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RESEARCH ARTICLE

ROLE OF NANO PHOSPHORUS IN MAIZE AND PIGEONPEA BASED INTERCROPPING SYSTEM UNDER MEDIUM-UPLAND SITUATION OF JHARKHAND.

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Abstract

All India Coordinated Research Project on Pulses Research of Birsa Agricultural University, Ranchi (Jharkhand) was conducted an experiment for two consecutive years during Kharif 2016 and 2017 with a view to study the response of Phosphorus on maize and Pigeon pea based inter-cropping system.

Maximum grain yield of pigeon pea and black gram were recorded with 50% RDP+ Nano-P 40 ppm followed by 100% RDP and Nano-P 40 ppm. Application of Nano-P 40 ppm increased grain yield of pigeon pea, maize and black gram compared to no phosphorus.

Pigeon pea + black gram 1:1 recorded higher straw yield of pigeon pea than that of pigeon pea + black gram 1:2 system and sole pigeon pea. Likewise, straw yield of maize under maize + black gram 1:1 was found higher than that of sole maize and maize + black gram 1:2 system. Straw yield of black gram was registered higher in both plant geometry with pigeon pea (1:1 and 1:2) than that of similar combinations with maize. Concerning to phosphorus management maximum straw yield of pigeon pea, black gram and maize were recorded with 50% RDP+ Nano-P 40 ppm followed by 100% RDP and Nano-P 40 ppm. Minimum grain and straw yield was registered under no phosphorus application.

System productivity in terms of 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). 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.

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Introduction:-

Jharkhand a newly created state having nearly 40 per cent of cultivable land under medium to upland land situation with medium to poor soil health. As Jharkhand has good rain fall and we are experiencing nearly 1300 to 1400 mm rain fall. Due to topography and rapid occurrence of rain farmers faces situation like partial dry. During Kharif low land preferably be covered by rice, while medium to upland can be successfully utilized by crops like less water requirement with high energy value, which not only nourished human being but also enrich soil health. To diversify the area under upland rice, a suitable short duration crop/intercropping system is required to increase the productivity in upland. Thus, in order to meet the food, feed, fiber, nutritional and other requirements of the increasing human population, productivity of cereals and pulses particularly in upland ecosystem of India as well as Jharkhand has to be enhanced.

Black gram is one of the important pulse crops in India and occupies an area of 4.49 million hectare with an average productivity of 652 kg ha⁻¹. In Jharkhand, it occupies an area of 94.9 thousand hectare with a production of 0.14 million tonne, and productivity of 933 kg ha⁻¹ (DoA. Govt. of Jharkhand, 2017-18). It is a very good source of protein (22.3%), calcium (154 mg), iron (9.1 mg), fat (1.4 g), riboflavin (0.37 g) and thiamin (0.42 mg) per 100 g (Asaduzzaman et al., 2010). 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. Intercrop of black gram with pigeon pea or maize can be a suitable option for rainfed upland condition, as this region largely depends upon vagaries of monsoon. 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.

In spite of liberal application of chemical fertilizers, a declining or stagnating yield trend has been observed in recent years which might be attributed to imbalanced supply of nutrients resulting in multiple nutrient deficiencies. Phosphorus is an important limiting primary nutrient element after nitrogen for plant growth and development. Besides, Phosphorus being the major nutrient plays a vital role in energy transformation, uniform grain filling, grain quality and higher yield. However, in 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). Alternatively, use of Nano-P in different combinations with bulk P-fertilizer for enhancing its use efficiency may be explored for profitable farming. The role of Nano phosphorus is to solve the problem of phosphorus fixation and supply adequate phosphorus to the crop for its proper growth and development. Use of Nano-P in legume based intercropping system is yet to be explored for cost effective option of P-management in acidic soils of Jharkhand

Materials and Methods:-

Field experiment was conducted at BAU, Ranchi, during kharif seasons of two consecutive years, 2016 and 2017. The soil condition of experimental plot were as mentioned here as physical character, Sand (60.8%), Silt (27.8 %), Clay (11.4 %), Textural class (Sandy loam), Water holding capacity at saturation (37.6 %), Bulk density (1.58 Mg cc⁻¹), While chemical properties Organic carbon (4.20g kg⁻¹), Available N (191.7 kg ha⁻¹), Available P (23.21kg ha⁻¹), Total P (511.4 kg ha⁻¹), Available K (157.8 kg ha⁻¹), pH (at 1 :2.5 soil to water 5.40) and EC (d S m⁻¹ at 25°C 0.06). The experiment was laid out in split-plot Design with three replications. The treatments consisted of seven different crop geometry, i.e crop combination viz. C1 - sole black gram, C2 - sole pigeon pea, C3 - sole maize, C4 - pigeon pea + black gram (1:1).

