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Nutrient management in pigeonpea [*Cajanus cajan* (L.) Millisp.] Based intercropping system under rainfed condition of eastern Uttar Pradesh

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Abstract
A field experiment was conducted during kharif season of 2017-18 at Agronomy Research Farm, Narendra Dev University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India on silty loam soils as influence of integrated nutrient management in pigeonpea based intercropping system. The treatments comprised of three intercropping systems of Pigeonpea sole, Pigeonpea + sesame and Pigeonpea + sorghum with five different integrated nutrient management's levels. On the basis of results, Pigeonpea with sorghum intercropping systems recorded significantly superior pigeonpea grain yield (16.59 q ha^{-1}), pigeonpea equivalent yield (20.62 q ha^{-1}), gross returns (Rs. 113454 ha^{-1}), net returns (Rs. 84176 ha^{-1}) and B:C ratio (2.87), respectively as compared to Pigeonpea sole and Pigeonpea + sesame intercropping. Among the INM practices, application of 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1} prove effective and recorded significantly higher pigeonpea grain yield (16.90 q ha^{-1}) and pigeonpea equivalent yield (20.79 q ha^{-1}), gross returns (Rs. 114363 ha^{-1}), net return (Rs. 84583 ha^{-1}) and B:C ratio (2.84).

Keywords: INM, intercropping, pigeonpea, sesamum, sorghum, yield

Introduction
In Indian agriculture role of pulses needs hardly any special importance. India is major pulse growing country. The pulses are integral part of cropping system all over the country. Pulses are considered as lifeblood of agriculture because they occupy a unique position in every known system of farming as a main, catch, cover, green manure, intercrop, relay and mixed crop. The area under pigeonpea during 2016-17 was 3.86 million hectares with production of 2.90 million tonnes and average productivity of 7.51 q ha^{-1}. In Maharashtra the area under pigeonpea was 1.53 million hectares with production of 1.17 million tonnes and average productivity of 7.64 q ha^{-1} and in Marathwada the area is 5.3 lakh hectares with production of 1.3 lakh tonnes (DES, 2016; FAO Stat., 2014) [6]. When pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index (Willey, 1980) [29]; therefore it is grown as intercrop, which helps in efficient utilization of available resources for enhancing the productivity and profitability. Pigeonpea is suitable for intercropping with different crops like sorghum, seasame, soybean, greengram, blackgram and cowpea for increasing production and maintaining soil fertility. The initial slow growth rate and deep root system of pigeonpea offers a good scope for intercropping with fast growing early maturing and shallow rooted crops (Ahamad *et al.*, 2016; Behara *et al.*, 2016) [1, 2].

Materials and Methods
The field experiment was conducted during kharif season of 2017-18 at Agronomy Research Farm, Narendra Dev University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India situated in subtropical sub humid climate in indo-gangatic plains and lies between 26.47° North latitude and 81.12° East longitude with is an elevation of about 113 m. The treatments comprised of three intercropping systems (Pigeonpea sole, Pigeonpea + sesame and Pigeonpea + sorghum) with five different integrated nutrient management's levels [RDF (20:40:0 kg NPK ha^{-1} for pigonpea and 60:30:30 kg NPK ha^{-1} for sorghum & sesame); 75% RDF + FYM @ 5 t ha^{-1}; 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1}; 75% RDF +FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha_{-1} and 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1})] alone with sole

