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Utilization of cultivable upland of Jharkhand through legume based intercropping system

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Abstract
A field experiment was conducted under All India Coordinated Research Project on (Pulse Research) of Birsa Agricultural University, Ranchi (Jharkhand) to study the suitability of Black gram as intercropped with Pigeon pea (*Cajanus cajan*) and Maize under varied source of Phosphorus during two consecutive *Kharif* seasons 2016 and 2017. Pooled data showed that, Pigeon pea + Black gram (1:1) at 50 % RDP+ 40 ppm nano P produced higher system productivity in terms of Black gram yield 1977 kg/ha, Land equivalent ratio 1.64 and benefit: cost ratio 1.83. However, Pigeon pea + Black gram (1:1) grown at 50 % RDP + 40 ppm nano P which were at par at 100 per cent recommended dose of Phosphorus.

Keywords: pigeon pea, black gram, maize, nano, phosphorus, p-use efficiency and legume based intercropping system

Introduction
Newly separated state Jharkhand is Middle to Southern part of undivided Bihar, which comes into existence during November 2000. At present it comprises total 24 districts, which comes under Agro climatic sub division IV, V and VI. Land of this state is undulating, platue, plain and red laterite soil *ie Alfisol* is major class of soil.

Agriculture in Jharkhand is mainly rain fed with predominance of upland condition, which is characterized by undulating terrain, shallow soil depth, low water retention capacity and poor soil fertility and fragmented holdings with meager irrigation facility. Black gram is one of the important pulse crops in India. The crop has special importance in intensive cropping system of the country due to its short maturity period and weeds being less competitive against it during early crop growth stage. Under upland situation of Jharkhand pulses and maize can be successfully grown as sole and as intercropped. As, intercropping of legumes with cereals offers scope for developing energy efficient and sustainable agriculture. Efficiency of production in cereal-legume intercropping systems could be improved by minimizing inter-specific competition between the component crops for growth limiting factors. Intercrop of black gram with pigeon pea or maize can be a suitable option for rain fed upland condition, as this region largely depends upon vagaries of monsoon. Black gram being a good option being short duration crop fits well in the intercropping system and its roots fix atmospheric nitrogen, breaks hardpans and utilize nutrients from deeper region besides, luxuriant initial growth habits suppresses weed growth. Apart from crop selection its proper fertilization is considered as a barometer of agricultural production, which plays a key role in agricultural productivity and transforms the country from a food scarce region to food sufficient nation. Besides nitrogen, Phosphorus being the major nutrient plays a vital role in energy transformation, uniform grain filling, grain quality and higher yield. Also, contribution of P for protein and oil production is un-debatable. Phosphorus, as usual helps in better root proliferation which extracts moisture from deeper layer of the soil particularly during moisture stress condition. However, acid lateritic soil of Jharkhand witnesses the major problem of applied P fixation and thereby causes low nutrients use efficiency and low yield of crops. This condition demands a smart nutrient delivery system so that crop can be supplied with proper and balanced amount of plant nutrients particularly P-in acidic soil for maximum yield realization. In the recent past, application of Nano-P fertilizer has given a new dimension to crop production (Tarafdar *et al.* 2012). Keeping the above facts in view present experiments was conducted on “Utilization of cultivable upland of Jharkhand through legume based intercropping system”.

Materials and Methods

A Field experiment was conducted during two consecutive *Kharif* seasons of 2016 and 2017. The soil of the experimental field was sandy loam in texture, slightly acidic in reaction having, physical and chemical properties mentioned here under (Table 1).

Table 1: Physiochemical properties of the soil of experiment plot (Initial).