C5 –maize + black gram (1:1), C6 - pigeon pea + black gram (1:2) and C7 –maize + black gram (1:2) in main plots and four phosphorus management practices viz. P1- Control, P2- 40 ppm Nano-P, P3- 50% recommended dose of phosphorus (RDP) +40 ppm Nano- P and P4-100 % RDP in subplots. Pigeon pea var. UPAS-120, black gram var. Uttara and maize var. Suwan composite-1 were grown with 20:40:20:20, 20:40:20:20 and 120:60:40 kg/ ha N, P₂O₅, K₂O, and S respectively. Data on grain yield, seed yield were taken and yield equivalent as well as harvest index were calculated and further, using the standard established mathematical formula under mentioned parameter year wise was taken accordingly elaborated here.

Grain yield (kg ha⁻¹):-

The dried grains of black gram, pigeon pea and maize from the net plot area were cleaned after threshing and weighed to compute the grain yield and expressed as kg ha⁻¹.

Stalk yield (kg ha⁻¹):-

Total biomass from each net plot was dried on sun. Before threshing, the bundle weight of each crop (kg plot⁻¹) was taken. Stover yield was obtained by deducting the grain yield from the bundle weight and expressed in kg ha⁻¹.

Harvest index:-

Harvest index is the ratio of economic yield to biological yield of the crop. It was calculated by using following formula given by Donald (1962).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

System productivity:-

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.

Result and Discussion:-**Grain yield (kg ha⁻¹):-**

Data (Table 1) revealed that higher grain yield of pigeon pea was recorded under pigeon pea + black gram 1:1 than that of sole pigeon pea and pigeon pea + black gram 1:2 systems. Similarly, grain yield of maize registered maximum under maize + black gram 1:1 followed by sole maize and maize + black gram 1:2 systems. In the intercropping system, black gram produced higher grain yield under pigeon pea + black gram combinations (C₄ and C₆) compared to maize + black gram combinations (C₅ and C₇).

With respect to phosphorus management practices, maximum grain yield of pigeon pea and black gram were recorded with 50 % RDP+ Nano-P 40 ppm followed by 100% RDP and Nano-P 40 ppm while in case of maize, maximum grain yield. Application of Nano-P 40 ppm increased grain yield of pigeon pea, maize and black gram compared to no phosphorus while minimum grain yield was registered under no phosphorus application. Although data was not analyzed but interaction between C₄ x P₃ recorded maximum grain yield. This might helped for efficient use for natural resources by the pigeon pea and black gram under intercropping system. The increase in grain yield in intercropping systems may be attributed to the application of SSP/bulk P fertilizers along with Nano phosphorus which possibly increased the P content in addition to N, and K in soil solution and ultimately affected the formation of more nodules, vigorous root development, better N fixation and better development of plant growth leading to higher photosynthetic activity and translocation of photosynthetic to the sink which in turn resulted in better development of yield attributes and finally in higher grain yield. Under favorable environment, Nano-P + phosphatic fertilizers might have helped to maintain proper nutrient concentration in plant thereby boost in development of new shoot and ultimately increased the growth; yield attributes and finally yield of the crops. Similar results have been obtained by Patil and Padmani (2007), Pal et al. (2016) and Sahay et al. (2016).