cropping of pigeonpea, sesame and sorghum. The experiment was laid out in Randomized Block Design with three replications. The experimental soil was silty loam in textural having low in organic carbon (0.33%), available N, P, and K was 158, 15 and 250 kg ha^{-1}, respectively with pH (8.0). The varieties namely Pigeonpea (Narendra Arhar-1), Sesame (T-12) and Sorghum (PKV-400) were sown in first week of July. Inter crops were harvested 90-110 days after sowing (sesame) and 110-120 days after sowing (sorghum) during 2017-18, respectively. Pigeonpea crop was harvested on 25th March in 2018. The soil samples up to 15 cm depth were collected from individual plot after harvesting the pigeonpea crop. One soil sample of each plot was air dried; proceed to pass through 2 mm sieve. Soil samples was stored at low temperature in the deep freezer and used for estimation of different soil biological properties. The other cultural operations were done as per recommendation and crop requirement. Seed yield was computed by threshing pods from net plot, cleaned and the seeds weight was recorded. From this seed yield per hectare was computed. Net return (Rs. ha^{-1}) was calculated by deducting cost of cultivation (Rs. ha^{-1}) from gross returns, while B:C ratio were worked out as ratio of gross returns (Rs. ha^{-1}) to cost of cultivation (Rs. ha^{-1}). The data was pooled for final statistical analysis as per the method suggested by (Gomez and Gomez 1984) [9]. Pigeonpea equivalent yield (PEY) was calculated as follows:

Results and Discussion

Growth observations

Results on growth pattern of pigeonpea, sesame and sorghum are presented in Table 1. Among the intercropping systems the maximum plant height, number of branches, number of nodule, effective nodules and nodulation index (290.43 cm, 19.92 plant^{-1}, 23.75 plant^{-1}, 0.84) were recorded with pigeonpea sole which was significantly higher than pigeonpea + sorghum (259.28 cm, 17.78 plant^{-1}, 21.20 plant^{-1}, 0.67) and pigeonpea + sesame (255.22 cm, 17.50 plant^{-1}, 20.87 plant^{-1}, 0.74) respectively, during the year. Maximum dry matter production (345.59 g plant^{-1}) of pigeonpea at harvest stage was significantly higher under in pigeonpea + sesame intercropping system which was significantly superior over pigeonpea sole (312.18 g plant^{-1}) and pigeonpea + sorghum (247.66 g plant^{-1}) intercropping system during the year. Here it may be pointed out that, the competition between pigeonpea and sorghum for space, sunlight, nutrient water etc. was more as compared to sesame which resulted poor growth and development of pigeonpea under pigeonpea + sorghum intercropping system. Further, sesame crop also improve the fertility status and physical condition of soil which augmented growth and development of pigeonpea under pigeonpea + sesame the results collaborated with the finding of Kumar *et al.* 2007; Chaudhary *et al.*, 2005; Dwivedi *et al.*, 1997 and Garud *et al.*, 2018) [14., 3, 5, 7]. It was due to less competition of main crop of pigeonpea with intercrop like sesame. Similar findings were reported by Singh *et al.* (2007) [24]. The data revealed that amongst integrated nutrient management system, application of 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} +$ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1} were recorded significantly maximum plant height, number of branches, dry matter production, total number of nodule, effective nodules and nodulation index (295.85 cm, 20.29 plant^{-1}, 331.78 g plant^{-1}, 30.43 plant^{-1}, 24.19 plant^{-1}, 0.80) respectively, during the experimentation. Dry matter accumulation was increased because more availability nutrient that promoted the metabolic activities accelerated cell division and of metabolic tissues, ultimately enhances the number of branches plant^{-1} (Giri *et al.*, 1978. Goyal *et al.*, 1991. Hedge, 1977; Jat *et al.*, 2003 and Kene *et al.*, 1990) [8, 10, 11, 12].

Table 1: Growth attributes of pigeonpea as influenced by pigeonpea based intercropping and integrated nutrient management systems

Treatments	Plant height (cm)	Number of branches plant^{-1}	Dry matter production (g plant^{-1})	Effective nodules plant^{-1}	Nodulation index
Inter cropping system					
Pigeonpea sole	290.43	19.92	312.18	23.75	0.84
Pigeonpea + Sesame	255.22	17.50	345.59	20.87	0.74
Pigeonpea + Sorghum	259.28	17.78	247.66	21.20	0.67
SEm±	7.08	7.55	7.05	6.59	7.56
CD (P=0.05)	14.20	1.03	15.62	1.082	0.04
Integrated nutrient management					
RDF (20:40:0 kg NPK ha^{-1} for pigonpea and 60:30:30 kg NPK ha^{-1} for sorghum & sesame)	221.57	15.19	253.41	18.12	0.76
75% RDF + FYM @ 5 t ha^{-1}	260.67	17.87	290.91	21.32	0.69
75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1}	274.98	18.86	308.64	22.49	0.73
75% RDF +FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1}	288.48	19.78	324.31	23.59	0.78
75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} +$ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1}	295.85	20.29	331.78	24.19	0.80
S.Em±	7.08	7.55	7.05	6.59	0.019
CD (P=0.05)	18.33	1.34	20.17	1.39	0.05