Soil character	pH	Org C	Avail. N	Avail.P_2O_5	Avail.K_2O	Ec	WHC
values	5.4	4.2 (g kg^{-1})	191.7 kg/ha	23.21 kg/ha	157.8 kg/ha	0.06 d S m^{-1}	37.6 %

The experiment was laid out in split plot Design (SPD) with seven main plot treatments namely, C1 : Sole black gram (30 cm), C_2 : Sole pigeon pea (60 cm), C_3 : Sole maize (60 cm), C_4 : Pigeon pea + Black gram (60/30cm) 1:1, C_5 : Maize + Black gram (60/30cm) 1:1, C_6 : Pigeon pea + Black gram (90/30cm) 1:2 and C_7 : Maize + Black gram (90/30cm) 1:2 under main plot and four different dose and types of Phosphorus *i.e* P_1- Control, P_2- Nano-P @ 40 ppm as foliar spray at 20 days after sowing (DAS), P_3- 50% Recommended-P + Nano-P @ 40 ppm as foliar spray at 20 DAS and P_4- 100% Recommended-P under sub plot. Data on different growth and yield were taken and using the standard established mathematical formula under mentioned parameter year wise are elaborated here.

System productivity

Yield of individual crop being converted into yield of Black gram on the basis of respective rate. Further, System productivity was calculated in terms of black gram equivalent yield (BEY) by taking minimum support price of black gram, pigeon pea and maize issued by Government of India for the 2017-18.

Land equivalent ratio (LER)

Land equivalent ratio is the most useful single index for expressing the yield advantage in intercropping defined as the relative land area required as sole crop to produce the some yield as intercropping (Willey, 1979) [1]. Land equivalent ratio which is an index for expressing the yield advantage in intercropping and measures biological efficiency of an intercrop was determined by the following formula used by Willey and Osiru (1972*)* [2].

$$\text{LER} = L_a + L_b = \frac{Y_a}{X_a} + \frac{Y_b}{X_b}$$

Where,

$Y_a + Y_b$ = total plot yield per unit area

Y_a & Y_b = the individual crop yields in the intercropping situation

X_a & X_b = the yield of crops a and b as sole crop

L_a & L_b = the LERs for individual crops

Benefit: cost ratio: It is the ratio of net return per unit cost involved. The formula used for calculating B:C ratio was as below

$$\text{Benefit : cost ratio} = \frac{\text{Net return(Rs. ha} - 1)}{\text{Cost of cultivation (Rs. ha} - 1)}$$

Data of individual year were recorded and after pooling subjected to statistical analysis through standered formulla prescribed by Cochran, and Cox (1957) [3].

Result and Discussion

System productivity in terms of Black gram equivalent yield (kg ha^{-1})

Data presented in Table 2 revealed that significantly maximum black gram equivalent yield (1763 kg ha^{-1}) was recorded under pigeon pea + black gram 1:1 system which is statistically at par with pigeon pea +black gram 1:2 followed by maize + black gram 1:2 and maize + black gram 1:1. All the crop combination gave higher black gram equivalent yield and was found superior over sole crop of black gram, pigeon pea and maize. The lowest black gram equivalent yield was obtained with sole maize (884 kg ha^{-1}). However, cropping system C_4 and C_6 recorded significantly superior system productivity over C_5 and C_7 treatments. With regards to phosphorus management practices, it markedly influenced the black gram equivalent yield as evident from data. Maximum black gram equivalent yield (1438 kg ha^{-1}) was registered under 50% RDP + Nano-P 40 ppm (P_3) which was statistically at par with 100% RDP (P_4) followed by Nano-P 40 ppm (P_2). The application of no phosphorus (P_1) recorded lowest system productivity (1111 kg ha^{-1}).

Interaction effect between crop combination and phosphorous management was significant. System productivity of pigeon pea + black gram 1:1(C_4) or pigeon pea + black gram 1:2 systems (C_6) with application of Nano-P 40 ppm (P_2) in similar crop combination were found superior to no phosphorus application (P_1) whereas, maize + black gram 1:1 (C_5) or maize + black gram 1:2 (C_7) with application of Nano-P 40 ppm (P_2) remained at par with no phosphorus application (P1) in similar crop combination. However, maximum system productivity was recorded under pigeon pea + black gram 1:1 (C_4) x 50% RDP+ 40 ppm Nano-P (P_3) which remained at par with C_6 x P_3, C_4 x P_4 and C_6 x P_4 but superior to the rest of the combinations.

