International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
IJCS 2019; 7(2): 2142-2146

Received: 19-01-2019
Accepted: 23-02-2019

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Yield and soil fertility in pigeonpea based cropping system under different fertility levels in Mollisol of *Tarai* region Uttarakhand

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Abstract
A two years field study was carried out at NEBCRC, GBPUA&T, Pantnagar, Uttarakhand to evaluate the Yield and soil fertility in pigeonpea based cropping system under different fertility levels in Mollisol of Tarai region of Uttarakhand. Results reveals that Maximum pigeon pea yield (1216 and 1892 kg/ha) and soil fertility parameters *viz.* available Nitrogen (218.00 and 223.11 kg/ha), phosphorus (20.94 and 21.23 kg/ha), potassium (215.45 and 271.78 kg/ha), organic carbon (0.86 and 0.88 %), PSB population (19.36 and 20.20 x 10^6) and dehydroginase activity (197.11 and 199.36 µg TPF/24h/g soil) was recorded in Pigeonpea + Urd cropping system than sole and Pigeonpea + Maize cropping system. Application of RDF + vermi @ 2.5 t/ha found as effective as RDF + FYM @ 5.0 t/ha and improved yield and residual soil fertility than RDF alone. Seed inoculation with PSB increased the yield and soil fertility status of soil over no inoculation.

Keywords: Cropping system, pigeonpea, urdmean, RDF and fertility status

Introduction

Being one of the most drought tolerant legumes, pigeonpea (C*ajanus cajan* (L) Millsp.) 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, urdbean, 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.

Among the different factors of production, inadequate fertilizer management has remained major constraint forever. Increasing agricultural production at the cost of deteriorating soil health, declining nutrient supply along with shrinking of natural resources is a daunting task for agronomist. In this context maintenance of soil fertility and/or plant nutrient supply to an optimum level for sustaining the desired productivity through optimization of the benefits from all the possible sources of plant nutrients would be desirable. The integrated applications of fertilizers with organic compost and bio-fertilizer are considered essential for the sustainability of a system.

Farmyard manure (FYM), though not useful as a sole source of nutrients, has a good complementary and supplementary effect with mineral fertilizer Chaudhary *et al.* (2004) [3]. In comparison to FYM, vermicompost is enriched with nearly two times more N and five times more P2O5 and equal K2O. Orozco *et al.* (1996) [10] reported that composting increased the availability of nutrients such as phosphorus, calcium and magnesium, after processing by Eisenia fetida. 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, and yields. In pulses, phosphorus is known to encourage root development in terms of root proliferation, ramification and greater root mass and also enhance the activity of Rhizobia resulting in increased nitrogen fixation by root nodules. Ali and Kumar, (2007) [1] has reported that, seed inoculation with Rhizobium and PSB improved productivity of pulses by 12-21%.

Under present scenario where food and nutritional securities are under threat, it has become imperative to ameliorate the soil-plant- atmosphere continuum as a whole rather than feeding the crops alone. With this background, present investigation “Yield and soil fertility in pigeonpea based cropping system under different fertility levels in Mollisol of Tarai region of Uttarakhand" has been conducted.

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 (0.80 and 0.81%), low in available nitrogen (205.6 and 211.2 kg/ha) and medium in available phosphorus (16.3 and 17.9 kg P/ha) and potassium (184.6 and 185.5 kg K/ha) content with neutral in soil reaction (pH= 7.4 and 7.2).

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), number of trifoliate leaves per plant, plant spread (cm), number of branches per plant, No. of pods per plant, Grain weight (g/plant), Straw yield (kg/ha), biological yield (kg/ha), harvest index, yield (kg/ha), pigeonpea equivalent yield (kg/ha), Nitrogen (kg./ha), phosphorus (kg./ha), potassium (kg/ha), Organic carbon (%), PSB population (x10^6) and dehydroginase activity (µg TPF formed per gram of dry soil per 24 hours) was calculated for both the year respectively. The important parameters were calculated according to their formulas.

Soil sample of 0 –15 cm depth was collected plot wise at harvest for soil chemical analysis, air dried in shade, powdered with the help of wooden roller and passed through 2 mm sieve. Organic carbon (%) by Walkley and Black method developed by Walkley and Black, (1934) [21], Available status of nitrogen (kg/ha) by Alkaline potassium permanganate ($KMnO_4$) method developed by Subbaiah and Asija, (1956) [18], phosphorus by Olsen's method developed by Olsen *et al.* (1954) [9], potassium by Neutral normal NH_4OAC method developed by Jackson, (1973) [7] was estimated.

