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Productivity and profitability of pigeonpea (*Cajanus cajan*) in pigeonpea based cropping system under different integrated nutrient management practices in *Tarai* region of Uttarakhand

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Abstract
A two years field study was carried out at Norman E. Borlaug Crop Research Centre, GBPUA&T, Pantnagar, Uttarakhand to evaluate the productivity and profitability of Pigeonpea (*Cajanus cajan*) in pigeonpea based cropping system under different integrated nutrient management practices in *Tarai* region of Uttarakhand. Results reveals that Maximum grain yield, biological yield, harvest index of pigeonpea and pigeonpea equivalent yield as well as net return and B:C ratio was recorded in Pigeonpea + Urd cropping system than sole and Pigeonpea + Maize cropping system. Application of Recommended Dose of Fertilizer + vermicompost @ 2.5 t/ha found as effective as Recommended Dose of Fertilizer + Farm Yard Manure @ 5.0 t/ha and improved all the growth and yield parameters of pigeonpea than Recommended Dose of Fertilizer alone. However, highest net return was obtained under Recommended Dose of Fertilizer + Farm Yard Manure @ 5.0 t/ha compared to Recommended Dose of Fertilizer alone.

Keywords: intercropping, pigeonpea, urdbean, equivalent yield, B:C ratio

Introduction
Pulses, together with cereals, have been fundamental to the development of modern agriculture. They are second only to cereals in importance for human and animal dietary needs. Deep rooting characteristics, ability to fix atmospheric nitrogen and huge leaf fall makes pulses an important component in cropping systems. In addition, many pulses release soil-bound phosphate through their symbiotic relationships with mycorrhizal fungi as stated by Hayman (1983) [10]. Besides expansion of cultivated area and increasing the yield per unit area of crop, the modern agriculture adds two more dimensions *viz*., time and space. The main concept of intercropping is to get increased total productivity per unit area and time, besides equitable and judicious utilization of land resources and farming inputs.

Pigeonpea grown as a sole crop shows inefficient utilization of resources especially the space because of its slow initial growth rate and low harvest index. Intercropping of short duration cereals and pulses provides an opportunity to utilize of available resources more efficiently with enhancement of productivity and profitability of system. Being one of the most drought tolerant legumes, pigeonpea has a great potential to increase the sustainability of cropping systems in the arid and semi-arid regions. In India, pigeonpea is generally intercropped with maize, sesamum, soybean, mungbean and groundnut. Different maturing habit, growth pattern, nutrient and water requirement and rooting pattern of these crops make them suitable to grow as intercropping system with pigeonpea. Blade *et al.* (1997) [2] argued that the sole crop produced higher yield when insecticide spray is used, most farmers traditionally practices mixed cropping. But in general, intercropping has been reported to be more productive than monocropping (Ghosh *et al.* 2006) [9] this might be through efficient use of light energy and other growth resources. Kamara *et al.* (2017) [12] stated that the optimization of land resource use could be achieved when crops are grown under intercropping and plant population density increased. However, intercropping offers potential advantage for resource utilization, decreased inputs and increased sustainability in crop production as reported by Egbe *et al.* (2010) [8].

In fact, combination of certain crops result in increased competition among component crops and this causes low yields, which may make some crop species unsuitable for intercropping. According to Carruthers *et al.* (2000) [3] increase competition may be for water, nutrients, light or any combination of the three, ultimately leading to changes in crop productivity levels. Therefore, the present investigation was undertaken to determine the productivity of pigeonpea based intercropping and find out the best intercropping system for doubling farmer's income at Taria Region of Uttarakhand.

Materials and Methods

A two year (2010 and 2011) field experiment was conducted in D_6 block of Norman E. Borlaug Crop Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar (Uttarakhand). The centre is situated at 29^0 N latitude, 79.3^0 E longitude and at the altitude of 243.83 metres above the mean sea level. It is located in the *tarai* belt of Uttarakhand, 30 Km southwards of foot hills of Shiwalik range of the Himalayas. The maximum temperature during the crop seasons ranged between 13.6 - 33.3^0C and 18.4-35.6^0C while the minimum temperature varied between 5.3-26.3^0C and 3.7-26.1^0C, respectively. The total rainfall of 1729.2 mm received during first year which was much lower than that of rainfall of 2032.8 received during second year.