The pigeon pea + black gram 1:1 was found maximum at all the phosphorus levels *i.e.* P_2, P_3 and P_4 which was at par with pigeon pea + black gram 1:2. Maximum BEY (1977) was recorded with the treatment combination of pigeon pea +black gram 1:1with 50 % RDP + Nano- P 40ppm (P_3). It was observed that at different levels of P in pigeon pea + black gram 1:1 the BEY increase significantly up to P_3 after that *i.e.* at P_4 the BEY reduced significantly. In maize + black gram 1:1 (C_5) and maize + black gram 1:2 (C_7) the BEY was increase significantly up to P3 but at P_4 the increase was not significant. In case of C_7 (maize + black gram 1:2) again BEY increased significantly up to P_3. At P_4 although there was reduction in BEY but it did not touched the level of P_3. Black gram equivalent yield was highest in intercropping system of pigeon pea + black gram 1:1 which remained at par with pigeon pea + black gram 1:2 which was significantly higher than maize + black gram system (C5 as well as C7) and sole stand of pigeon pea, maize and black gram (Table 2). System productivity of pigeon pea + black gram 1:1 and pigeon pea + black gram 1:2 increased by 58.8 % and 52.8 % respectively over sole pigeon pea. The productivity of intercropping system is not only governed by the inputs applied to the crops but also by the harmony between the crops grown in association and inclusion of legumes in these systems helps in utilizing natural resources efficiently and maintaining the fertility status of soil which may contributes to the productivity of the component crop. Leguminous crop with finger millet attributes to indirect benefit since legumes do not compete with cereals for soil nitrogen owing to variation in rooting pattern. Further, pigeon pea being long duration crop with slow initial growth and deep root system did not pose any severe competition for natural resources with black gram under different crop geometry and also it adds organic matter through leaf litter production and biologically fixed nitrogen for the benefit of crops. On the other hand, black gram being fast growing shallow rooted crop utilized the resources from top layer (0-30 cm) of the soil. Black gram serving as cover crop conserved soil moisture, reduced soil temperature and added organic matter to the soil and hence improve soil fertility status. This is in accordance with the findings of Sarkar *et al*. (2002) [4], Chalka and Nepalia (2004) [5], Datta and Bandyopadhayay (2005) [6], Bhatti *et al*. (2006) [7], Pramod *et al*. (2006) [8], Padhi *et al*. (2010) [9]; Dwivedi and Shrivastava (2010) [10], Tarafdar *et al.* (2012) [11] and Pandey *et al.* (2013) [12].

Combined application of inorganic phosphorus and Nano-P, also helped in conversion of unavailable nutrients to available form through increased enzymatic and microbial activity and enabled the crop to absorb nutrients resulting in higher dry matter production. Besides, nutrients management through inorganic phosphorus and Nano- phosphorus application improved the physical, chemical and biological properties of the soil, which provided congenial conditions for the pigeon pea and black gram. These results are in accordance with the findings of Nagar *et al*. (2015) [13].

Agronomic efficiency: Among the different agronomic efficiency land equivalent ratio which will reflect the efficiency of system which is mentioned here under

Land equivalent ratio (LER)

Results showed that all the intercropping system registered land equivalent ratio greater than one indicating benefit over sole cropping. Maximum LER (1.64) was registered under pigeon pea + black gram 1:1 (C_4) cropping system which was statistically at par with pigeon pea + black gram 1:2 (1.60). Pigeon pea + black gram 1:1 (C_4) and pigeon pea + black gram 1:2 (C_6) was found statistically superior to maize + black gram 1:1 (C_5) and maize + black gram 1:2 (C_7) with respect to LER. While, minimum LER (1.36) was recorded under maize + black gram 1:1(C_5) gave only 36% more land utilization over sole maize (C_3). Phosphorus management practices did not influence LER significantly. Interaction effect between cropping system and phosphorus management practices was found not significant.