Straw yield (kg ha⁻¹):-

Pigeon pea + black gram 1:1 recorded higher straw yield of pigeon pea than that of pigeon pea + black gram 1:2 system and sole pigeon pea. Likewise, straw yield of maize under maize + black gram 1:1 was found higher than that of sole maize and maize + black gram 1:2 system. Straw yield of black gram was registered higher in both plant geometry with pigeon pea (1:1 and 1:2) than that of similar combinations with maize. Concerning to phosphorus management maximum straw yield of pigeon pea, black gram and maize were recorded with 50% RDP+ Nano-P 40 ppm followed by 100 % RDP and Nano-P 40 ppm. Minimum straw yield was registered under no phosphorus application (Table 2).

Harvest index (%):-

Maximum harvest index of pigeon pea was recorded under (C₄) followed by (C₂) and (C₆) (Table 3). Higher harvest index of maize was noted under C₅ plant geometry compared to C₇ and C₃. Harvest index of black gram was higher in pigeon pea + black gram system (1:1 or 1:2) compared to maize + black gram systems (1:1 or 1:2). With regards to phosphorus management practices, maximum harvest index of pigeon pea and black gram were recorded with 50%

RDP+ Nano-P 40 ppm followed by 100 % RDP and Nano-P 40 ppm while in case of maize, higher harvest index was registered under 100 % RDP followed by 50% RDP+ Nano-P 40 ppm and Nano-P 40 ppm. Minimum harvest index in all plant geometry were reported under no phosphorus application (Table 3). Grain and straw yield of pigeon pea, maize and black gram increased as results of increasing levels of phosphorus up to 100 % RDP. However, maximum increase in yield was reported when 50 % of phosphoric fertilizer with Nano-P40 ppm applied plots. Mardalipour et al. (2014) observed that Nano bio-fertilizer application in wheat increased spike length, spike number, seed number, seed number in spike, seed weight and number of days until maturity. Generally, Nano bio-fertilizer application increased crop growth and improved yield and yield components through extending growing period. Tarafdar et al. (2012) reported that under arid condition (40 ppm concentration) foliar application of Nano-phosphorus gave 80 kg ha⁻¹ P of cluster bean and pearl millet. The improvement in yield components might have resulted from favorable influence of phosphorus nutrition on the growth parameters (plant height, LAI, branching and dry matter accumulation) finally leading to greater nutrient uptake, efficient partitioning of metabolites, adequate translocation and accumulation of photosynthesis (Tisdale et al., 1995).

Such observations were also recorded by Yadav et al. (1992), Singh et al. (1998), Shivran et al. (2000) and Adhikari et al. (2014). The increase in grain, as well as biological yield and harvest index of pigeon pea due to application of Nano-P and phosphatic fertilizer was largely a function of improved growth, translocation of more photosynthates from source to sink and consequent development of yield attributes. These results are in conformity with the results of Chittapur et al. (1994) and Jat and Ahlawat (2003). Application of phosphorus also enhanced the yield attributes viz., pods plant⁻¹, grains pod⁻¹ and grain, and Stover yields of black gram.

System productivity /Black gram equivalent yield (kg ha⁻¹):-

Data on system productivity i.e. Black gram equivalent yield (Table 4) as influenced by cropping system and phosphorus management sown in Table 6 reflect that, 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 C₄ and C₆ recorded significantly superior system productivity over C₅ and C₇ 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 (P₃) which was at par with 100 % RDP (P₄) followed by Nano-P 40 ppm (P₂). The application of no phosphorus (P₁) 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(C₄) or pigeon pea + black gram 1:2 systems (C₆) with application of Nano-P 40 ppm (P₂) in similar crop combination were found superior to no phosphorus application (P₁) whereas, maize + black gram 1:1 (C₅) or maize + black gram 1:2 (C₇) with application of Nano-P 40 ppm (P₂) 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 (C₄) X 50% RDP+ 40 ppm Nano-P (P₃) which remained at par with C₆ x P₃, C₄ x P₄ and C₆ x P₄ but superior to the rest of the combinations.

The BEY of interaction table indicated that pigeon pea + black gram 1:1 was found maximum at all the phosphorus levels i.e. P₂, P₃ and P₄ 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 1:1with50% RDP +Nano- P 40ppm (P₃). It was observed that at different levels of P in pigeon pea + black gram 1:1 the BEY increase significantly up to P₃ after that i.e. at P₄ the BEY reduced significantly. In maize + black gram 1:1 (C₅) and maize + black gram 1:2 (C₇) the BEY was increase significantly up to P₃ but at P₄ the increase was not significant. In case of C₇ (maize + black gram 1:2) again BEY increased significantly up to P₃.