The field was ploughed once, harrowed thrice and leveled properly with the help of tractor drawn implements. Pre–sowing irrigation was not applied as sufficient moisture was available in the soil during both the year. A composite soil sample was taken from the experimental plot before sowing of crops upto a depth 15 cm and analyzed for different constituents. The soil of the experimental plot was sandy loam in texture. The soil was found high in organic carbon, low in available nitrogen and medium in available phosphorus and potassium content with neutral in soil reaction.

The experiment plot (4.5 m X 4.0 m) was laid out in split plot design keeping three cropping system as main plot and three fertility status as sub plot with three replications. Among the treatments, Sole Pigeonpea, Pigeonpea + Urdbean (1:2) and Pigeonpea + Maize (1:2)} was selected as cropping system, whereas, Recommended dose of fertilizer (RDF), Recommended dose of fertilizer (RDF) + Farm Yard Manure (FYM) @ 5.0 t/ha and Recommended dose of fertilizer (RDF) + Vermicompost @ 2.5 t/ha) was selected as fertility status during the course of investigation. The Row spacing for pigeonpea, maize urdbean were 90 cm, 45 cm and 30cm respectively.

Recommended dose of fertilizer (RDF) for both urdbean and pigeonpea *i.e.* 20 Kg N + 40 Kg P_2O_5 + 30 Kg K_2O/ha, was applied as basal at the time of sowing. However, in maize RDF was 120 Kg N + 60 Kg P_2O_5 + 40 Kg K_2O/ha. Half of the nitrogen i.e., 60 Kg N and full dose of P_2O_5 and K_2O was applied as basal. Remaining half of N (60 kg N/ha) was top dressed in two equal splits, one at knee high stage and another at tasseling stage of the crop. Urea (46% N), Single Super Phosphate (16% P_2O_5) and Muriate of Potash (60% K_2O) were used as source for nitrogen, phosphorus and potassium, respectively. FYM @ 5.0 t/ha and Vermicompost @ 2.5 t/ha was also applied as per treatment on dry weight basis one week before sowing. Fertilizers in intercropping treatments were given as per row arrangements.

Urdbean (Pant U 31) and maize (Surya) were intercropped with pigeonpea (UPAS 120) as per treatment during both the years of experimentation and the seeds of urdbean/pigeonpea were sown @ 15 kg/ha and of maize @ 20 kg/ha. Pigeonpea and maize were sown on the same day while urdbean was sown 15 and 22 days after pigeonpea and maize sowing in order to avoid the excessive growth. After 15 days of sowing thinning was done in each crop as well as each plot to keep the plant to plant distance at 20 cm in pigeonpea and maize and 10 cm in urdbean, during both the years of experimentation. Weeds were controlled manually with the help of *Khurpi.* During the investigation morpho-metric traits *viz.*, plant height (cm), plant spread (cm), number of branches per plant, No. of pods/plant, Grain weight (g/plant), Straw yield (kg/ha), biological yield (kg/ha), harvest index, yield (kg/ha), pigeonpea equivalent yield (kg/ha), cost of cultivation (Rs./ha), Gross return (Rs./ha) and benefit: cost ratio was calculated for both the year respectively. The following important parameters was calculated according to their formulas,

Pigeonpea grain equivalent yield: Grain yield of urdbean and maize crop obtained from intercropping system was converted into pigeonpea equivalent yield and added with pigeonpea yield of the system on the basis of price of the urdbean and maize. The pigeonpea grain equivalent yield (PEY) was calculated as follows:

1. $$PEY = \frac{Yu}{Pp} \times P_u + Y_p$$

2. $$PEY = \frac{Ym}{Pp} \times P_m + Y_p$$

Where,
PEY = Pigeonpea grain equivalent yield
Y_u = Yield of urdbean as intercrop
Y_p = Yield of pigeonpea (of the same treatment)
Y_m = Yield of maize as intercrop
P_u = Price of urdbean
P_p = Price of pigeonpea
P_m = Price of maize

Benefit: Cost ratio: Benefit–cost ratio was calculated as follows:

$$\text{Benefit: cost ratio} = \frac{\text{Net return}}{\text{Cost of cultivation}}$$

The collected data for various studies in pigeonpea, urdbean and maize crops were subjected to the statistical analysis by using STPR-1, programme developed by department of statistics and mathematics, college of basic science and humanities. Comparison of treatment means was done using critical differences (CD) at 5 per cent level of significance.

