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Uptake of macro nutrients and their effects on yield and economics of pigeonpea (*Cajanus cajan*) as influenced by different pigeonpea based intercropping systems

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Abstract
A field experiment was conducted during *kharif* 2018 and 2019 at research farm, College of Agriculture RVSKVV Gwalior to see the impact of nutrients uptake and their effect on yield and economics in Pegionpea. Seven crops i.e. sesame, groundnut, soybean, greengram, blackgram, cowpea and cluster bean were sown as a sole crop as well as intercropped with pigeonpea and replicated thrice in randomized block design. The nutrients uptake (nitrogen, phoshphorus and potassium) was significantly higher in sole pigeonpea over intercropped pigeonpea. It was observed that after harvesting of crops, the level of nitrogen was increased in all pigeonpea intercropping systems as well as sole pigeonpea and recorded maximum in pigeonpea + cowpea intercropping system. Whereas, phosphorus and potassium were significantly not affected by different intercropping systems.

Keywords: Economics, intercropping, nitrogen, phoshphorus, pigeonpea, potassium uptake, yield

Introduction
Pigeonpea [*Cajanus Cajan* (L.) Millsp] is a multipurpose legume crop that can provide food, fuel, wood and fodder for the small-scale farmers in subsistence agriculture. In India, it is grown in an area of 4.43 mha with a production of 4.25mt and productivity of 950 kg/ha (Anonymous 2019) [1].

Legumes can play a complementary role as source of organic fertiliser. Research has shown that legumes have the potential to sustain soil fertility (Bhadu *et al*., 2018a) [2]. Pigeonpea has been found to have a great potential in this respect because of its ability to recycle nutrients and tolerate wide environmental conditions and low soil fertility (Hughes and Venema, 2005) [5]. In addition, pigeonpea improves nitrogen availability for subsequent crops. Positive effects of grain legumes other than nitrogen fixation are soil structure improvement (Bhadu *et al*., 2018b) [3] and enhanced P-availability through secretion of enzymes and acids in the legume rhizosphere (Schlecht *et al*., 2006) [12].

Short duration pigeonpea gives a reasonable grain yield with a large volume of leaf biomass could offer food security to the farmers and improving soil fertility. The low productivity of pigeonpea has been recorded due to its large area under rainfed situation grown in wider spacing. It is generally intercropped with sorghum, cotton and pulses. Under such situation, short duration pulse crop such as blackgram/greengram/cowpea can be grown as an intercrop to increase the productivity and nutrients availability of the system (Bhadu *et al*., 2020) [4]. When pigeonpea is grown as a sole crop, it is relatively inefficient because of its slow initial growth rate and low harvest index. Therefore, it is grown as intercrop, which helps in efficient utilization of available resources for enhancing the productivity and profitability (Willey 1979) [16].

The lack of information on suitable intercropping system, made as inspire us to undertake the present study, we evaluated the impact of major nutrients uptake and their effect on yield and economics in pigeonpea as influenced by different pigeonpea based intercropping systems. We also assessed the status of macro nutrients in soil after harvesting of crops.

Materials and Methods
A field experiment was conducted during rainy seasons of 2018 and 2019 at Research Farm, College of Agriculture RVSKVV Gwalior in sandy clay loam soil.

The experimental soil was poor in organic carbon (0.40% and 0.41%), available nitrogen (231 kgha^{-1} and 237 Kgha^{-1}) and medium in available phosphorus (19.1 kgha^{-1} and 19.7 Kgha^{-1}) and available potassium (274 kgha^{-1} and 277 Kgha^{-1}) during both the years respectively. The rainfall received during the growing period of crop was 357 mm in 2018 and 651.6 mm in 2019. The experiment was laid-out in randomized block design with three replications. The eight treatments comprised with sole crops *i.e*. pigeonpea, sesame, groundnut, soybean, greengram, blackgram, cowpea, cluster bean and seven treatment combinations comprised as intercropping with pigeonpea *i.e.* pigeonpea + sesame, pigeonpea + groundnut, pigeonpea + soybean, pigeonpea + green gram, pigeonpea + blackgram, pigeonpea + cowpea and pigeonpea + cluster bean in 1:2 ratio. The plot size was 5.0 m x 3.6 m, with variety of pigeonpea (ICPL 88039), sesame (TKG-308), groundnut (Mallika), soybean (RVS-2001-4), greengram (TJM-3), blackgram (Shekhar-3), cowpea (RC-101) and clusterbean (HG-2-20) were used for experimental purpose. Nitrogen, phosphorus and potassium fertilizers were applied just before sowing according to the base crop *i.e*. pigeonpea in all the intercropping systems and in sole plots it was applied according to respective crop of that plot using urea, SSP and MOP. The other cultural operations were done as per recommendations and crop requirement.

Grain and stover samples were collected, dried, processed and analyzed for nitrogen, phoshphorus, and potassium uptake at harvest stage. Nutrient uptake in grain and stover of pigeonpea were calculated in kgha^{-1} in relation to dry matter production ha^{-1} by using the following formula.

$$\text{Nutrient uptake (kgha}^{-1}) = \frac{\text{Nutrient content (\%)} \times \text{yield (grain/stover in kgha}^{-1})}{100}$$

Soil samples were also collected at harvest stage, oven dried and sieved to analysed nitrogen, phoshphorus, and potassium using alkaline potassium permanganate (KMnO4) method, colorimeter and flame photometer, respectively.