T r e t m e n t	P ₁ -		P ₂ -		P ₃ -50		P ₄ -		Mean	
	B	P	B	P	B	P	B	P	B	P
C	8		8		1		1		1	
C		9		1		1		1		1

C		3		3		3		3		3
C	4	(	5	(	6	(	6	(	5	(
C	3	(	2	(	3	(	4	(	3	(
C	5	(	6	(	8	(	7	(	6	(
C	4	(	5	(	6	(	5	(	5	(
M	5	9	5	1	7	1	7	1		

Table 1:-Grain yield (kg ha⁻¹) as influenced by legume based crop geometry and phosphorus management (mean of 2016 and 2017).

BG-black gram, PP- pigeon pea, M-maize, NB: Value in parenthesis is of pigeon pea (C4&C6) and maize (C5&C7)

Table 2:-Straw yield (kg ha⁻¹) as influenced by legume based crop geometry and phosphorus management (mean of 2016 and 2017).

T r	P ₁ -		P ₂ -		P ₃ -50		P ₄ -		Mea	
	B	P	B	P	B	P	B	P	B	P
C	2		3		3		3		3	
C		4		4		5		5		5
C		7		7		8		7		7
C	1	(	1	(	2	(	2	(	1	(
C	1	(	1	(	1	(	1	(	1	(
C	1	(	2	(	2	(	2	(	2	(
C	1	(	1	(	2	(	2	(	1	(
M	1	(	1	(	2	(	2	(

BG-black gram, PP- pigeon pea, M-maize, NB: Value in parenthesis is of pigeon pea (C4&C6) and maize (C5&C7)

Table 3:-Harvest index (%) as influenced by legume based crop geometry and phosphorus management (pooled of 2016 and 2017).

T r	P ₁ -		P ₂ -		P ₃ -50		P ₄ -		Mea	
	B	P	B	P	B	P	B	P	B	P
C	2		2		2		2		2	
C		1		1		1		1		1
C		2		2		3		3		2
C	2	(	2	(	2	(	2	(	2	(
C	2	(	2	(	2	(	2	(	2	(
C	2	(	2	(	2	(	2	(	2	(
C	2	(	2	(	2	(	2	(	2	(
M	2	1	2	1	2	1	2	1		
					S. Em		CD at		CV	
Crop combination (only black gram)					0.41		1.32		7.5	
Phosphorus management					0.24		0.71			
Int era	Between P, at same				0.81		NS			
	Between C ,at same or				0.62		NS			

BG-black gram, PP- pigeon pea, M-maize, NB: Value in parenthesis is of pigeon pea (C4&C6) and maize (C5&C7)

Table 4:-Black gram equivalent yield, BEY (kg ha⁻¹) as influenced by legume based crop geometry and phosphorus management (pooled of 2016 and 2017).

Treatme	P ₁ -	P ₂ -	P ₃ -	P ₄ -	Me
C ₁ -Sole	818	889	117	113	100
C ₂ -Sole	994	104	122	120	111

C ₃ -Sole	799	840	940	956	884
C ₄ -	1504	166	197	190	176
C ₅ -	1088	115	136	138	124
C ₆ -	1414	160	193	188	170
C ₇ -	1161	124	145	143	132
Mean	1111	120	143	141	
			S.	CD	CV
Crop combination			21.6	66.7	8.2
Phosphorus management			11.8	33.6	
Interactio n	Between P, at same		43.3	91.9	
	Between C ,at same or		34.6	101.	

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

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.

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 Ali et al. (2003) and Nagar et al. (2015).

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, grain yield, straw yield as well as system productivity in terms of black gram equivalent yield. The grain yield and straw yield of the system productivity at 50 % RDP+ 40 ppm nano P which were comparable under same intercropping system at 100 per cent recommended dose of Phosphorus. Pigeon pea and black gram (1:1) ratio with 50% RDP+ Nano-P 40 ppm produced higher grain yield, straw yield as well as 58.8 % more system productivity over sole pigeon pea

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