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Nodulation and Yield of Pigeonpea Based Intercropping System as Influenced by Integrated Nutrient Management in Mollisols of the *Tarai* Region

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A B S T R A C T

The effect of integrated nutrient management on nodulation and yield of pigeonpea based intercropping system were investigated. A field experiment was carried out during *kharif* season of 2007 and 2008 at N.E. Borlaug Crop Research Centre, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Uttarakhand to assess the effect of three cropping system (pigeonpea sole, pigeonpea + blackgram and pigeonpea + maize), two levels of inoculation [with and without phosphorus solubilizing bacteria (PSB)] and three levels of farm yard manure (0, 2.5 and 5.0 t ha^{-1}) on nodulation and yield of pigeonpea, blackgram and maize. Eighteen treatment combinations were replicated three times in a factorial randomized block design. The soil of experimental site is characterized as upland Mollisols of the *Tarai* region. Results revealed that intercropping of blackgram with pigeonpea recorded higher values of nodules characters of pigeonpea such as number of nodules per plant, nodule fresh weight, nodule dry weight, nodulation index and yields of pigeonpea and its equivalent over its other counter parts. Similar results were also obtained with PSB-inoculation and FYM @ 5.0 t ha^{-1} for nodulation and yield of main & inter crop.

Introduction

Pulses have played an important role in the agricultural economy in sustaining the productivity of soil. Out of major rainfed pulses, pigeonpea [*Cajanus cajan* (L.) mill sp.] is one of the most important pulse crop grown in India. The low productivity of pigeonpea in the country may be ascribed to many reasons, however inadequate and imbalanced fertilization, limited seed inoculation, indeterminate growth, flower drop and dry matter partition are important. It has potential to give comparable yield under improved management system. Pigeonpea have been replaced by short duration and photo-insensitive cultivars, viz. ‘UPAS 120’, ‘T21’, ‘ICPL 87’. The cultivation of these varieties becomes popular because they provide opportunity for late sown wheat

(*Triticum aestivum* L. emend.).There is possibility of growing short duration intercrops like blackgram (*Vigna mungo* L.), greengram and cow pea with pigeonpea, as the growth of the letter crop plants remain quite slow with little canopy during early stage (Rajput *et al.,* 1995).The green revoulation brought impressive gains in food production but due to intensive use of agro-chemicals soil biodiversity is being disturbed. There is now fabulous pressure on growers to use integrated nutrient management approach to increase productivity and soil health. Organic amendment offers an alternative tactic to increase production (Meena, 2013). Biofertilizers are cheaper, eco-friendly and based on renewable energy sources has gained momentum to supplement the parts of chemical fertilizer (Meena *et al.*, 2015a). Inoculation with an effective and persistent PSB strains has numerous benefits, which increase the pod yield due to increased nodulation (Podile, 1995). The use of farm-derived source such as FYM has extensively been used in various crops. These organic additives can be used to promote the development of beneficial organisms in the soil, water holding capacity and cation exchange capacity (Singh *et al.*, 2008). Organic amendment also increases the efficiency of biofertilizers. Therefore, the present investigation was undertaken to see the response of ‘UPAS 120’ a short duration pigeonpea cultivar, to study the effect of integrated nutrient management on nodulation and yields of component crops in pigeonpea based intercropping system in Mollisols of *Tarai* region.

