reported by Kumar and Rana (2007).

Table 2. Growth, root parameters, yield and quality of black gram as influenced by intercropping system and integrated nutrient management

Treatments	Dry matter/plant (g)		CEC of roots (meq 100 g^{-1} dry roots)		Root N content (%)		Grain yield (kg/ha)		Protein content (%)		Protein harvest (kg/ha)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
A. Cropping system												
	-	-	-	-	-	-	-	-	-	-	-	-
S_2	26.84	24.93	33.16	32.28	1.71	1.65	503	362	21.51	21.20	109.00	77.47
S_3	26.30	23.45	32.55	31.90	1.65	1.57	465	327	20.93	20.90	97.32	68.85
SEm±	0.91	0.56	0.87	0.80	0.04	0.04	11	8	0.41	0.37	3.84	3.02
CD(P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
B. Integrated nutrient management												
F_0	20.32	18.45	27.83	27.50	1.37	1.34	302	237	19.44	19.12	58.86	45.44
F_1	23.32	22.12	31.32	30.02	1.62	1.49	434	303	20.78	20.58	90.35	62.41
F_2	24.25	22.85	31.67	30.27	1.67	1.52	447	313	21.17	20.75	94.55	64.93
F_3	27.27	24.40	33.49	33.23	1.70	1.68	528	348	21.31	21.15	112.71	73.90
F_4	25.25	23.51	33.02	31.58	1.69	1.58	463	321	21.31	21.07	98.73	67.68
F_5	24.98	22.86	32.50	31.55	1.68	1.56	454	318	21.09	20.97	95.90	66.82
F_6	29.92	26.76	34.83	34.57	1.74	1.73	549	396	21.43	21.21	117.94	84.22
F_7	32.87	29.05	35.80	35.23	1.85	1.80	603	442	22.59	22.37	136.67	98.94
F_8	30.99	27.68	35.22	34.87	1.80	1.78	575	424	22.17	22.10	127.69	93.79
SEm±	0.72	0.50	0.80	0.69	0.04	0.03	10	6	0.38	0.31	3.72	1.91
CD(P=0.05)	2.07	1.44	2.29	1.99	0.11	0.09	29	19	1.09	0.90	10.72	5.50

3.3 Nitrogen Uptake of System and Balance Sheet

Total nitrogen uptake by cropping system was significantly higher under both the intercropping treatments over sole pigeonpea. Among the different intercropping system, normal intercropping system had significantly higher nitrogen uptake which was on par with paired intercropping system during both the years (Table 3). This might be due to compound effect of grain and stalk yield of their content (Meena *et al*., 2009).

The available soil N did not affected by cropping system. However, maximum value was recorded with the sole pigeonpea. It is may be due to lower plant population in sole cropping system then intercropping system. The computed N balance was negative under all the intercropping system.The maximum negative balance was recorded under normal intercropping system in both the years.

Significant improvement in nitrogen uptake was observed in the all the integrated nutrient levels. The maximum uptake of nitrogen was recorded under 100% RDF + 50% RDN + 5 kg Zn/ha. Since uptake of nutrients is a function of their content and yield, increase in grain and stalk yield along with higher content of nitrogen might have resulted in higher uptake of nitrogen in the crop.

The application of 100% RDF + 50% RDN + 5 kg Zn/ha improved the N status of soil after harvest which was at par with 50% RDF + 100% RDN + 5 kg Zn/ha and 50% RDF + 50% RDN + 5 kg Zn/ha and significantly superior to rest of the treatments. A net gain of N status 19.35 and 21.26 kg/ha was recorded under 100% RDF + 50% RDN + 5 kg Zn/ha followed by 18.11 and 19.98 kg/ha under 50% RDF + 100% RDN + 5 kg Zn/ha during 2008 and 2009, respectively. The computed N balance was negative under all the integrated nutrient levels except control.

The maximum negative balance was recorded under 100% RDF + 50% RDN + 5 kg Zn/ha during both the years. This uncountable N might have come through symbiotic nitrogen fixation.