Results and Discussion

Growth and Its Components

Growth and its component was affected significantly due to cropping system, and fertility level during both the year of experimentation. Maximum plant height (262.15 and 262.84 cm) of pigeonpea was recorded when intercropped with urd followed by sole pigeonpea (250.37 and 251.90 cm) while pigeonpea plant height decreased when intercropped with maize (229.20 and 235.52 cm) it indicating that the maize crop suppressed pigeonpea plant height during both the years. Intercropped pigeonpea with urd also had maximum plant spread (96.19 and 103.53) than sole pigeonpea (96.53 and 99.55) and minimum pigeonpea plant spread (56.16 and 61.03) was recorded when intercropped with maize (Table 1).

Differences in pigeonpea plant spread when interceropped with urd and maize may be due to the differences in their plant height and growth habits. Significantly lower number of branches per plant (14.54 and 13.64) was counted in pigeonpea + maize intercerpping system whereas; highest average number of branches per plant (30.06 and 28.26) was counted in pegionpea + urd intercropping system which is at par with sole pigeonpea (28.91 and 26.70) during both the years. Similar trend was observed in numbers of trifoliate leaves per plant.

Table 1: Growth and its component traits of pigeonpea at harvest as influenced by cropping system and fertility levels

Treatment	Plant Height (cm)		No. of trifoliate leaves/plant		Plant spread (cm)		No. of branches/plant	
Intercropping system	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
Sole pigeonpea	250.37	251.9	44.71	50.6	96.53	99.56	28.91	26.7
Pigeonpea + Urdbean	262.15	262.84	66.53	73.98	96.19	103.53	30.06	28.26
Pigeonpea + Maize	229.2	235.52	22.04	26.34	56.16	61.03	14.54	13.64
SEm±	2.02	1.5	0.77	1.11	1.58	1.3	0.82	1.15
CD at 5%	5.83	4.33	2.22	3.2	4.57	3.76	2.37	3.34
Fertility level								
RDF	242.67	244.52	42.4	48.06	77.72	78.5	22	20.36
RDF + FYM @ 5 t/ha	248.85	250.7	45.12	51.39	88.21	93.29	24.44	22.95
RDF + Vermi. @ 2.5 t/ha	250.2	252.03	45.76	51.47	88.25	92.33	27.07	25.13
SEm±	2.15	1.66	0.99	1.07	1.65	1.34	0.81	0.85
CD at 5%	6.1	4.81	2.28	3.09	4.77	3.86	2.33	2.47

Minimum growth in Pigeonpea + Maize cropping system might be due to the more competition maize and pigeonpea for moisture, nutrient and solar energy than pigeonpea and urd crop. All the growth and its component traits was higher in pigeonpea + urd cropping system than piegonpea + maize cropping system because of the beneficial effect of urdbean reflected on pigeonpea was probably due to addition of N in soil by decay of urd nodules and also due to insignificant crop competition persuaded by urdbean. Here it may be pointed out that, the competition between pigeonpea and maize for space, sunlight, nutrients, water etc. was more as compared to urdbean which resulted in poor growth and development of pigeonpea under pigeonpea + maize intercropping system. Similar findings have also been reported by Sharma *et al.* (2010) [19], Yadav *et al.* (1997) [25], Bajpai and Singh (1992) [1], and Tewari *et al.* (1989) [22].

In the present study application of vermicompost @ 2.5 t/ha along with Recommended Dose of Fertilizer (RDF) improved the plant growth of pigeonpea in terms of plant height (250.2 cm and 252.03 cm), number of trifoliate leaves (45.76 and 51.47 cm), plant spread (88.25 and 92.33 cm), number of branches per plant (27.07 and 25.13 cm). The positive response of pigeonpea, urdbean and maize to FYM or vermicompost application have also been reported by Singh *et al.* (2008) [21] and Nalatwadmath *et al.* (2003) [15], respectively.