Materials and Methods

Achallenge was made to study the response of pigeonpea based intercropping system to integrated nutrient management on Mollisols. A field experiment was conducted during *kharif* seasons of 2007 and 2008 at N.E. Borlaug Crop Research Centre, GovindBallabh Pant University of Agriculture and Technology, Pantnagar is situated at 29^{o}N latitude, 79^{o}30’ E longitude and at an altitude of 243.83 meter above mean sea level (M.S.L.) under sub-humid and sub-tropical climate zone with hot dry summers and cool winters in *Tarai* region, 25 km away from the foot hills of Himalayas. *Tarai* region remains dry from early October to mid-June and wet from mid-June to early October. The maximum temperature is recorded in May-June (38^{o}C) and the lowest in December-January (4^{o}C) with occasional frost. Relative humidity is the highest in July (81%) and the lowest in May (37%). The average annual rainfall is 1400 mm and most of it is received during monsoon season between June and September. The soil of experimental area was sandy loam in texture with neutral pH (7.2). Eighteen treatments comprised of three cropping system (pigeonpea sole, pigeonpea + blackgram and pigeonpea + maize), two levels of inoculation (with PSB and without PSB) and three FYM levels (0, 2.5 and 5 t ha^{-1}) were tested in factorial randomized block design with three replications. The crop pigeonpea (*cv*. UPAS-120), blackgram (*cv*. Pant Urd-40) and maize (*cv*. Surya) was sown on 2nd and 16th July during 2007 and 2008, respectively. The plant-to-plant spacing of pigeonpea and maize was maintained at 20 cm and of blackgram at 10 cm by thinning out extra plants at 15 days after sowing. Intercultural operations *i.e.* weeding and bird watching were taken care of during crop growing season in both the years. After field preparation, a basal dose of 20 kg N, 40 kg P_2O_5 and 30 kg K_2O ha^{-1} to pigeonpea & blackgram and 60 kg N, 60 kg P_2O_5 and 40 kg K_2O ha^{-1} to maize was applied irrespective of fertilizer treatment. Remaining half amount (60 kg N ha^{-1}) was top-dressed to maize rows only in two equal splits at knee height and tasseling stages. The N, P and K were applied through urea, single super phosphate and muriate of potash. Seeds of crops were inoculated with PSB (*Bacillus polymyxa*) before sowing. The crop was sprayed with thiodon + metasystox (1:1 ratio) by using 700 litres of water ha^{-1} at 90 DAS and pod filling stages for the control of *Maruca* and *Heliothis*. Intercrop blackgram was harvested at 100 and 105 days after sowing (DAS) while maize was harvested at 94 and 83 DAS during 2007 and 2008, respectively. The pigeonpea crop was harvested on 29th December in 2007 and 30th December in 2008. The experimental site experienced a total rainfall of 1244.8 and 1667.2 mm during the crop period in 2007 and 2008, respectively.

Five plants were randomly selected in each plot to count the number of nodules per plant and weighed to get their fresh weight. The nodules thus obtained was kept in the petri dish and dried in the oven at 70 ± 1°C for 48 hours to record the dry weight of nodules per plant. The nodulation index, which accounts for the effect of the plant size on nodules mass, was calculated for each plant sample by using the formula as suggested by Betts and Herridge (1987).

$$\text{Nodulation index} = \frac{\text{Nodule dry weight per plant (g)}}{\text{Dry matter yield per plant (g)}} \times 100$$

The plants from the net plot area (9.6 square meters) in each plot were harvested, bundled, weighed after sun drying.

Thereafter, the materials were threshed and to record the biological yield (grain + stalk yield) per plot, which was converted to kg ha^{-1}. The pigeonpea equivalent yield was calculated by using following formula:

Pigeonpea equivalent yield (q ha^{-1}) = [Price of urd/maize x Yield of urd/maize (q ha^{-1})] / [Price of pigeonpea] + Yield of pigeonpea (q ha^{-1})

All the data were analyzed statistically by applying ANOVA technique (Panse and Sukhatme, 1978). The differences among treatments were compared by applying "F" test of significance at 5 per cent of probability.

Results and Discussion

Effect of integrated nutrient management in pigeonpea based intercrop on nodulation

The data pertaining to number of nodules per plant, fresh weight, dry weight and nodulation index of pigeonpea are furnished in table 1. The number of nodules, fresh and dry weight of nodules per plant and nodulation index in pigeonpea significantly increased under pigeonpea + blackgram intercropping system compared to sole and pigeonpea + maize intercropping. Higher values of no. of nodules (11.68 and 11.2), nodule fresh weight (169.0 and 154.67 mg $plant^{-1}$), nodule dry weight (17.85 and 15.66 mg $plant^{-1}$) and nodulation index (0.2053 and 0.2056) in pulse + pulse intercropping system during both the years. Better nodulation and more fresh and dry weight occurred in pigeonpea + blackgram intercrop of pigeonpea that might be attributed to better photosynthesis and translocation of photosynthate to root nodules, because of adequate light and space. These results are in secure accord with the findings of Singh and Faroda (1986).