Results and Discussion

Total nutrient uptake (kgha^{-1}):

Uptake of nitrogen, phoshphorus and potassium by pigeonpea was significantly influenced by different intercropping systems. Sole planting of pigeonpea was recorded significantly higher uptake of nitrogen (102.28 kgha^{-1}), phoshphorus (8.29 kgha^{-1}) and potassium (78.44 kgha^{-1}) over intercropping system. This might be due to more number of plants in sole planting system which results more nutrient uptake over the intercropping systems. Similar results were reported by Kumar and Rana (2007), Singh *et al.* (2013) and Kumawat *et al*. (2015) [9, 14, 10]. Among the intercropping systems significantly lowest uptake was observed in pigeonpea intercropped with sesame whereas the significantly maximum nutrients uptake was found in pigeonpea intercropped with cowpea system which was at par with rest of the intercropping systems except sesame with pigeonpea.

Soil nutrient status

There was an increase in available nitrogen and phoshphorus in the soil at harvest as compare to their initial status. The available nitrogen in the soil was significantly increased by different intercropping systems (Table 1) however, pigeonpea based intercropping systems failed to show any significant effect on available phoshphorus and potassium status in the soil. This may be attributed to reduction in competition effect after harvest of intercrops and the pigeonpea was applied with full recommended dose and its leguminous nature helped in fixing atmospheric nitrogen, which might helped in increasing the nutrient availability in the soil (Kumawat *et al*. 2015 and Singh *et al*. 2016) [10].

Available nitrogen in the soil at harvest was observed highest in pigeonpea intercropped with cowpea system which was at par with groundnut, greengram, blackgram and sole pigeonpea as well. However lowest available nitrogen was found in pigeonpea intercropped with sesame system. This might be due to non-nitrogen fixing nature of sesame. Similar results were also noticed by Jaya Kumar *et al*. (2008) and Sheoran *et al.* (2010) [7, 13].

Table 1: Status of macro nutrients in the soil (Kg ha^{-1}) after harvesting as influenced by different intercropping systems

Treatment details		Nitrogen	Phoshphorus	Potassium
T_1	sole pigeonpea	267.03	20.04	254.97
T_9	pigeonpea + Sesame	238.84	19.58	251.78
T_{10}	pigeonpea + groundnut	267.21	20.06	256.83
T_{11}	pigeonpea + soybean	253.00	19.95	255.09
T_{12}	pigeonpea + greengram	267.12	20.06	256.87
T_{13}	pigeonpea + blackgram	267.23	20.06	256.69
T_{14}	pigeonpea + cowpea	267.67	20.07	257.15
T_{15}	pigeonpea + Clusterbean	252.81	20.04	256.23
S.Em.±		3.159	0.176	4.489
LSD (P=0.05)		9.150	NS	NS
Initial Status		234	19.4	275.37

Table 2: Yield and Economics of treatments

Treatments detail		PEY* (Kg ha^{-1})	Net returns (₹ ha^{-1})	B:C Ratio
T1	Sole Pigeonpea	1684	71948	3.30
T2	Sole Sesame	721	15589	1.57
T3	Sole Groundnut	1506	48873	2.14
T4	Sole Soybean	679	8264	1.25

T5	Sole Green gram	1129	38678	2.38
T6	Sole Blackgram	908	26034	1.93
T7	Sole Cowpea	1368	52982	2.83
T8	Sole Clusterbean	1015	30706	2.01
T9	Pigeonpea + Sesame (1:2)	1114	39127	2.36
T10	Pigeonpea + Groundnut (1:2)	1983	82215	3.14
T11	Pigeonpea + Soybean (1:2)	1164	38972	2.20
T12	Pigeonpea + Green gram (1:2)	1650	69528	3.37
T13	Pigeonpea + Blackgram (1:2)	1446	57829	2.97
T14	Pigeonpea + Cowpea (1:2)	1826	79685	3.69
T15	Pigeonpea + Clusterbean (1:2)	1416	54994	2.79
S.Em.±		8.1	10.4	0.067
LSD (P=0.05)		22.9	29.4	0.190

* Pigeonpea Equivalent Yield

Yield and economics

The pigeonpea equivalent yield differed significantly among all the cropping systems (Table 2). The pigeonpea equivalent yield was recorded significantly highest with groundnut followed by with cowpea intercropping system. The pigeonpea equivalent yield was 17.76% higher in intercropped with groundnut and it was 8.43% higher with cowpea as compare to sole pigeonpea. The higher pigeonpea equivalent yield was recorded due to higher yield of groundnut and higher market price of intercrops like cowpea and greengram etc. These results are in agreement with the findings of Jat and Ahlawat (2004) and Bhadu *et al*. (2020) [6, 4] who recorded higher equivalent yield of pigeonpea by intercropped with groundnut. Koli *et al.* (2013) [8] also reported that intercropped pigeonpea gave significantly higher yield as compared to sole pigeonpea.

Among the sole and intercropping systems, The pigeonpea with groundnut recorded 14.27% higher net returns followed by the intercropped with cowpea which have 10.75% higher net returns as compare to sole pigeonpea. Whereas, the cowpea intercropping system gave maximum per rupee returns than rest of the treatments (Table 2) which was 11.82% more over sole pigeonpea. Bhadu *et al*. (2020) [4] also reported the similar results.

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