Table 3. Available balance sheet of N (kg/ha) as influenced by intercropping system and integrated nutrient management

Treatments	Initial N Status (a)		N Added (b)		N uptake by cropping system (c)		Soil N status after harvest (d)		Actual gain (a-d)		N Balance (a+b)-(b+c)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
A. Cropping system												
S_1	190.5	193.6	20	20	135.59	103.84	205.75	209.72	-15.25	-16.12	-130.84	-99.96
S_2	190.5	193.6	20	20	160.59	121.61	201.99	205.79	-11.49	-12.19	-152.08	-113.80
S_3	190.5	193.6	20	20	152.54	116.31	200.69	204.18	-10.19	-10.58	-142.73	-106.89
SEm±	-	-	-	-	2.32	1.80	2.26	2.38	-	-	-	-
C D(P=0.05)	-	-	-	-	9.11	7.06	NS	NS	-	-	-	-
B. Integrated nutrient management												
F_0	190.5	193.6	0	0	91.31	72.06	189.15	190.06	1.35	3.54	-89.96	-68.52
F_1	190.5	193.6	20	20	136.88	102.00	200.59	203.54	-10.09	-9.94	-126.96	-91.94
F_2	190.5	193.6	20	20	141.92	104.58	201.62	204.57	-11.12	-10.97	-133.04	-95.55
F_3	190.5	193.6	30	30	159.61	120.24	203.66	208.19	-13.16	-14.59	-142.77	-104.83
F_4	190.5	193.6	30	30	145.10	110.05	203.05	206.63	-12.55	-13.03	-127.65	-93.08
F_5	190.5	193.6	20	20	140.56	107.60	202.06	206.02	-11.56	-12.42	-132.12	-100.02
F_6	190.5	193.6	20	20	169.96	131.12	206.68	211.62	-16.18	-18.02	-166.15	-129.14
F_7	190.5	193.6	30	30	183.67	141.17	209.85	214.86	-19.35	-21.26	-173.02	-132.43
F_8	190.5	193.6	30	30	177.16	136.46	208.61	213.58	-18.11	-19.98	-165.27	-126.44
SEm±	-	-	-	-	1.97	1.53	2.12	2.34	-	-	-	-
C D(P=0.05)	-	-	-	-	5.59	4.36	6.02	6.65	-	-	-	-

3.4 Phosphorus Uptake of System and Balance Sheet

Significantly higher P uptake was obtained in normal intercropping system which on par with paired intercropping during both the years. Soil P status did not affected by cropping system. It might be due to less uptake of nutrient by sole cropping.The actual maximum P gain was recorded under paired planting (0.49 and 1.45 kg/ha). The positive value of P was recorded under paired intercropping during both the years (Table 5).

Table 4. Available balance sheet of soil P (kg/ha) as influenced by intercropping system and integrated nutrient management

Treatments	Initial P Status(a)		P Added (b)		P uptake by cropping system (c)		Soil P status after harvest(d)		Actual gain (a-d)		P Balance (a+b)-(b+c)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
A. Cropping system												
S_1	19.3	20.45	20	20	19.83	14.95	20.00	20.38	-0.70	0.08	-0.53	5.13
S_2	19.3	20.45	20	20	22.30	16.80	19.41	19.64	-0.11	0.92	-2.41	4.12
S_3	19.3	20.45	20	20	21.07	15.76	18.81	19.10	0.49	1.45	-0.58	5.69
SEm±	-	-	-	-	0.33	0.25	0.33	0.34	-	-	-	-
C D(P=0.05)	-	-	-	-	1.29	0.97	NS	NS	-	-	-	-
B. Integrated nutrient management												
F_0	19.3	20.45	0	0	12.36	9.62	17.94	18.01	1.36	3.13	-11.00	-6.49
F_1	19.3	20.45	40	40	18.61	13.54	18.80	19.15	0.50	1.30	21.89	27.76
F_2	19.3	20.45	26	26	19.35	13.97	19.04	19.27	0.26	1.18	6.92	13.21
F_3	19.3	20.45	46	46	22.26	16.40	19.64	19.89	-0.34	0.56	23.40	30.16
F_4	19.3	20.45	32	32	19.84	14.84	19.35	19.57	-0.05	0.88	12.11	18.05
F_5	19.3	20.45	40	40	19.33	14.45	19.23	19.43	0.07	1.02	20.74	26.58
F_6	19.3	20.45	26	26	24.88	19.14	19.72	20.22	-0.42	0.23	0.70	7.09
F_7	19.3	20.45	46	46	26.94	20.71	20.91	21.31	-1.61	-0.86	17.45	24.43
F_8	19.3	20.45	32	32	26.03	19.88	20.04	20.51	-0.74	-0.10	5.23	12.03
SEm±	-	-	-	-	0.29	0.22	0.31	0.29	-	-	-	-
C D(P=0.05)	-	-	-	-	0.81	0.62	0.88	0.82	-	-	-	-