The enhancement in nodulation in terms of nodule, their fresh and dry weight and nodulation index per plant of pigeonpea were obtained by the efficiency of inoculated of *Bacillus polymyxa* in the results in both the years over uninoculated control. PSB-inoculation resulted in significant increase in nodule number, their fresh and dry weight and nodulation index of pigeonpea (9.08, 119.56 mg, 13.92 mg and 0.1763 in 2007 and 8.57, 111.22 mg, 12.21 mg&0.1808 in 2008), respectively.

Table.1 Nodules number, fresh weight, dry weight and nodulation index of pigeonpea as influenced by integrated nutrient management in pigeonpea based intercropping system

Treatment	No. of Nodules per plant		Nodule Fresh Weight (mg plant^{-1})		Nodule Dry Weight (mg plant^{-1})		Nodulation Index	
	2007	2008	2007	2008	2007	2008	2007	2008
A. Cropping System								
Sole pigeonpea	9.32	8.78	110.00	101.83	14.06	12.33	0.1831	0.1867
Pigeonpea + Blackgram	11.68	11.02	169.00	154.67	17.85	15.66	0.2053	0.2056
Pigeonpea + Maize	3.99	3.80	39.33	37.00	6.34	5.56	0.1128	0.1157
S.Em.±	0.18	0.17	2.37	2.01	0.22	0.19	0.0018	0.0017
CD (5%)	0.51	0.48	6.82	5.78	0.62	0.54	0.0053	0.0050
B. PSB inoculation								
With PSB	9.08	8.57	119.56	111.22	13.92	12.21	0.1763	0.1808
Without PSB	7.58	7.17	92.67	84.44	11.58	10.16	0.1578	0.1579
S.Em.±	0.15	0.14	1.94	1.64	0.18	0.15	0.0015	0.0014
CD (5%)	0.42	0.39	5.57	4.72	0.50	0.44	0.0043	0.0042
C. FYM levels (t ha^{-1})								
0	6.36	6.00	62.33	58.33	9.69	8.50	0.1449	0.1530
2.5	8.09	7.63	105.17	95.33	12.31	10.79	0.1626	0.1653
5.0	10.55	9.97	150.83	139.83	16.26	14.26	0.1937	0.1897
S.Em.±	0.18	0.17	2.37	2.01	0.22	0.19	0.0018	0.0017
CD (5%)	0.51	0.48	6.82	5.78	0.62	0.54	0.0053	0.0050
CV (%)	9.08	9.01	9.49	8.72	7.15	7.06	4.69	4.44

Table.2 Grain yield of component crops and pigeonpea equivalent yield as influenced by integrated nutrient management in pigeonpea based intercropping system

Treatment	Yield (Kg ha^{-1})							
	Pigeonpea		Blackgram		Maize		Pigeonpea Equivalent	
	2007	2008	2007	2008	2007	2008	2007	2008
A. Cropping System								
Sole pigeonpea	1631	1394	-	-	-	-	1631	1294
Pigeonpea + Blackgram	1833	1484	597	486	-	-	2476	2096
Pigeonpea + Maize	1057	820	-	-	2557	2047	2036	1679
S.Em.±	57	48	-	-	-	-	67	57
CD (5%)	163	137	-	-	-	-	193	164
B. PSB inoculation								
With PSB	1581	1260	641	526	2760	2217	2164	1791
Without PSB	1432	1139	553	446	2353	1876	1931	1589
S.Em.±	46	39	24	23	120	94	55	47
CD (5%)	133	112	77	71	379	296	158	134
C. FYM levels (t ha^{-1})								
0	1290	999	463	362	2054	1666	1718	1384
2.5	1492	1189	558	457	2645	2049	2030	1668
5.0	1738	1410	771	640	2972	2424	2395	2018
S.Em.±	57	48	30	28	148	115	67	57
CD (5%)	163	137	94	87	465	362	193	164
CV (%)	16.01	16.82	12.26	13.98	14.13	13.74	13.91	14.34

