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Studies on nutrient management in pigeonpea [*Cajanus cajan* (L) Millsp] based intercropping system of urd bean, sesame and mung bean

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Abstract
A field experiment was conducted during *kharif* season of 2016-17 at Mahatma Gandhi Chitrakoot Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.) to evaluate the effect of intercropped urd bean, mung bean and sesame under two level of fertility (100 and 125 % RDF) with pigeonpea regular and paired system. Intercropped pigeonpea numerically reduced seed yield and yield attributes to that of sole cropping. Among interropping pigeonpea+sesame (2:2) produced significantly maximum seed yield (2106 kg/ha). Intercropped urd bean mung bean and sesame produce lower yield attribute than sole cropping of urd bean mung bean and sesame. Among intercropping statistically equal seed yield and yield attribute were recorded in all intercrops. Higher dose of nutrient failed to increase yield attribute and yield of all components crops. Pigeonpea + sesame (2:2) row ratio gave the highest pigeonpea gross returns of 203114/ha, net returns of 185486/ha and benefit: cost ratio of 11.51.

Keywords: pigeonpea, mung bean, urd bean sesame, row ratio pigeonpea equivalent, LER, gross retuns, net returns, seed yield

Introduction
Pigeonpea [*Cajanus cajan* (L.) Millsp.] is the most verstile food legume with diversified uses as food, feed, fodder and fuel. In India pigeonpea ranks second in both acreage (5.13 million ha) and production (4.23 million tonnes) among the pulses in India with average productivity of 824 kg/ha (Anonymous 2015-16) [1]. When pigeonpea is grown as pure crop, it is relatively inefficient because of its slow initial growth rate due to indeterminate growth habit, poor source-sink relationship, poor harvest index and poor biomass production. Therefore, it is grown with intercrop which helps in efficient utilization of available resources for enhancing the productivity and profitability. Intercropping is one of the potent means of increasing total pulse production and income per unit area. Pigeonpea is wide spaced crop having deep root system and initial slow rate of growth offers good scope for intercropping with short duration crops like green gram, black gram or sesame. Inter cropping of pigeonpea + green gram/black gram may be helpful in total pulse production and pigeonpea + sesame for enhancing production of pulses and oil seed. For successful cultivation of any intercropping, plant geometry, suitable varieties and fertilizer management of component crop become important which may vary with crop combination, varieties and location.
Nutrient management is the most basic factor and is found to exert a great influence not only on growth and yield attributes of crops but also for obtaining sustained productivity. Among all nutrients N, P, K are most important nutrients which contribute to proper growth and yield of crop plant and it also has direct effect on metabolism of plant. In intercropping system, intercrop has lower plant population than its sole crop thus higher dose of nutrients may be helpful in improving yield. Hence present study was under taken to see the feasibility of pigeonpea with intercropping of black gram, sesame and mung bean in order to make efficient utilization of natural resources under varying row ratio and nutrient management to intercropping for higher production of pulse and oil seed.

Method and Materials
The present field experiment was conducted at Agriculture farm of the Mahatma Gandhi Chitrakkoot Gramodaya Vishwavidyalaya Chitrakoot, Satna (M.P.) during *kharif* season 2016-17. The farm is situated under agro climatic zone-Kymore Plateau of Northern Madhya Pradesh ($25^0 10'$ N and $80^0 32'$ E longitude and about 190-210 meter above mean sea level.) Agro-ecologically Chitrakoot is characterised by semi-arid and sub tropical climate with hot summer and cold winters. The total mean annaul rainfall is almost 950 mm. While the crop recived 905 mm rainfall from July to January 2017. Treatment consisted six intercropping

system viz. pigeonpea + sesame (1:1 row ratio), pigeonpea + sesame (2:2 row ratio), pigeonpea + urd bean (1:1 row ratio), pigeonpea + urd bean (2:2 row ratio), pigeonpea + mung bean (1:1 row ratio), pigeonpea + mung bean (2:2 row ratio) and two fertility levels of nutrient management in intercrops (100 and 125 % RDF). Sole cropping of pigeonpea urd bean, mung bean, sesaqme were included for comprison. Thus 12 treatment combination were tested in a three replicated split plot design in which intercropping system were kept in main plot and nutrient management in sub plots. The soil of the experimental plot was sandy loam in texture having soil p^H 7.79, low organic carbon (40 %), available nitrogen (204.5kg/ha), high available phosphorus (67.87 kg/ha), and low available potassium (123.9 kg/ha).

