Int.J.Curr.Microbiol.App.Sci (2020) *9*(11): 550-555

International Journal of Current Microbiology and Applied Sciences
***ISSN: 2319-7706* Volume 9 Number 11 (2020)**
Journal homepage: http://www.ijcmas.com

Original Research Article https://doi.org/10.20546/ijcmas.2020.911.067

Phosphorus Use Efficiency as Influenced by NP Ratios to Pigeonpea and Fertilizer Levels to Intercrop in Pigeonpea + Blackgram System

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Keywords

Fertilizer levels, NP ratios, PEY (pigeonpea equivalent yield), Net returns, PUE (phosphorus use efficiency)

Article Info

Accepted:
07 October 2020
Available Online:
10 November 2020

A B S T R A C T

The field experiment included nine treatment combinations with two fertilizer levels to intercrop as main plot (F_1 - 50 % and F_2 - 100 % RDF to intercrop) and four N:P ratios to pigeonpea as sub plots [L_1 – 1:2 (25:50 kg N:P_2O_5 ha^{-1}), L_2 – 1:2.5 (25:62.5 kg N:P_2O_5 ha^{-1}), L_3 – 1:3 (25:75 kg N:P_2O_5 ha^{-1}) and L_4 – 1:3.5 (25:87.5 kg N:P_2O_5 ha^{-1})] and one absolute control (without any fertilizer application to both the crops). Non- significant difference was noticed in nutrient status of soil with respect to different fertilizer levels to intercrop. Among the N:P ratios to pigeonpea, 1:3, 1:3.5 recorded significantly higher available nitrogen, phosphorus and organic carbon (239.72, 241.60 and 45.35, 47.50 kg ha^{-1} and 0.49, 0.50 %, respectively). Among the interactions, available nitrogen, phosphorus and organic carbon in soil was found significantly higher with 100 % RDF to intercrop with N:P ratio of 1:3.5 (243.20, 49.14 kg ha^{-1} and 0.52 %, respectively). Agronomic efficiency was found significantly higher with 50 and 100 % RDF to intercrop with N:P ratio of 1:3 and 1:3.5 (7.50,7.57 and 7.93, 7.63, respectively) of the system. Among the interactions, F_2L_3, F_2L_4 showed significantly higher PEY, gross and net returns (2537, 2597 kg ha^{-1}, ₹ 1,43,971, 1,47,390 ha^{-1}, and ₹ 1,02,771, 1,05,566 ha^{-1}, respectively) over others except F_1L_3, F_1L_4 and indicated that 50% RDF was enough to intercrop when main crop was supplied with 75 and 100 kg P_2O_5.

Introduction

India is the largest producer, consumer and importer of pulses in the world. In the present scenario, because of tremendous increase in population there is decrease in per capita availability of land. So there is need to maximise productivity per unit area. One of the best approaches to increase production potential and profitability per unit land area is intercropping system (Nagar *et al.,* 2015). Since pulses are rich sources of proteins, for majority of vegetarians they aid in building of tissues. So they are regarded as backbone of nutritional security of our country. Among different intercropping systems the legume based intercropping system provides advantages like roots increase the solubility of phosphorus in the rhizosphere by release of some organic acids like picidic, citric, maleic acids, addition supply nitrogen to component crop and increase in population of beneficial

microorganisms that maintains proper soil health and provides a synergistic effect.

Pigeonpea (*Cajanus cajan* L. Millsp) is the second most important pulse crop after chickpea with protein content of 22 % that makes an excellent source of protein supplement to vegetarian population. In India it is being cultivated on an area of 5.33 million hectare, with a production of 4.87 million tonnes and productivity of 913 kg ha^{-1} (Anon., 2018). Wider row spacing of pigeonpea offers scope to grow intercrops in between the rows to improve productivity. Other special features include drought tolerance, withstanding capacity of harsh climate, biological nitrogen fixation etc…

Blackgram (*Vigna mungo* L.) is short duration legume crop grown on an area of 4.47 million hectare, with a production of 2.83 million tonnes and productivity of 632 kg ha^{-1} (Anon., 2018a). It fetches higher price because of its high nutritional value.