Podile (1995) also found increasing nodulation in pigeonpea (18-24%) by the inoculation of seeds with *Bacillus subtilis* over control. This may be due to produce many plant growth-promoting substance like IAA, gibberellic acids and vitamins etc., which help in the synthesis of nodular tissue.

Application of FYM brought about significant changes in no. of nodules, fresh & dry weight and nodulation index during both the years. The increased fresh and dry weight of nodules under higher doses of FYM might be because of beneficial effects of FYM on number of nodules assuming that FYM has direct role in biological nitrogen fixation in legumes, by increasing the nodules weight of pigeonpea and intercrop blackgram. Sufficient amount of FYM also enhanced the activities of *Rhizobia* and increased the formation of nodules. Singh *et al.,* 1998 and Singh *et al.,* 2008 also reported similar findings.

Effect of Integrated Nutrient Management in pigeonpea based intercrop on yields of component crops and pigeonpea equivalent

Data in respect of grain and straw yield of pigeonpea and intercrop (blackgram and maize) are presented in table 2. Significantly higher grain yield (1833 and 1484 kg ha^{-1}) of pigeonpea was obtained under pigeonpea + blackgram cropping system during both the years as compare to its sole crop (1631 and 1294 kg ha^{-1}) and intercrop with maize (1057 and 820 kg ha^{-1}). This might be due to complimentary effect of blackgram, which supplemented nitrogen to pigeonpea, and the better utilization of environmental resources in the intercropping system. On the contrary, maize intercropped with pigeonpea had adverse effect on pigeonpea yield resulting in significant reduction in grain yield (54 and 58%) as comparable to the sole pigeonpea. This might be due to poor dry matter accumulation of pigeonpea crop and vigorous growth of component cereal like maize (Singh and Pal, 2003). Seed inoculation with phosphorus solubilizing biofertilizer recorded significantly improvement in grain yield of pigeonpea (1581 and 1260 kg ha^{-1}) and intercrops viz., blackgram (641 and 526 kg ha^{-1}) and maize (2760 and 2217 kg ha^{-1}) as compared to uninoculation in 2007 and 2008, respectively. This may be due to ability of PSB in producing indole acetic acid, solubilization of tricalcium phosphate, inhibition of *Aspergillus flavus* and *Aspergillus niger in vitro* and best in rhizosphere colonizer, which enhanced yield attributing characters of crops and finally the grain yields. These results are in close conformity with those of Reddy *et al.,* 2000.

Grain yield of pigeonpea (1738 and 1410 kg ha^{-1}) and intercrop blackgram (771 and 640 kg ha^{-1})/ maize (2972 and 2424 kg ha^{-1}) was significantly higher when 5.0 t FYM ha^{-1} was applied to crops in 2007 and 2008, respectively. However, application of only chemical fertilizer (no FYM) caused significant reduction in grain yield of crops during both the years. Since FYM forms different organic complexes with the metal cations, it helps in decreasing their losses from the system. This could have helped in manipulation of nodulation and yields.

Erikson and Mortensen (1999) also reported similar findings. The maximum productivity in terms of pigeonpea grain equivalent yield was recorded with pigeonpea + blackgram (2476 and 2096 kg ha^{-1}) which was significantly superior to pigeonpea + maize (2036 + 1679 kg ha^{-1}) and sole pigeonpea (1631 and 1294 kg ha^{-1}) in both the years. The higher grain equivalent yield under intercropping system might be attributed to additional advantage of intercrop yield and their support rice (Reddy *et al.*, 2007). Similarly, PSB-inoculation and application also increase the pigeon equivalent yield.

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