Pigeonpea variety UPAS-120, green gram (PDM-139), black gram (SEKHAR-3) and sesame (T-36) were used in pigeonpea in experiment. Pigeonpea seed was sown at a row spacing of 60 cm in sole and intercropping and 45/75 cm in pigeonpea in paired (intercropping system). Intercrops green gram, black gram and sesame were sown one row between two row of pigeonpea (regular) and two row in skip space in paired system. The seed rate in pigeonpea was 18 kg/ha (pure and intercropping), 15 kg/ha in sole black gram and green gram and 5 kg/ha in sole sesame crops while in intercropping 50 % seed rate was used in all intercrops. The seed were inoculated by *Rhizobium* culture @ 20g/ kg seed + phosphate solubilizing bacteria (PSB) @ 40g/kg seed of legume crop (pigeonpea, green gram and black gram) and by thiram @ 3 g/kg seed of sesame. The recommended procedure for seed treatment and seed inoculators was followed. Pigeonpea crops was fertilized @ 20 kg N, + 60 kg P_2O_5 + 20 kg K_2O/ ha in sole and intercropping. Sole black gram and green gram crops was fertilized @20 kg N, + 40 kg P_2O_5 + 20 kg K_2O/ ha. Sole sesame was fertilized @ 40 kg N, + 30 kg P_2O_5 + 20 kg K_2O/ ha. In intercropping, intercropping fertilized as per treatment 100 and 125 % RDF on row basis (50 % to row to sole crop).Crop was irrigated once on 06-09-2016. The crop were harvested 19-12-2016 (pigeonpea), 27-09-2016 (mung bean), 26-10-2016 (black gram), and 25-10-2016 (sesame). Remaining input cum operation were done as per recommendation of crops. The important observation were recorded at appropriate time and procedure.

Pigeonpea equivalent yield

The seed yield of green gram, black gram and sesame in each plot was converted into pigeonpea seed equivalent yield on the basis of sale price of green gram, black gram and sesame and pigeonpea seed in `/kg. It was calculated with the following formula.

$$Pigonpea\ seed\ equivalent\ yield\ \left(\frac{kg}{ha}\right) = Yield of\ pigeonpea\ (kg) + \frac{Yield\ of\ intercrop\ \left(\frac{kg}{ha}\right) \times Price\ of\ intercrop\ \left(\frac{Rs}{kg}\right)}{sale\ price\ of\ pigeonpea\ (Rs./kg)}$$

Land equivalent ratio (LER)

Land equivalent ratio is sum of fraction of the yields of intercrops, relative to their sole crop yields. It is calculated with the following formula.

$$LER = \frac{partial\ yield\ of\ intercrops\ 'a'}{Yield\ of\ pure\ crop\ 'a'} + \frac{Yield\ of\ intercrop\ 'b'}{Yield\ of\ pure\ crop\ 'b'}$$

Result and Discussion

Yield attribute and yield of pigeonpea

The highest pods (70.92), pod length (4.17 cm) and seeds/pod (3.87) were observed under pigeonpea + urd bean (2:2) paired row. The significantly highest seed weight/plant of 5.70 was recorded under pigeonpea + sesame (1:1) alternate row but 1000-seed weight of pigeonpea was maximum of 76.37 g under pigeonpea + urd bean (1:1) alternate row. All yield attributes were numerically superior in sole pigeonpea. It was due to more competition for space for proper growth and development of plants in intercropping.

Appliation of 125% RDF produced significantly maximum pods/plant (70.61 pods), seed weight/plant (4.31 g) and numerically higher pod length (4.13 cm) and 1000-seed weight (76.27 g). Higher fertility level promote yield attributes might be due to more uptake of nutrients and formation of higher photosynthates resulted superior yield attributes. Similar finding were observed by Dutta and Banopadhaya (2006) and Pandey *et al*. (2013) [9].