Table 5. Available balance sheet of soil K (kg/ha) as influenced by intercropping system and integrated nutrient management

Treatments	Initial K Status (a)		K Added (b)		K uptake by cropping system(c)		Soil K status after harvest(d)		Actual gain (a-d)		K Balance (a+b)-(b+c)	
	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009	2008	2009
A. Cropping system												
S_1	201.15	203.41	20	20	90.30	76.94	215.38	219.43	-14.23	-16.02	-84.54	-72.96
S_2	201.15	203.41	20	20	116.93	95.90	212.55	216.98	-11.40	-13.57	-108.33	-89.47
S_3	201.15	203.41	20	20	112.84	92.09	210.82	214.67	-9.67	-11.26	-102.50	-83.35
SEm±	-	-	-	-	1.81	1.43	2.56	2.46	-	-	-	-
C D(P=0.05)	-	-	-	-	7.10	5.63	NS	NS	-	-	-	-
B. Integrated nutrient management												
F_0	201.15	203.41	0	0	66.62	58.13	199.17	200.29	1.98	3.12	-64.63	-55.01
F_1	201.15	203.41	20	20	101.96	83.29	210.52	214.98	-9.37	-11.57	-91.33	-74.86
F_2	201.15	203.41	17.47	17.47	104.30	84.76	211.28	215.72	-10.13	-12.31	-96.96	-79.60
F_3	201.15	203.41	27.47	27.47	111.45	92.49	214.02	218.47	-12.87	-15.06	-96.85	-80.08
F_4	201.15	203.41	24.93	24.93	107.76	88.35	213.18	217.66	-12.03	-14.25	-94.86	-77.67
F_5	201.15	203.41	20	20	105.39	86.93	211.90	216.15	-10.75	-12.74	-96.15	-79.67
F_6	201.15	203.41	17.47	17.47	116.93	97.02	216.88	221.72	-15.73	-18.31	-115.19	-97.86
F_7	201.15	203.41	27.47	27.47	124.95	103.55	220.87	224.71	-19.72	-21.30	-117.21	-97.30
F_8	201.15	203.41	24.93	24.93	120.86	100.34	218.41	223.55	-17.26	-20.14	-113.19	-95.55
SEm±	-	-	-	-	1.45	1.15	2.37	2.18	-	-	-	-
C D(P=0.05)	-	-	-	-	4.05	3.20	6.73	6.19	-	-	-	-

Maximum P uptake was observed under 100% RDF + 50% RDN + 5 kg Zn/ha which was significantly superior over rest of the treatments (Table 4). Increase in P uptake was due to increase in P availability from applied fertilizers, vermicompost and inherent soil source and combined effect of release organic acids and organic anions on decomposition of vermicompost. The result corroborated the finding of Kachot *et al*. (2001). The available P status after harvest was observed higher over the initial status except under control. Maximum P status of soil was recorded under 100% RDF + 50% RDN + 5 kg Zn/ha followed by50% RDF + 100% RDN + 5 kg Zn/ha both on par to each other during both the years The positive balance was computed in all the treatments except control, however, the maximum positive balance was observed under 100% RDF + 50% RDN /ha.

3.5 Potassium Uptake of System and Balance Sheet

Highest uptake of K was recorded with normal intercropping which was on par with paired intercropping and both significantly superior to sole pigeonpea during both the years. Similar result was reported by Kumar and Rana (2007). Cropping system had no significant effect on available soil K after harvest. However maximum value was recorded with sole pigeonpea (Table 5). The net gain of K was maximum recorded under sole pigeonpea in both the years. However, K balance maximum negative recorded under normal intercropping.

K uptake was highest recorded with the application of 100% RDF + 50% RDN + 5 kg Zn/ha and significantly superior over rest of integrated nutrient levels. This might be due to better physical condition in the rhizosphere might have helped in more absorption of nutrients by the crops. Kumar and Rana (2007) had similar observation. Application of 100% RDF + 50% RDN + 5 kg Zn/ha recorded the higher of available soilK status after harvest that was at par with 50% RDF + 100% RDN + 5 kg Zn/ha and 50% RDF + 50% RDN + 5 kg Zn/haduring both the years. Maximum gain was recorded under 100% RDF + 50% RDN + 5 kg Zn/ha followed by under 50% RDF + 100% RDN + 5 kg Zn/ha. However, a negative K balance was computed under all the treatments which indicated K mining. This negative balance computed was maximum under application of 100% RDF + 50% RDN + 5 kg Zn/ha followed by under 50% RDF + 50% RDN + 5 kg Zn/ha and lowest under control during both the years (Table 6).