This might be due to application of FYM or vermicompost helps in conversion of unavailable nutrients to available form through increased microbial activity and enables the crop to absorb nutrients resulting in more dry matter accumulation (Rekha and Reddy, 1999) [17]. Besides, FYM and vermicompost improve the physical, chemical and biological properties of the soil, which provided better conditions to the crop. Similar findings have also been reported by Datt *et al.* (2003) [4]. However, it is important to note here that RDF + FYM @ 5.0 t/ha proved as effective as RDF + vermicompost @ 2.5 t/ha. The similar effects of vermicompost at lower dose in comparison to higher dose of FYM on plants are not solely attributed to the quality of mineral nutrition is provided but also to its other growth regulating components such as plant growth hormones and humic acids, plant growth promoting substances such as NAA, cytokinins, gibberellin etc. In comparison to FYM, vermicompost contained nearly two times more N and five times more P_2O_5 and almost equal amount of K_2O. Vermicompost have large microbial diversity and activity, it is possible that vermicompost could be a definitive source of plant growth regulators produced by interactions between microorganisms and earthworms, which could contribute significantly to enhancement of plant growth, at lower doses compared to higher dose of FYM. Vermicompost contain large amounts of humic substances and applications of humic substances to soils increased the dry weights of shoots, roots, and nodules of soybean and peanut plants. Kale *et al.* (1992) [11] also observed that the application of vermicompost @ 5 t/ha + 50% RDF recorded significantly higher value of growth components and yield of sunflower compared to FYM @ 5 t/ha + RDF.

Yield and its components

Crop yield is the ultimate product of conversion of solar energy into useful form of chemical energy which is mainly governed by its genetic makeup. However, efficiency for utilization of solar energy in terms of yield can be enhanced either by the alteration in genetic makeup of crop plant or by agronomic manipulations. Intercropping system is one of the ways of agronomic manipulations which harnesses solar energy more efficiently by changing the microclimate in the system. In present study, yield and yield component its components of pigeonpea significantly influenced by intercropping system (Table 2). Maximum pigeonpea grain yield (1216 and 1892 kg/ha) was recorded when intercropped with urd than sole pigeonpea (1025 and 1415 kg/ha) while statistically minimum pigeonpea grain yield (656 and 675 kg /ha) was recorded when intercropped with maize. Similar trend was observed for biological yield, no. of pods per plant, grain weight, straw yield during both the years. Pigeonpea + urd cropping system had maximum (18.14 and 18.66) harvest index which is at par with sole pigeonpea (17.28 and 17.85) and lowest harvest index (15.82 and 16.83) was recorded in pigeonpea + maize intercropping system.

Intercropping of pigeonpea reduced the maize grain yield per plant by 16.7 per cent and pigeonpea by 41.3 per cent. It showed that intercropping had a little effect on yield per plant of maize, while more suppressive effect on pigeonpea yield per plant. This could be attributed to the faster growth rate of maize as against slow rate of growth of pigeonpea at the early stages of growth which make little shift in competition for above ground resources, especially light energy, between the intercrop components and high demand of nitrogen of maize was met through biological nitrogen fixation from pigeonpea. Presence of legumes in the mixtures benefited the associated non-legumes, as the legumes provide a portion of biologically fixed nitrogen to non-legume components is confirmed by Kavamahanga *et al*. (1995) [13]. These results are in close conformity with the findings of Egbe and Adeyemo (2006) [7] Thakur and Sharma (1988) [23] and Rafey and Prasad (1992) [16].

Pigeonpea equivalent yield was calculated during both the year and maximum pigeonpea equivalent yield (1605 and 2196) was recorded in pigeonpea + urd cropping system than pigeonpea + maize (1333 and 1349) and lowest pigeonpea equivalent yield was recorded in sole pigeonpea (1025 and 1415) during both the year respectively due to an additional yield of intercrops as a bonus in intercropping system. Crop equivalent yield of the intercropping systems involving urdbean and maize with pigeonpea were greater than sole indicating greater biological efficiency in utilization of land, space and time by intercrops and there by yield advantages over the respective sole crops. Similar findings were also reported by Kavamahanga *et al*. 1995 [13]; Dua *et al*. (2005) [5] and Sharma *et al*. (2006) [20].

Application of RDF + vermicompost @ 2.5 t/ha significantly higher number of pods/plant (138.52 and 149.19), Grain weight (38.05 and 52.05 g/plant), straw yield (4567 and 6058 kg/ha), biological yield (5592 and 7447 kg/ha) number of pods per plant significantly over RDF alone, during both the years respectively. However the difference between application of either FYM @ 5.0 t/ha or vermicompost @ 2.5 t/ha were remain non significant. This could be attributed to the higher number yield attributes like number of pods per plant, number of grains per pod of pigeonpea. It was interesting to note that, at constant plant population FYM or vermicompost application altered the per plant yield significantly by altering the values of yield attributes viz; pods per plant, grain weight and number of grains per pod of pigeonpea (Table 2). Sarkar *et al.* (1997) [18] also reported favourable response of pigeonpea to FYM and vermicompost application.