Pulse production has many constraints that include poor nutrient management. Macro nutrients like nitrogen, phosphorus have a vital role in pulse productivity. Nitrogen is building block of plant proteins, constituent of chlorophyll that keeps plant tissues green with vigorous growth.

Phosphorus is the most limiting nutrient for legumes. It assists in root development, nodulation, photosynthesis and respiration. Being a constituent of adenosine tri phosphate (ATP) it is involved in an energy transfer in various biochemical reactions, cell division and development of new tissues.

An essential index that determines the use of applied phosphorus by a plant is phosphorus use efficiency (PUE). In general, the phosphorus use efficiency is less as only 30 % of the applied phosphorus is taken by plants in its entire growing season and phosphorus recovery efficiency of applied fertilizers in soil by the crop plant is less than 20 % (Fageria *et al.,* 2011). Intercropping system is one of the best strategies to improve PUE (Hasan *et al.,* 2016).

Materials and Methods

A field experiment was conducted at the Main Agricultural Research Station, University of Agricultural Sciences, Dharwad, during July 2018. The soil was clay loam, neutral in p^H (7.34), low in available nitrogen (254.2 kg ha^{-1}), medium in available phosphorus (24.7 kg ha^{-1}) and high in available potassium (392 kg ha^{-1}), low in organic carbon (0.38 %), normal in salt content (0.36 dSm^{-1}).

The experiment was laid out in split plot design with three replications and consisted of two fertilizer levels to intercrop as main plots, (50 and 100 % RDF to intercrop), four N:P ratios to pigeonpea as subplots (1:2-25:50 kg $N:P_2O_5$ ha^{-1}, 1:2.5-25:62.5 kg $N:P_2O_5$ ha^{-1}, 1:3-25:75 kg $N:P_2O_5$ ha^{-1}, 1:3.5-25:87.5 kg $N:P_2O_5$ ha^{-1} and one absolute control - without any fertilizer to both the crops. The pigeonpea and blackgram cultivator used were TS-3R and DBGV-5, with recommended spacing of 120 × 20 cm for pigeonpea and 30 ×10 cm for blackgram in intercropping ratio of 1:3 and were sown on July 14 2018 simultaneously.

At the time of sowing both the crop seeds were treated with liquid based microbial cultures of *Rhizobium* and *Pseudomonas straita* at 4 ml kg^{-1} of seeds. Nitrogen and phosphorus were supplied in the form of Urea and SSP as per the treatments. Weeding and plant protection measures were undertaken as per the need of the crops.

Blackgram and pigeonpea were harvested during October and January. The observations

on yield attributes and yield were recorded at harvest. The economics was worked out based on the prevailing market price for the existing year. Agronomic efficiency of phosphorus indicates increase in yield per kg of phosphorus fertilizer applied. It was calculated by the following formula as suggested by Fageria *et al.*, (2011).

$$\text{Agronomic efficiency of phosphorus} = \frac{\text{Yield of fertilized crop- Yield of un-fertilized crop}}{\text{Quantity of fertilizer applied}}$$

Data analysis and interpretation was done using Fischer's method of variance technique as described by Gomez and Gomez (1984). The level of significance used in 'F' test was P=0.05.