In particular, LER verified the effectiveness of intercropping for using the resources of the environment compared to sole cropping]. When LER is greater than 1; intercropping favors the growth and yield of the species. Agronomic efficiency in terms of LER (1.64) was maximum under pigeon pea + black gram 1:1 cropping system which was statistically at par with pigeon pea + black gram 1:2 (1.60) and superior over other plant geometry (Table 3). Increase in LER under pigeon pea might be attributed to better complementary relationship between component crops (pigeon pea and black gram) leading to better use of growth resources. Moreover, it was also noted that legume + legume (pigeon pea + black gram) combination were more efficient than cereal + legume (maize + black gram) combination. Maitra *et al.* (2000) [14] also reported that the greater value of land equivalent ratio indicated greater biological efficiency of crops grown in association and was probably due to temporal and spatial complementary effect and thereby giving corresponding yield advantages. These results confirm the findings of Omprakash and Bhusan (2000) [15], Kumar *et al*. (2010) [16], Padhi *et al*. (2010) [9], and Pandey *et al.* (2013) [12].

Economic evaluation/Benefit: Cost ratio: As Benefit: cost ratio is one of the important tool which gives ideas about benefit on per rupees investment**.**

Maximum benefit cost ratio was recorded under pigeon pea + black gram 1:1 (C_4) system which was statistically superior over rest of plant geometry and minimum B:C ratio was noted in sole maize(C_3). In respect of phosphorus management practices application of 50% RDP+ Nano-P 40 ppm (P_3) was superior over100% RDP (P_4), Nano-P 40 ppm (P_2) and no phosphorus (P_1). Minimum was registered with no phosphorus (P_1).

Interaction effect between plant geometry and phosphorus management practices was significant. Pigeon pea + black gram 1:1 (C_4) x 50% RDP+ Nano-P 40 ppm (P_3) remained on par with Pigeon pea + black gram 1:1 (C_4) x 1000% RDP (P_4). Similarly, Pigeon pea + black gram 1:1 (C_6) x 50% RDP+ Nano-P 40 ppm (P_3) remained at par with Pigeon pea + black gram 1:1 (C_6) x100 % RDP (P_4). Both the plant geometry x phosphorus management combinations was superior to rest of the combinations. The B: C ratio was increased from P_1 to P_3 in all the cropping system under test (C_4, C_5, C_6 and C_7). P_3 was at par with P_4.

All intercropping combinations gave higher gross return, net return and benefit: cost ratio than that of sole cropping. Pigeon pea + black gram 1:1 intercropping systems recorded maximum gross return, net return and B: C ratio (Tables 4). Also in case of intercropping systems the highest value of cost of cultivation was found in intercropping because combine rate of both crop seeds and fertilizers have more price. Highest gross return, net return and B: C ratio might be due to higher seed yield of pigeon pea and black gram coupled with higher market price of component crops under the intercropping system. This affirms that legume + legume intercropping would be more beneficial than legume + cereal in terms of monetary gain. These findings are in accordance with the result of Shivran and Ahlawat (2000) [17], Gunasena (2006) [18], Prasad *et al*. (2007) [19], Kasbe and Karanjikar (2009) [20] and Chaudhari *et al.* (2017) [21].

Among phosphorus management practices, gross return under the treatment 50% RDP + 40 ppm Nano-P was at par with 100% RDP. However, the net return and benefit: cost ratio was higher with treatment 50% RDP + 40 ppm Nano-P compared to rest of the systems. This might be due to the fact that 50% RDP + 40 ppm Nano-P recorded maximum grain and straw yield as well as higher price. Similar results were also observed by Jat (2002) [22], Prasad *et al.* (2007) [19], Kasbe and Karanjikar (2009) [20] and Chaudhari *et al*. (2017) [21].