Pikovskaya's agar medium was sterilized in autoclave at 1.06 kg/cm^2 pressure at 121^0C for 30 minutes. Sterilized medium (about 15ml) was poured into sterilized Petri plates. Serial dilution of 10^{-6} was prepared and 1 ml of it was planted on Pikovskaya's agar medium. Plates were incubated at 28±2^0C for 2 days in an inverted position and number of colonies was counted. The plates were selected from dilution (10^{-6}), which contained colonies in the range of 30–300 and plate counts were made. Dilution (10^{-6}) was replicated thrice and the average of three replications was determined. Then number of micro–organisms (Total PSB Count) was calculated by applying following formula:

Number of micro–organisms (PSB)/ml=

$$\frac{\text{Number of colonies (average of 3 replications)xDilution factor}}{\text{Volume of sample (ml)}}$$

Dehydrogenase activity of soil was determined by colorimetric procedure of Tabatabai (1982) [19]. For this purpose one gram of air dried soil was taken in an air tight screw capped test tube. 0.2 ml of 3.0% 2, 3, 5 triphenyl tetrazolium chloride (TTC) solution was added to each tube to saturate the soil. Thereafter 0.5 ml of 1.0 % of glucose solution was added to each tube, ensuring no air bubble formation. Tubes were inoculated at 28±0.5^0C for 24 hours at 35^0C in dark. After inoculation, 10 ml of methanol was added and shaken vigorously. The samples were put to stand in a refrigerator for 6 hours to allow settling down of soil particles and better extraction of TriPhenyl Formazan (TPF). The clean pink colored supernatant liquid was withdrawn and readings were taken with a spectrophotometer at wavelength of 485 nm (blue filter). Results were expressed in terms of µg TPF formed per gram of dry soil per 24 hours.

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, GBPUAT, Pantnagar, Uttarakhand. Comparison of treatment means was done using critical differences (CD) at 5 per cent level of significance.

Results and Discussion

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 1). 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) [8]. These results are in close conformity with the findings of Egbe and Adeyemo (2006) [5] Thakur and Sharma (1988) [20] and Rafey and Prasad (1992) [12].

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 [8]; Dua *et al*. (2005) [4] and Sharma *et al*. (2006) [17].

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) [14] also reported favourable response of pigeonpea to FYM and vermicompost application.

Table 1: 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
PSB Inoculation														
PSB	135.49	145.87	36.08	50.08	4555	5952	5395	7422	16.04	17.23	888	1283	1159	1415
No PSB	138.54	149.21	38.36	52.36	4641	6058	5654	7433	18.12	18.33	1044	1376	1346	1521
SEm±	0.92	1.05	0.73	0.77	74	26	111	52	0.76	0.25	61	13	53	13
CD at 5%	2.66	3.03	NS	NS	NS	79	NS	NS	NS	6.72	NS	66	153	53

Effect on residual soil fertility

Effect of intercropping system

Significantly higher content of available phosphorus was obtained in pigeonpea + urdbean than rest of the other systems, during both the years. The minimum available phosphorus content was recorded in pigeonpea + maize treatment. Pigeonpea and urdbean, being legume crops, are likely to make liberal use of atmospheric nitrogen by symbiosis process and thus, may add in the fertility status of soil resulting improvement in PSB population (16.95 and 17.34 $x10^6$) (Table 2) and the physical condition of soil. It is well elucidated from the present study where intercropping of pigeonpea + urdbean improved the level of available N (218 and 223 kg/ha), P (20.94 and 21.23 kg/ha), K (215.45 and 217.78 kg/ha) and organic carbon (0.86 and 0.88 %) over pigeonpea + Maize in the soil, however, it remained on par with pigeonpea sole (Table 2). It might be due to the fact that legumes contribute more to the organic matter pool than do non-legumes during decomposition, and use less N from this pool while growing. Consequently, there is often more nutrient left in the soil. It may, further be seen that when maize was grown as intercrop with pigeonpea, significant reduction took place in the fertility status of above nutrients. Here, it may be pointed out that, maize is a heavy feeder crop which removed higher amounts of N, P and K, and resulted poor fertility status of soil, even lower than original status of available N, P, K and organic carbon (%).

Pigeonpea + urdbean cropping system numerically increased dehydrogenase activity (197.11 and 199.36 µg TPF/24h/g soil) of soil over remaining cropping system during both the years (Table 2). This is possibly due to both pulses root exudates and secretions, organic residue added in soil through leaf fall, decomposing root nodule and root tissue also provides carbon and energy to the soil microbes resulting into higher dehydrogenase activity. Similar results have been reported by workers Geethakumari and Shivashankar, (1991) [6].

Effect of fertility level

Fertility treatment, RDF + vermicompost @ 2.5 t/ha and RDF + FYM @ 5.0 t/ha were statistically comparable and increased the nitrogen (208.90 and 210.03 kg/ha), phosphorus (18.46 and 19.02 kg/ha), potassium (206.66 and 208.01 kg/ha) and organic carbon (0.82 and 0.85 %) content significantly in soil after harvest of crop over RDF alone during both the years. On reviewing the results (Table 2), it is quite clear that increase in the availability of N, P, K and organic carbon in the soil with organic manure may be attributed to addition of nutrients. Besides, FYM and vermicompost reacts with native nutrients present in the soil and thereby improved the soluble and available forms of nutrients. Bhardwaj and Omanvar (1994) [2] also opined the similar views. According to Shapira *et al*. (1987) [16], organic nitrogen compounds upon decomposition get splitted into simpler forms, which results in the release of NH^{+4}-N. A portion of it is adsorbed to cation exchange sites of the soil and remaining is readily available to plants. Thereafter a steady out flow from exchange complex indicates continued supply of N to crop. Organics like FYM could enhance the available P content in soil. Further, they stated that, the appreciable increase of organic phosphorus in soil is done by complexing the cations like Ca, Mg and Al which are responsible for fixation of phosphorus.