Table 6. Production efficiency and economics of pigeonpea as influenced by intercropping system and integrated nutrient management (Mean data of 2 years)

Treatment	Production efficiency		Gross return	Net return	B:C ratio
	Kg/ha/day*	Rs/ha/day**	(Rs/ha)	(Rs/ha)	
S_1F_0	4.9	219.4	77702	59745	3.33
S_1F_1	6.3	286.1	97428	77936	4.00
S_1F_2	6.6	290.6	99668	79143	3.86
S_1F_3	7.0	309.8	105698	84406	3.97
S_1F_4	6.7	295.0	102660	80335	3.60
S_1F_5	6.4	291.2	98983	79325	4.04
S_1F_6	7.7	339.4	113210	92519	4.46
S_1F_7	7.9	353.3	117969	96511	4.51
S_1F_8	7.6	333.4	113334	90843	4.04
S_2F_0	5.4	250.6	86228	68271	3.80
S_2F_1	7.5	343.2	113013	93522	4.80
S_2F_2	7.5	347.8	115249	94725	4.62
S_2F_3	8.3	378.4	124385	103094	4.84
S_2F_4	7.7	350.2	117768	95444	4.28
S_2F_5	7.5	354.2	116149	96491	4.91
S_2F_6	8.8	407.1	131599	110909	5.36
S_2F_7	**9.5**	**429.4**	**138468**	**117010**	**5.45**
S_2F_8	9.5	422.5	137593	115102	5.12
S_3F_0	4.8	231.0	80941	62985	3.51
S_3F_1	7.1	333.0	110204	90713	4.66
S_3F_2	7.4	341.1	113462	92938	4.53
S_3F_3	8.5	384.5	126018	104726	4.92
S_3F_4	7.2	330.6	112386	90062	4.04
S_3F_5	7.2	336.6	111380	91722	4.67
S_3F_6	8.8	400.4	129771	109081	5.28
S_3F_7	9.3	420.5	136019	114560	5.34
S_3F_8	9.1	411.7	134064	111574	4.97

S_1= Pigeonpea sole, S_2 =Normal planting of pigeonpea,S_3= Paired planting of pigeonpea, F_0= Control, F_1=00% RDF, F_2=50% RDF + 50% RDN, F_3=100% RDF + 50% RDN, F_4=50% RDF + 100% RDN, F_5=100% RDF + 5 kg Zn/ha, F_6=50% RDF + 50% RDN +5 kg Zn/ha, F_7=100% RDF + 50% RDN + 5 kg/Zn ha, F_9 =50% RDF + 100% RDN+5 kg Zn/ha

*Based upon grain yield of system, **based upon net return

3.6 Production Efficiency

Owing to better utilization of applied 100% RDF + 50% RDN +5 kg Zn/ha and normal intercropping system combination recorded higher production efficiency and net return 9.5 kg/ha/day and Rs 429.4 ha/day, respectively followed by 9.5 kg/ha/day and net return of Rs 422.5 ha/day with 50% RDF + 100% RDN +5 kg Zn/ha + normal intercropping system. Lower production efficiency of 4.9 kg/ha/day and net return of Rs 219.4 ha/day was recorded with sole pigeonpea + no fertilizer application (Table 6).

3.7 Economics

The maximum gross (Rs 1, 38,468), net return (Rs 1, 17,010) and B:C ratio (5.45) were recorded with normal intercropping + 100% RDF + 50% RDN +5 kg Zn/ha followed by under normal intercropping +50% RDF + 100% RDN +5 kg Zn/ha (Table 3).

4. Conclusion

Based on the conclusions, it is recommended that in order to achieve higher yield and economic profitability in rainfed pigeonpea, one row of black gram intercropped between two rows of pigeonpea planted at 60 × 20 cm and fertilized with 100% recommended dose of fertilizers + 50% recommended dose of nitrogen through vermicompost along with 5 kg zinc per hectare should be practiced.

References

A. O. A. C. (1970). Association of official analytical chemistry. *Methods of analysis,* Washington DC 2044, 11^{th} Ed.

Anonymous. (2011). *Directorate of Economics and Statistics*, Department of Agriculture and Cooperation., Govt. of India.

Chamuah, G. S., & Dey, S. K. (1982). Determination of cation exchange capacity of woody plant roots using ammonium acetate extractant. *Plant and Soil, 68*, 135-138.