Summery and Conclusion

Pigeon pea grown at row to row distance of 60 cm and one row of Black gram in between rows of Pigeon pea produced better growth, and system productivity at 50 % RDP+ 40 ppm nano P. The maximum productivity in terms of Black gram yield 1977 kg ha^{-1}, Land equivalent ratio 1.64 and benefit: cost ratio 1.83 were under Pigeon pea + Black gram (1:1) grown at 50 % RDP + 40 ppm nano P which were at par under same intercropping system at 100 per cent recommended dose of Phosphorus.

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Table 2: Black gram equivalent yield, BEY (kg ha^{-1}) as influenced by legume based Crop geometry and phosphorus management (Pooled of 2016 and 2017)

Treatment	P_1-Control	P_2-Nano-P 40 ppm	P_3-50 % RDP + Nano- P 40 ppm	P_4-100 % RDP	Mean
C_1-Sole BG.	818	889	1175	1130	1003
C_2-Sole PP	994	1042	1227	1207	1117
C_3-Sole M	799	840	940	956	884
C_4-PP+BG(1:1)	1504	1668	1977	1901	1763
C_5-M+BG(1:1)	1088	1157	1366	1383	1249
C_6-PP+BG(1:2)	1414	1600	1931	1883	1707
C_7-M+BG(1:2)	1161	1243	1451	1438	1323
Mean	1111	1205	1438	1414	
			S.Em±	CD at5%	CV %
Crop combination			21.650	66.72	8.2
Phosphorus management			11.802	33.69	
Interaction	Between P, at same level of C		43.313	91.91	
	Between C, at same or different P		34.645	101.96	

* BG-black gram, PP- pigeon pea, M-maize

Table 3: LER of system as influenced by legume based crop geometry and phosphorus management (pooled of 2016 and 2017)

Treatment	P_1-Control	P_2-Nano-P 40 ppm	P_3-50 % RDP + Nano- P 40 ppm	P_4-100 % RDP	Mean
C_1-Sole BG.	1.00	1.00	1.00	1.00	1.00
C_2-Sole PP	1.00	1.00	1.00	1.00	1.00
C_3-Sole M	1.00	1.00	1.00	1.00	1.00
C_4-PP+BG(1:1)	1.62	1.69	1.64	1.61	1.64
C_5-M+BG(1:1)	1.35	1.36	1.37	1.38	1.36
C_6-PP+BG(1:2)	1.54	1.65	1.61	1.59	1.60
C_7-M+BG(1:2)	1.44	1.45	1.41	1.41	1.42
Mean	1.48	1.53	1.51	1.50	
			S. Em±	CD at5%	CV %
Crop combination			0.0171	0.0527	7.74
Phosphorus management			0.0126	NS	
Interaction	Between P, at same level of C		0.0342	NS	
	Between C, at same or different P		0.0336	NS	

* BG-black gram, PP- pigeon pea, M-maize

Table 4: B:C ratio of system as influenced by legume based crop geometry and phosphorus management(pooled of 2016 and 2017)

Treatment	P_1-Control	P_2-Nano-P 40 ppm	P_3-50 % RDP + Nano- P 40 ppm	P_4-100% RDP	Mean
C_1-Sole BG.	0.96	1.06	1.66	1.50	1.30
C_2-Sole PP	1.00	1.06	1.30	1.23	1.15
C_3-Sole M	0.60	0.63	0.76	0.70	0.67
C_4-PP+BG(1:1)	1.36	1.56	1.83	1.76	1.63
C_5-M+BG(1:1)	0.60	0.63	0.86	0.80	0.72
C_6-PP+BG(1:2)	1.16	1.33	1.66	1.53	1.42
C_7-M+BG(1:2)	0.66	0.66	0.86	0.80	0.75
Mean	0.91	0.99	1.28	1.19	
			S. Em±	CD at5%	CV %
Crop combination			0.035	0.11	9.4
Phosphorus management			0.021	0.06	
Interaction	Between P, at same level of C		0.07	0.15	
	Between C, at same or different P		0.06	0.16	

* BG-black gram, PP- pigeon pea, M-maize

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