Table 2: Yield attributes and yield of pigeonpea as influenced by cropping system and fertility levels

Treatment	No. of pods/plant		Grain Weight (g/plant)		Straw Yield (kg/ha)		Biological Yield (kg/ha)		Harvest Index		Yield (kg/ha)		Pigeonpea Equivalent Yield (kg/ha)	
Intercropping system	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
Sole pigeonpea	130.2	139.03	38.14	51.14	4777	6481	5802	7910	17.28	17.85	1025	1415	1025	1415
Pigeonpea + Urdbean	177.16	185.45	48.44	63.44	5419	8240	6641	10132	18.14	18.66	1216	1892	1605	2196
Pigeonpea + Maize	103.29	118.13	25.08	39.08	3444	3280	4098	3955	15.82	16.83	656	675	1333	1349
SEm±	1.08	2.06	0.94	0.93	86	26	135	66	0.9	0.3	35	26	56	26
CD at 5%	3.13	5.95	2.7	2.69	271	105	407	211	NS	0.88	135	106	181	79
Fertility level														
RDF	134.6	144.85	35.57	49.57	4271	5873	5150	7076	15.15	16.46	826	1190	1083	1310
RDF + FYM @ 5 t/ha	137.93	148.58	38.04	52.04	4617	6071	5666	7473	18.11	18.55	1050	1389	1333	1521
RDF + Vermi. @ 2.5 t/ha	138.52	149.19	38.05	52.05	4567	6058	5592	7447	17.98	18.34	1029	1376	1346	1574
SEm±	1.13	1.28	0.95	0.94	98	26	148	66	0.93	0.31	70	40	49	26
CD at 5%	3.26	3.72	2.73	2.72	296	105	432	211	2.7	0.88	202	106	142	66

Economics

Pigeonpea + urdbean proved superior intercropping system as this system fetched higher net return (Rs.38513/ha) as well as benefit: cost (B: C) (1.86) ratio than sole pigeonpea (Rs.20500/ha) and pigeonpea + maize (Rs.19322/ha) cropping system (Table-3). This might be due to a sizable increase in pigeonpea yield and additional yield of urdbean, which resulted in higher PEY and net return in pigeonpea + urdbean cropping system than in sole pigeonpea. The findings of present investigation were close conformity with the findings by Dubey *et al*. (1991) [6], Verma (2001) [24] and Kumar and Rana (2007) [14].

The economic significance of different fertility level (Table 3) revealed that the maximum gross return (Rs. 45370/ha) were obtained with the use of RDF + vermicompost @ 2.5 t/ha, while maximum net profit (Rs 25811/ha) and B: C ratio (1.39) were obtained with the application of RDF + FYM @ 5.0 t/ha. The highest net return and B: C ratio with the application of RDF + FYM @ 5.0 t/ha might be due to low price of FYM compared to vermicompost. Undoubtly, such a result quite clearly indicated the superiority of the application of either vermicompost @ 2.5 t/ha or FYM @ 5.0 t/ha along with RDF for profitable cultivation of the intercropping of pigeonpea.

Table 3: Economics of pigeonpea based intercropping system as influenced by cropping system and fertility levels

Treatment	Cost of Cultivation (Rs/ha)	Gross Return (Rs/ha)			Net Return (Rs/ha)			Benefit : Cost ratio		
Intercropping system	**Mean**	**2010**	**2011**	**Mean**	**2010**	**2011**	**Mean**	**2010**	**2011**	**Mean**
Sole pigeonpea	17515	30740	45290	38015	13225	27775	20500	0.75	1.51	1.13
Pigeonpea + Urdbean	20693	48147	70264	59205.5	27454	49571	38512.5	1.32	2.39	1.855
Pigeonpea + Maize	22265	39999	43174	41586.5	17734	20909	19321.5	0.79	0.93	0.86
Fertility level										
RDF	16027	32481	41904	37192.5	16454	25877	21165.5	1.02	1.61	1.315
RDF + FYM @ 5 t/ha	18527	39999	48671	44335	21472	30150	25811	1.15	1.62	1.385
RDF + Vermi. @ 2.5 t/ha	23027	40370	50370	45370	17343	27343	22343	0.75	1.18	0.965

Conclusion

Based on two years investigation it may be concluded that pigeonpea + urdbean intercropping system was identified as more sustainable system compared to pigeonpea + maize, as well as sole pigeonpea for higher productivity and profitability of Pigeonpea in in *Tarai* region of Uttarakhand.

Application of RDF + FYM @ 5.0 t/ha proved most economical and beneficial compared to RDF alone.

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