Yield attributes

Number of pods, number of grains per pod, pod length and test weight were significantly influence by intercropping system during years of the experimentation. It is evidence from the data that maximum number of pods, numbers of grains, pod length and test weight (145.05 plant^{-1}, 4.31 pod^{-1}, 5.48 cm, 98.12 g) were recorded with pigeonpea sole followed by pigeonpea + sorghum (129.49 plant^{-1}, 3.85 pod^{-1}, 4.89 cm, 95.03 g) and pigeonpea + sesame (127.46 plant^{-1}, 3.79 pod^{-1}, 4.81 cm, 94.25 g) intercropping system, respectively. Sizable reduction in pigeonpea yield under pigeonpea + sorghum intercropping system was due to more competition between sorghum and pigeonpea for space, nutrients, soil moisture and solar energy (Kumawat *et al.*, 2013; Pilbeam *et al.*, 1999; Prasad *et al.*, 1992 and Rao *et al.*, 1980b) [15, 16, 18, 19]. The data revealed that amongst integrated nutrient management system, the application of 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1} were recorded significantly maximum number of pods (147.75 plant^{-1}), number of grains (4.40 pod^{-1}), pod length (5.58 cm) and test weight (98.70 g) during the experimentation. Inclusion of sesame and intercrop with pigeonpea attributed to less exhaustion of soil fertility reduced early stage of crop weed competition due to their smothering effect on weeds compared to sole pigeonpea and pigeonpea+ sorghum intercropping, thereby increased the yield indices and finally the grains equivalent yield of pigeonpea (Reddy *et al.*, 1991; Reddy *et al.*, 2007 and Sharma *et al.*, 2010) [21, 22, 23].

Yields

Intercropping system significantly influence grain yield and stalk yield of pigeonpea during the years. Grain yield, stalk yield and harvest index (16.59 q ha^{-1}, 84.66 q ha^{-1} and 17.71%) were found significantly higher under pigeonpea sole intercropping system as compared to pigeonpea + sorghum (14.81 q ha^{-1}, 48.16 q ha^{-1} and 17.33%) and pigeonpea + sesame (14.58 q ha^{-1}, 53.41 q ha^{-1} and 17.20%) respectively, during 2017-18. Pigeonpea + sorghum (20.62 q ha^{-1}) intercropping system were recorded significantly higher pigeonpea equivalent yield as compared to pigeonpea sole (16.59 q ha^{-1}) as well as pigeonpea + sesame (19.52 q ha^{-1}) intercropping system. Here it may be elucidated that yield attributing characters were also maximum under pigeon pea + sesame as compared to rest other inter cropping system. On the other hand intercropping of pigeonpea + sorghum reduced the above yield attributes significantly which results the lowest yield of pigeonpea under pigeon pea + sorghum intercropping system. Further, the beneficial effect of sesame reflected on pigeonpea yield was probable due to addition of N in soil by decay of nodules and also due to non significant crop competition resulted by sesame. Similar finding have also been reported by Srivastava *et al.*, 2004; Tiwari *et al.*, 2018 and Tiwari *et al.*, 2018. Data revealed that amongst integrated nutrient management system, the application of 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} +$ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1} recorded maximum grain yield, stalk yield and harvest index and pigeonpea equivalent yield (16.90 q ha^{-1}, 64.49 q ha^{-1}, 17.84% and 20.79 q ha^{-1}) and minimum (12.66 q ha^{-1}, 62.60 q ha^{-1}, 16.75% and 15.88 q ha^{-1}) respectively, with RDF during year of study.