Gomez Kwanchai, A., & Gomez Arturo, A. (1984). *Statistical procedures for Agricultural Research* (2nd ed.). John Wiley and Sons Inc., New York, U. S. A.

Goud, V. V., & Kale, H. B. (2010). Productivity and profitability of pigeonpea under different sources of nutrients in rainfed condition of Central India. *Journal of Food Legume*, *23*(3&4), 212-217.

Helmy, A. K., & Elgalaby, M. M. (1985). Exchange capacity of plant roots. II Some factors affecting the cation exchange capacity. *Plant and Soil, 10*, 93-100.

Jackson, M. L. (1973). *Soil Chemical Analysis*. Prentice Hall of India Pvt. Ltd., New Delhi, India, pp. 183-204.

Kachot, N. A., Malvia, D. D., Solanki, R. M., & Sagarka, B. K. (2001). Integrated nutrient management in rainy season ground nut (*Arachis hypogea*). *Indian Journal of Agronomy, 46*(3), 516-522.

Kantwa, S. R., Ahlawat, I. P. S., & Gangaiah, B. (2005). Effect of land configuration, post-monsoon irrigation and phosphorus on performance of sole and intercropped pigeonpea. *Indian Journal of Agronomy, 50*(4), 278-280.

Kumar, A., & Rana, K. S. (2007). Performance of pigeonpea (*Cajanuscajan*) + greengram (*Phaseolusradiatus*) intercropping system as influenced by moisture – conservation practices and fertility level under rainfed conditions. *Indian Journal of Agronomy, 52*(1), 31-35.

Kumar, R. P., Singh, O. N, Singh, Y., Dwivedi, S., & Singh, J. P. (2009). Effect of integrated nutrient management on growth, yield, nutrient uptake and economics of french bean (*Phaseolus vulgaris*). *Indian Journal of Agricultural Sciences*, *79*(2), 122-128.

Kumar, S., Singh, R. C., & Kadian, V. S. (2003). Performance of mungbean as influenced by seed inoculation with *Rhizobium* and level of organic and inorganic sources of nutrients.*Indian Journal of Pulses Research*, *16*(1), 67-68.

Linder, R. C. (1944). Rapid analytical method for some of the more common inorganic constituents of plant tissues. *Plant Physiology, 19*, 76-89.

Meena, S. L., Shamsudheen, M., & Dayal Devi. (2009). Productivity of clusterbean (*Cyamopsis tetragonoloba*) and sesame *Sesamum indicum*) intercropping system under different row ratio and nutrient management in arid region. *Indian Journal of Agricultural Sciences*, *97*(11), 901-905.

Olsen's, S. R., Cole, C. W., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *USDA Circular No. 939*. pp. 19-23.

Patil, A. B., & Padmani, D. R. (2007). Nutrient uptake pattern of pigeonpea (*Cajanuscajan*) as influenced by integrated nutrient management. *International Journal of Agriculture Science*, *3*(2), 176-178.

Ramesh, P., Singh, M., Panwar, N. R., Singh, A. B., & Ramana, S. (2006). Response of pigeonpea (*Cajanusn cajan*) varieties to organic manures and their influence on fertility and enzyme activity of soil. *Indian Journal of Agricultural Sciences, 76*(4), 252-254.

Sharma, A., Nakul, H. T., Jelgeri, B. R., & Surwenshi, A. (2010). Effect of micronutrients on growth, yield and yield components in pigeonpea (*Cajanus cajan* L. Millsp.). *Research Journal of Agricultural Sciences, 1*(2), 142-144.

Singh, R. P., Singh T., Singh, J. P., & Singh, Rajpal. (2008). Effect of Fertility Level, Plant Density and Methods of Planting on the Performance of Rainfed Pigeonpea. *Indian Journal of Dryland Agricultural Research & Development*, *23*(2), 24-27.

Singh, R. S. (2007). Effect of organic and inorganic sources of nutrition on productivity of long duration pigeonpea (*Cajanuscajan* (L.) Millsp.). *Environment and Ecology* 25 S (Special 3A), 768-770.

Singh, T., & Pal, M. (2003). Growth parameters, yield attributes and yield of pigeonpea as influenced by cropping systems and Nitrogen + Phosphorus levels. *Annals of Agricultural Research*, *24*(4), 755-759.

Subbaiah, B. V., & Asija, G. L. (1973). A rapid procedure for estimation of available nitrogen in soils. *Current Science, 28*(8), 259-260.

Willey, R. W. (1979). Intercropping-its importance and research needs, competition and yield advantage. *Field Crop Abstract, 31*(1), 1-10.