Among different fertility levels, application of RDF + vermicompost @ 2.5 t/ha gave significantly more PSB population (18.34 and 18.47 x10^6) than RDF alone (15.24 and 15.40 x10^6) during both the years. Here, it may also be pointed out that the addition of FYM also increased microbial (PSB) population (Table 2) which also contributed in restoration of fertility status of soil.

Maximum dehydrogenase activity (187.52 and 184.97 µg TPF/24h/g soil) was found with RDF + vermicompost @ 2.5 t/ha treated plot. This could be supported by study of Fraser *et al*., (1988) who linked dehydrogenase activity with the level of readily available organic carbon status of soil and Dinesh *et al*. (2004) who reported that there is positive relationship of dehydrogenase activity with the organic carbon content of soil. The reason for maximum dehydrogenase activity may be because of significant role of this enzyme in the oxidation of soil organic matter by transferring H from substrate (organic matter) to acceptors. The stronger effect of FYM or vermicompost on dehydrogenase activity might be due to the more easily decomposable component of these manure on metabolism of soil microorganism.

Effect of PSB inoculation

It may be recalled from Table 2 that available N (206.84 and 208.44 kg/ha), P (18.06 and 18.62 kg/ha), K (205.83 and 207.50 kg/ha) and organic carbon (0.81 and 0.83 %) in soil were improved with PSB-inoculation during both the year of investigation. However, the significant improvement was made only in phosphorus status. Increased nitrogen availability may be due to increase in symbiotic activities and higher nodule number, as root nodules also release some part of fixed nitrogen to soil. Similar results were reported by Rout and Rout and Kohire (1991) [13] and Pal (1997) [11]. Higher phosphorus availability with PSB inoculation may be due to phosphorus solubilizing ability of PSB. Sayed (1998) [15] also observed increased available phosphorus in soil due to seed inoculation with PSB.

Table 2: Status of available nitrogen, phosphorus, potassium, organic carbon and microbial heterogineity of soil at harvest as influenced by cropping system, fertility levels and PSB inoculation

Treatment	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)		Organic Carbon (%)		PSB Population (x10^6)		Dehydroginase activity (µgTPF/24h/g soil)	
Intercropping system	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**	**2010**	**2011**
Sole pigeonpea	209.05	211.05	17.91	19.11	208.15	209.98	0.81	0.84	17.64	17.19	185.31	183.54
Pigeonpea + Urdbean	218.00	223.11	20.94	21.23	215.45	217.78	0.86	0.88	19.36	20.20	197.11	199.36
Pigeonpea + Maize	196.22	195.17	15.34	15.83	200.20	201.43	0.76	0.81	16.95	17.34	179.05	175.30
SEm±	3.56	3.22	0.76	0.73	1.97	1.86	0.01	0.013	0.42	0.48	2.10	2.19
CD at 5%	10.13	9.16	2.17	2.00	5.62	5.30	0.03	0.039	1.20	1.39	5.98	6.22
Fertility level												
RDF	197.53	198.63	15.86	16.64	201.76	200.08	0.77	0.80	15.24	15.40	180.59	178.17
RDF + FYM @ 5 t/ha	207.86	209.17	17.33	17.89	206.46	206.83	0.80	0.83	17.53	17.72	186.07	183.48
RDF + Vermi. @ 2.5 t/ha	208.90	210.03	18.46	19.02	206.66	208.01	0.82	0.85	18.34	18.47	187.52	184.97
SEm±	2.97	2.65	0.63	0.58	1.59	1.53	0.01	0.011	0.34	0.39	1.70	1.78
CD at 5%	8.44	7.54	1.81	1.66	4.52	4.37	0.03	0.032	0.99	1.12	4.84	5.06
PSB Inoculation												
PSB	202.68	203.44	16.37	16.93	204.09	205.77	0.79	0.82	16.44	16.60	182.75	180.91
No PSB	206.84	208.44	18.06	18.62	205.83	207.50	0.81	0.81	0.83	17.80	186.70	183.50
SEm±	2.42	2.17	0.52	0.47	1.29	1.25	0.01	0.009	0.28	0.32	1.39	1.45
CD at 5%	NS	NS	1.48	1.35	NS	NS	NS	NS	0.81	0.92	3.95	4.13

Conclusion

Based on two years investigation, Maximum yield and higher soil fertility 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 yield and residual soil fertility than Recommended Dose of Fertilizer alone. Seed inoculation with PSB increased the yield and residual soil fertility status of soil over no inoculation.

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