Seed yield and stover yield of pigeonpea was found higher under sole cropping than that of intercropped treatment. Such increased was associated with higher value of yield attributes. The least competition under sole pigeonpea as compared to inter cropping could be facilitated the better growth and development to primordial which resulted higher seed yield and stover yield. Among intercropping, highest seed yield of 2107 kg/ha was recorded in pigeonpea + sesame (2:2) paired row followed by 1832 kg/ha in pigeonpea + sesame (1:1) while stover yield (8365 kg/ha) was maximum in pigeonpea + mung bean (1:1). This could be ascribed due to better yield attribute. These results corroborate to the finding of Shanwad *et al* (2009) [11], and Pandey *et al* (2013) [9]. Seed and stover yield of pigeonpea did not differ significantly due to application of 100 and 125 % RDF to intercrop but numerically higher value (seed yield 1819 kg/ha and stover yield 7713 kg/ha) were found under 125% RDF. It was due to production of more photosynthates and numerically superior characters of yield attributes. Its was supported by Bhardwaj (2016) [2].

Yield attribute and yield of Urd bean

Yield attributes of urd bean viz. pods per plant, pods lenght, seeds per pod and 1000-seed weight were not found significant higher due to cropping system nor nutrient management (Table 4.22). The highest pods (19.07) was found under pigeonpea + urd bean (2:2) paired row and 1000-seed weight of 41.87 g was observed under pigeonpea + urd bean (1:1) alternate row. It was because of almost similar competition for space, light and pigeonpea shoot and root. Sole urd bean had almost similar type yield attributes characters. It indicate that neutral effect of pigeonpea on urdbean. There was no response of 125% RDF on yield contributing characters of urd bean because of 100% RDF was sufficient for development of yield attributes Patidar (2015) [10] and Bhardwaj (2016) [2] observed the similar findings.

Pigeonpea + urd bean (1:1) produced numerically higher but statistically equal seed and stover yield (2:2). It was probably due to equal plant stand of urd bean in both row ratio and at par yield attribute. Sole urd bean produced highest yield (418 kg/ha seed yield and 1060 kg/ha stover yield) which was 100 kg and 116 kg/ha higher seed yield and 45 kg and 101 kg/ha stover yield than intercropping urb bean of 1:1 and 2:2 row

ratio, respectively. It might be due to double plant population of urd bean in sole cropping than both intercropping system. Results corroborate to the findings of Patidar (2015) [10] and Bhardwaj (2016) [2].

Yield attribute and yield of Sesame

Yield attributes of sesame viz capsules/plant and seeds per capsule were significantly higher under 2:2 row ratio while1000-seed weight was higher in 1:1 row ratio og pigeonpea + sesame. Remaining charater were atpar. application of 125 % RDF produced significantly superior capsule/plant, seed/capsule, seed weight/plant and 1000 seed weight. It was due to higher uptake nutrients and ultimately formation of more photosynthates resulted superior yield attributed. It was supported by the findings of Patidar (2015) [10] and Bhardwaj (2016) [2]. Sole sesame produced maximum seed yield 407 kg and stover yield 562 kg/ha. Which was 89 and 91 kg/ha higher seed yield and 20 and 4 kg/ha higher straw yield than 1:1 and 2:2 row ratio of pigeonpea + sesame due to higher plant population of sole sesame (About double of intercropped). Both intercropped sesame produced statistically equal seed yield and stover yield. Application of 100 and 125 % RDF had almost similar grain as well as stover yield. Harvest index was affected neither by cropping system nor nutrient management.

Yield attribute and yield of Mung bean

Yield attributes of mung bean such as pods per plant, pod length, seeds per pod and 1000-seed weight. Seed yield, stover yield and harvest index were not affected due to row ratio in both intercropping system. All these were numerically better in 1:1 row ratio. Similarity in these character and yield were due to equal competition from pigeonpea, space and light and equal plant population in both system. Sole mung bean produce better yield attributes and seed and stover yield. Sole mung bean had 130 and 145 g/ha higher grain yield and 277 and 518 kg/ha stover yield than pigeonpea + mungbean 1:1 and 2:2 row ratio, respectively. It was due to better yield attributes and higher plant population (Ust double to intercropped mungbean). Nutrient management failed to improve the yield attributes and yield of mung bean over 100 % RDF. It indicates 100 % RDF was significient in intercropping for mungbean.

Effect on whole intercropping system

All intercropping system with nutrient management had more than one LER but it was highest of 1.81 under pigeonpea+sesame (2:2) followed by 1.69 in pigeonpea+sesame (1:1). It indicate all system proved better than sole pigeonpea but highest benefitted pigeonpea + sesame (2:2). It was due to better planting geometry to avoid comptition and sufficient nutrient supplied.