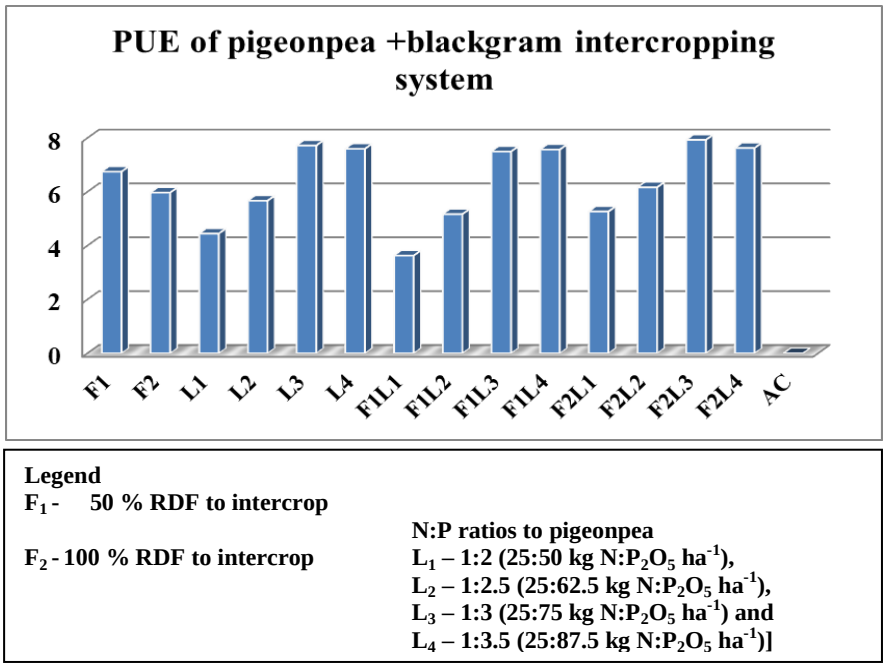
Results and Discussion

There was no significant effect of fertilizer levels to intercrop on pigeonpea (Table 1). Application of different fertilizer levels to intercrop observed significant effect on seed yield of blackgram (Fig. 1).

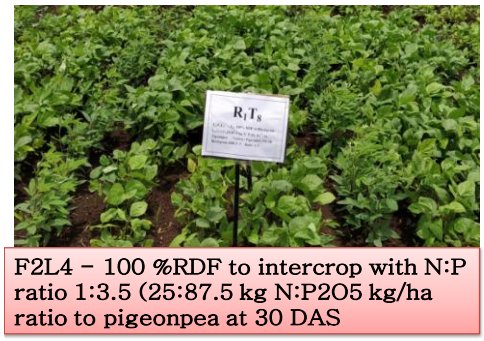
Table.1 Effect of fertilizer levels to intercrop and NP ratios to pigeonpea on productivity, economics and phosphorus use efficiency of pigeonpea + blackgram intercropping system

Treatments	Seed yield (kg ha^{-1})		Pigeonpea equivalent yield (kg ha^{-1})	Net returns (₹ ha^{-1})	Agronomic efficiency of P (kg kg^{-1})
	Pigeonpea	Blackgram			
F_1	1576^{a}	566^{b}	2129^{b}	80968^{b}	6.75^{a}
F_2	1676^{a}	696^{a}	2363^{a}	93187^{a}	5.97^{b}
S.Em.±	36	21	36	1371	0.09
L_1	1367^{b}	588^{a}	1947^{b}	71086^{b}	4.45^{b}
L_2	1498^{b}	631^{a}	2120^{b}	80278^{b}	5.67^{b}
L_3	1780^{a}	644^{a}	2416^{a}	96435^{a}	7.72^{a}
L_4	1847^{a}	661^{a}	2499^{a}	100509^{a}	7.60^{a}
S.Em.±	61	23	80	3963	0.60
F_1 L_1	1327^{c}	499^{d}	1820^{d}	64386^{e}	3.63^{b}
F_1 L_2	1435^{c}	571^{cd}	1999^{cd}	73932de	5.17^{ab}
F_1 L_3	1716^{ab}	587^{b-d}	2295^{a-c}	90100^{a-d}	7.50^{a}
F_1 L_4	1802^{ab}	606^{a-d}	2400^{ab}	95452^{a-c}	7.57^{a}
F_2 L_1	1407^{c}	677^{a-c}	2075^{b-d}	77786^{c-e}	5.27^{ab}
F_2 L_2	1560^{bc}	691^{ab}	2241^{bc}	86624^{b-d}	6.17^{ab}
F_2 L_3	1845^{ab}	702^{a}	2537^{a}	102771^{ab}	7.93^{a}
F_2 L_4	1891^{a}	715^{a}	2597^{a}	105566^{a}	7.63^{a}
S.Em.±	83	35	104	5044	0.85
Absolute control	1179	373	1547	53444	0.00
S.Em.±	88	35	122	5151	0.77
C.D. (P=0.05)	265	104	367	15443	2.33

Fig.1 Agronomic efficiency of phosphorus in pigeonpea + blackgram intercropping system



Images of superior treatments and absolute control at harvest stage of pigeonpea


F2L4 – 100 %RDF to intercrop with N:P ratio 1:3.5 (25:87.5 kg N:P2O5 kg/ha ratio to pigeonpea at 30 DAS