Economical studies

Pigeonpea + sorghum intercropping system recorded significantly higher gross returns (Rs. 113454 ha^{-1}), net returns (Rs. 84176 ha^{-1}) and B:C ratio (2.87) as compared to the gross returns (Rs. 107382 ha^{-1}), net returns (Rs. 78314 ha^{-1}) and B:C ratio (2.69) obtained from pigeonpea + sesamum intercropping system during the year (Table 2). Among the different fertility levels, application of 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1} recorded significantly higher gross returns (Rs. 114363 ha^{-1}), net returns (Rs. 84583 ha^{-1}) and B:C ratio (2.84) over other fertility levels during the year. Similar reports were obtained by Rathod *et al*., (2004) [20], The lower net return per rupee investment in pigeon pea + sorghum inter cropping was obviously due to increased in the cost of production with no commensurate increasing crop yields. Similar results were also reported by Verma and Warsi (1997) [27] and Kumar and Rana (2007) [14].

Conclusion

Combined application of 75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1} was found economically beneficial for obtaining higher productivity and economic returns of pigeonpea + sesamum intercropping over sole pigeonpea and pigeonpea + sorghum under rainfed condition during the years.

Table 2: Yield and economics of pigeonpea as influenced by pigeonpea based intercropping and integrated nutrient management systems

Treatments	No. of pods plant^{-1}	No. of grain pod-1	Pod length (cm)	Test weight (gm)	Pigeonpea yield (q ha^{-1})	Intercrop Yield (q ha^{-1})		Stalk yield (q ha^{-1})	Harvest index (%)	Pigeonpea equivalent yield (q ha^{-1})	Cost of cultivation (Rs.ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Benefit: Cost (Rs. ha^{-1})
						Sesame	Sorghum							
Inter cropping system														
Pigeonpea sole	145.05	4.31	5.48	98.12	16.59	-	-	84.66	17.71	16.59	25378	91245	65867	2.59
Pigeonpea + Sesame	127.46	3.79	4.81	94.25	14.58	4.29	-	53.41	17.20	19.52	29068	107382	78314	2.69
Pigeonpea + Sorghum	129.49	3.85	4.89	95.03	14.81	-	12.78	48.16	17.33	20.62	29278	113454	84176	2.87
S.Em±	7.76	7.34	7.27	7.07	0.85	-	-	5.57	6.89	0.77	-	-	-	-
CD (P=0.05)	8.00	0.21	0.09	5.06	9.82	-	-	2.58	0.89	10.93	-	-	-	-
Integrated nutrient management														
RDF (20:40:0 kg NPK ha^{-1} for pigonpea and 60:30:30 kg NPK ha^{-1} for sorghum & sesame)	110.66	3.29	4.18	91.38	12.66	3.15	11.00	62.60	16.75	15.88	24740	87358	62618	2.52
75% RDF + FYM @ 5 t ha^{-1}	130.19	3.87	4.92	95.45	14.89	4.00	12.42	58.61	17.33	18.23	27620	100265	72645	2.63
75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1}	137.33	4.09	5.19	96.43	15.71	4.55	13.00	61.75	17.50	19.34	28170	106388	78218	2.77
75% RDF +FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} + $ZnSo_4$ @ 25 kg ha^{-1}	144.07	4.29	5.44	97.05	16.48	4.80	13.62	62.94	17.66	20.32	29230	111760	82530	2.82
75% RDF + FYM @ 5 t ha^{-1} + sulphur @ 40 kg ha^{-1} +$ZnSo_4$ @ 25 kg ha^{-1} + boron @ 1.5 kg ha^{-1}	147.75	4.40	5.58	98.70	16.90	4.95	13.85	64.49	17.84	20.79	29780	114363	84583	2.84
S.Em±	7.76	7.34	7.27	7.07	0.85	-	-	5.57	6.89	0.77	-	-	-	-
CD (P=0.05)	10.03	0.28	0.35	6.53	12.68	-	-	3.34	1.15	14.11	-	-	-	-

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