Pigeonpea equivalent yield (PEY)

Pigeonpea equivalent seed yield were recorded higher of 2510.67kg//ha under in pigeonpea + sesame (2:2) with 100% (RDF (2511 kg/ha) followed by 2333 kg/ha under pigeonpea + sesame (2:2) with 125% RDF and 2217.33 kg/ha in pigeonpea + sesame (1:1) with 100% RDF. The higher pigeonpea equivalent yield might be attributed to higher seed yield of pigeonpea and intercrops as well as market price of both component crops. It may be supported by finding of Kuamr *et al.* (2012) and Pandey *et al.* (2013) [9].

Economics

Total cultivation cost varied (Pigeonpea + intercrops) in intercropping system perhaps due to additional cost of seed, labour, fertilizer etc. The maximum gross return of `209422/ha, net return of `183485/ha and B:C ratio (10.33) were achievement under pigeonpea + sesame (2:2) with 100 % RDF, Gross return trends associated with the higher seed stover yield of pigeonpea and pigeonpea and intermediate order of seed and stover yield yield of blank gram, sesame, intercropping system was due to more increase in gross return as compared lesser increase in cost of cultivation. The resulted may be supported by the findings of Kujur *et al* (201) [6], Kumawat *et al* (2013) [5].

Table 1: Yield attribute and yield of pigeonpea as influenced by intercropping and nutrient management

Treatment	Pod /Plant	Pod length(cm)	1000 seed weight (g)	Seed/pod	Seed weight/ plant(g)	Seed yield(kg/ha)	Stover yield(kg/ha)	Harvest index (%)
Cropping system								
PP+UB(1:1)	68.6	4.08	76.37	3.88	3.84	1701	7276	19
PP+SES(1:1)	69.25	4.05	76.27	3.78	5.7	1832	7425.33	20
PP+MB(1:1)	69.75	3.94	76.35	3.62	3.4	1617	8364.5	16.31
PP+UB(2:2)	70.92	4.17	76.08	3.87	3.32	1743	7148.83	19.45
PP+SES(2:2)	69.5	4.16	76.22	3.73	3.91	2106	7380.33	22.32
PP+MB(2:2)	69.37	4.16	76.23	3.82	3.35	1734	7206.83	19.45
SEm±	**1**	**0.1**	**0.21**	**0.1**	**0.34**	**93.24**	**235.9**	**1.05**
CD (P=0.05)	**NS**	**NS**	**NS**	**NS**	**1.06**	**293.82**	**743.34**	**3.31**
(B)Sub plot : Nutrient Management								
100% RDF	68.52	4.06	76.24	3.82	3.53	1764.11	7221.06	19.77
125%RDF	70.61	4.13	76.27	3.75	4.31	1813.61	7712.89	19.07
SEm±	**0.48**	**0.05**	**0.1**	**0.05**	**0.11**	**23.66**	**186.54**	**0.39**
CD (P=0.05)	**1.47**	**NS**	**NS**	**NS**	**0.35**	**NS**	**NS**	**ns**
SOLE PP	70.8	4.33	76.46	3.73	4.6	2024	8012	22.73

Table 2: Effect of cropping system and nutrient management on yield of black gram.

Treatment	Pod/plant	Pod length(cm)	1000 seed weight(g)	Seed weight/plant(g)	Seed/pod	Seed Yield (kg/ha.)	Stover yield(kg/ha)	Harvest index (%)
(A)Cropping system								
PP+UB(1:1)	18.27	3.85	41.87	3.8	6.07	318	1014.67	24.2
PP+UB(2:2)	19.07	3.76	40.93	3.97	6.08	301	958.83	24.22
SEm±	**0.47**	**0.08**	**0.86**	**0.08**	**0.1**	**12.67**	**114.66**	**1.92**
CD (P=0.05)	**NS**	**NS**	**NS**	**Ns**	**NS**	**NS**	**NS**	**Ns**
(B)Nutrient management								
100% RDF	18.47	3.79	41.62	3.88	6.07	309	986.67	24.34
125% RDF	18.87	3.83	41.18	3.89	6.08	309.67	986.83	24.07
SEm±	**0.46**	**0.06**	**0.55**	**0.07**	**0.08**	**6.51**	**86.43**	**1.59**
CD (P=0.05)	**NS**	**NS**	**NS**	**Ns**	**NS**	**NS**	**NS**	**Ns**
mean	**18.62**	**3.81**	**41.4**	**3.89**	**6.8**	**310**	**987**	**24.21**
SOLE UB	18.6	3.7	42.1	3.87	6.1	418	1060	22.28

Table 3: Effect of cropping system and nutrient management on yield of sesame.