F2L4 at 60 DAS


Absolute control at 60 DAS


Absolute control at 30 DAS

The application of 100 % RDF to intercrop recorded significantly higher seed yield (696 kg ha^{-1}) of blackgram over 50 % RDF (566 kg ha^{-1}) and absolute control (373 kg ha^{-1}). The percent increase in yield compared to absolute control was 86.8 %. This was due to optimum

availability of nutrients (N, P, S, Ca) through urea and SSP for normal growth of intercrop that improved root system, photosynthetic activity, nutrient uptake, dry matter production, reduced flower drop, better pod formation and reduced competition between component crops. Since application method of different fertilizers to component crop was independent that means recommended dose of fertilizer to blackgram and pigeonpea were applied to respective rows of crops, there was no competition for nutrients between the component crops. Similar results were reported by Vishwanatha *et al.,* (2012) in pigeonpea + sunflower.

Among the NP ratios to pigeonpea, 1:3 and 1:3.5 ratios (25:75, 25:87.5 kg $N:P_2O_5$ ha^{-1}) recorded significantly higher seed yield (1780 and 1847 kg ha^{-1}, respectively) of pigeonpea. These treatments also observed significantly higher PEY (2416 and 2499 kg ha^{-1}, respectively), net returns (₹ 96,435 and 1,00,509 ha^{-1}, respectively) and PUE (7.72 and 7.60 kg kg^{-1}, respectively). This was due to beneficial effect of nitrogen and phosphorus that relatively increased higher root proliferation, more N_2 fixation by nodules, photosynthesis and better translocation of photosynthates from source to sink. These results are in conformity with Singh *et al.,* (2017) in pigeonpea. Yield of blackgram recorded was non-significant due to NP ratios to pigeonpea where it influenced the pigeonpea yield significantly (Table 1).

Among the interactions, the 100 % RDF to intercrop with NP ratio of 1:3 and 1:3.5 to pigeonpea recorded significantly higher seed yield (1845, 1891 and 702, 715 kg ha^{-1}, respectively) of pigeonpea and blackgram. Meanwhile, these treatments also exhibited significantly higher PEY and net returns (2537, 2597 kg ha^{-1} and ₹ 1,02,771, 1,05,566 ha^{-1}, respectively) compared to others and absolute control (1547 kg ha^{-1} and ₹ 53,444 ha^{-1}, respectively) which remained on par with 50 % RDF to intercrop with N:P ratio of 1:3 and 1:3.5 (2295, 2400 kg ha^{-1} and ₹ 90,100, 95,452 ha^{-1}, respectively) given in Table 1. PUE was recorded significantly higher with 50 and 100 % RDF to intercrop and NP ratio of 1:3 and 1:3.5 (7.50, 7.57 and 7.93, 7.63 kg kg^{-1}, respectively) over absolute control (0.00). This was due to legume effect, an associated blackgram had a positive effect on yield of pigeonpea by adding some nitrogen to soil and during its early stage of crop growth, it suppressed weeds, enhanced moisture availability, reduced evapotranspiration, added organic matter to soil to improve soil physical, chemical and biological properties. Here, higher price of both the crops resulted in higher PEY and net returns. In the system efficiency, crop responded very well for upto 75 kg phosphorus application and further it starts to decline gradually. This indicated the response of pigeonpea for P nutrient is relatively high; upto 75 kg P_2O_5 ha^{-1} Ahirwar *et al.,* (2016).

Based on the results of the present investigation it can be concluded that, when main crop (pigeonpea) was given with N:P ratio of 1:3, fertilizer dose of intercrop (blackgram) can be reduced to 50 % without compromising the PEY, net returns and PUE in pigeonpea + blackgram intercropping system.

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How to cite this article:

Deepa Kempagoudra and Ganajaxi Math. 2020. Phosphorus Use Efficiency as Influenced by NP Ratios to Pigeonpea and Fertilizer Levels to Intercrop in Pigeonpea + Blackgram System. *Int.J.Curr.Microbiol.App.Sci.* 9(11): 550-555. doi: https://doi.org/10.20546/ijcmas.2020.911.067