Treatment	Capsule/plant	Capsule length(cm)	1000 seed weight(g)	Seed/capsule	Seed weight/plant(g)	Seed Yield (kg/ha.)	Stover yield(kg/ha)	Harvest index (%)
(A)Cropping system								
PP+SEC.(1:1)	33.89	2.22	3.24	33.89	0.94	318	541.67	36.63
PP+SEC.(2:2)	36.1	2.35	3.19	36.1	0.92	316	557.17	36.38
SEm±	**0.35**	**0.06**	**0.01**	**0.35**	**0**	**7.93**	**17.66**	**1.22**
CD (P=0.05)	**2.13**	**NS**	**0.04**	**2.13**	**NS**	**NS**	**NS**	**Ns**
(B)Nutrient management								
100% RDF	34.24	2.33	3.21	34.24	0.92	322.5	555.33	36.95
125% RDF	35.76	2.24	3.23	35.76	0.94	310.67	543.5	36.27
SEm±	**0.34**	**0.15**	**0.01**	**0.34**	**0**	**5.05**	**51.9**	**2.68**
CD (P=0.05)	**1.33**	**NS**	**NS**	**1.33**	**0.01**	**NS**	**NS**	**Ns**
Mean	**35**	**2.28**	**3.27**	**35**	**0.93**	**317**	**550**	**36.6**
SOLE SEC.	39.1	2.3	3.2	37.2	0.946	407	562	34.81

Table 4: Effect of cropping system and nutrient management on yield of mung bean.

Treatment	Pod/plant	Pod length(cm)	1000 seed weight(g)	Seed/pod	Seed Yield (kg/ha.)	Stover yield(kg/ha)	Harvest index(%)
(A)Cropping system							
PP+MB(1:1)	15.83	6.07	34.48	11.13	334	1472	18.6
PP+MB(2:2)	15.63	5.93	34.98	11.15	319	1231	20.8
SEM±	0.71	0.2	0.18	0.37	8.48	54.85	1.06
CD (P=0.05)	NS	NS	NS	NS	NS	NS	Ns
(B)Nutrient management							
100% RDF	15.67	5.95	35.17	11.3	328.67	1286.17	20.82
125% RDF	15.8	6.05	34.3	10.98	323.67	1416.17	18.58
SEM±	0.34	0.15	0.7	0.15	6.17	62.08	1.01
CD (P=0.05)	NS	NS	NS	NS	NS	NS	Ns
Mean	15.74	6	34.74	11.14	326	1352	19.7
SOLE MB	16.46	6.1	35.3	11.4	464	1749	23.2

Table 5: Effect of cropping system and nutrient management on economics, pigeonpea equivalent yield and LER (Land Equivalent Ratio) of pigeonpea.

Treatment	Cost of cultivation (Rs/ha)	Gross Return	Net Return	B:C Ratio	PEY	LER
Cropping system						
PP+UB(1:1)	20293	180269	159976	8.9	1954.83	1.62
PP+SES(1:1)	19655	181067.33	161412	9.21	2153	1.69
PP+MB(1:1)	20293	175211.17	3154918	8.63	1883.83	1.51
PP+UB(2:2)	19293	181662	161369	8.95	1983.33	1.6
PP+SES(2:2)	19655	203140.17	183485	10.33	2421.67	1.81
PP+MB(2:2)	20293	177464.67	157171	8.74	1971	1.53
SEm±		**6042.78**	**7121.94**	**0.73**	**90.87**	**0.11**
CD (P=0.05)		**NS**	**NS**	**NS**	**286.33**	**NS**
(B)Sub plot : Nutrient Management						
100% RDF	17735	180849.5	162557	10.12	2035.83	1.62
125%RDF	18424	185421.94	165890	10.06	2086.72	1.63
SEm±		**2548.15**	**2397.56**	**0.3**	**28.67**	**0.04**
CD (P=0.05)		**NS**	**NS**	**NS**	**NS**	**NS**
SOLE PP	18013	177997	159984	9.87	2024	1
SOLE UB	16101	405992	24491	2.51	418	1
SOLE SES.	14935	25181	10246	1.68	407	1
SOLE MB	16101	35559	19458	2.2	464	1

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