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Phosphorus uptake at different growth stages in relation to yield of maize as influenced by nitrogen and phosphorus levels during *Kharif* season

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Abstract
Present investigation was carried out during two consecutive *kharif* seasons of 2014 and 2015 to evaluate the phosphorus uptake at different growth stages and yield of hybrid maize as influenced by different nitrogen (200, 250 and 300 kg ha^{-1}) and phosphorus (40, 60, and 80 kg ha^{-1}) levels. The uptake of phosphorus was found to increase with each successive increase in nitrogen level from 200 to 300 kg ha^{-1} and phosphorus up to 60 kg ha^{-1} with increase in age of the crop with higher uptake of above nutrients with 300 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1}. During both the years, the highest and lowest grain and stover yields were recorded with N level of 300 kg ha^{-1} and 200 kg ha^{-1} and with P level of 60 kg ha^{-1} and 40 kg ha^{-1} respectively.

Keywords: Phosphorus, uptake, maize, grain, stover, yield

Introduction
Maize (*Zea mays* L.) is the third most important cereal after rice and wheat for food by contributing to 9 per cent of India's food basket and 5 per cent to World's dietary energy supply (Saikumar *et al.*, 2012) [16]. India is the sixth largest producer of maize with 22.36 million tonnes of production from 9.40 million hectares, with a productivity of 2.4 t ha^{-1}.
The demand for maize owing to burgeoning growth rate of poultry, livestock, fish and wet and dry milling industries is expected to increase from current level of 22.36 million tonnes to 45 million tonnes by 2030 (DMR, 2011) [4]. Among the factors limiting the amount of possibly obtainable higher yield, mineral nutrient imbalances play a major role. Adjustment of the fertilization system to plant quantitative needs and especially to nutrient uptake dynamics in field crops, results in balance in the functions of individual nutrients (Roberts, 2008) [15]. The fulfillment of the fundamental goal of maize fertilization, i.e. obtaining high and stable yields, requires a suitable supply of N and P to the plant, maintained at a level with no deleterious effects. In support of the maximum crop response, nitrogen needs and adequate phosphorus levels as well as prospective nutrient interactions in plant uptake. The aim of the present study was to assess phosphorus content in maize as well as its accumulation in the crop at all the stages of crop growth, under differentiated rates of mineral fertilization with N and P.

Materials and Methods
Field trial was conducted at College Farm of Agricultural College, Mahanandi campus of Acharya N. G. Ranga Agricultural University, situated at 15.51°N latitude, 78.61°E longitude and at an altitude of 233.5 m above the mean sea level, in the Scarce Rainfall Zone of Andhra Pradesh during *kharif* seasons of 2014 and 2015. The soil was sandy loam in texture, neutral in reaction (pH of 7.34), low in organic carbon (0.45%) and available nitrogen (275 kg ha^{-1}), high in available phosphorus (153 kg ha^{-1}) and high in available potassium(670 kg ha^{-1}), during beginning of experimentation.
The trials were laid down in a randomized block design with factorial concept. The treatments included three nitrogen levels (200 kg ha^{-1} (N_1), 250 kg ha^{-1} (N_2) and 300 kg ha^{-1} (N_3)) and three phosphorus levels (40 kg ha^{-1} (P_1), 60 kg ha^{-1} (P_2) and 80 kg ha^{-1} (P_3)). The test variety of maize was P-3396 a single cross hybrid. Recommended practices for disease and insect pest control were followed. Nitrogen was applied at graded levels as per the treatments in three splits *i.e.*, one third at basal, one third at knee high stage and the remaining one third at

tasseling stage. Entire quantity of P_2O_5 as per the treatments and K_2O (60 kg K_2O ha^{-1}) was applied as a basal dose. The sources of nitrogen, phosphorus and potassium were urea, single super phosphate and muriate of potash respectively. The split dose of nitrogen fertilizer was applied by placement method. Five plants from the destructive sampling area were cut to the base at 30 days interval and at harvest, sun dried and then oven dried at 60 °C till a constant weight was obtained. The above samples were then ground into fine powder and used for estimation of phosphorus and potassium, employing the standard procedures as outlined by Jackson (1973) [8] and the nutrient content of maize crop was expressed. The grain on the cobs was dried after shelling and was weighed. The data recorded on hybrid maize for nitrogen uptake in the course of investigation were statistically analyzed following the method of analysis of variance for randomized block design with factorial concept. Treatmental differences that were non-significant are denoted as NS.

Results and Discussion

Phosphorus uptake at 30 DAS

Maize crop fertilized with 300 kg N ha^{-1} (N_3) resulted in significantly higher uptake of phosphorus over lower doses (Table. 1). Application of nitrogen at 200 kg N ha^{-1} (N_1) recorded the lowest phosphorus uptake which was however on par with 250 kg N ha^{-1} (N_2), during both the years of investigation. Uptake of phosphorus by maize was higher with the application of phosphorus at 60 kg ha^{-1} (P_2) but all the levels recorded statistically on par values of P uptake. Crop fertilized with 40 kg P_2O_5 ha^{-1} (P_1) recorded the lowest phosphorus uptake, during both the years of study.

Phosphorus uptake at 60 DAS

Phosphorus uptake in maize was significantly higher with the application of nitrogen at 300 kg ha^{-1} (N_3), than other lower doses tried during *kharif*, 2014 (Table. 1). Similarly during *kharif*, 2015 application of 300 kg N ha^{-1} (N_3) recorded significantly higher phosphorus uptake which was however on par with 250 kg N ha^{-1} (N_2). Maize fertilized with 60 kg P_2O_5 ha^{-1} (P_2) registered the higher phosphorus uptake, however all the P levels were statistically at par with each other during both the years of study.

Phosphorus uptake at 90 DAS

Phosphorus uptake of maize was significantly higher with the application of nitrogen at 300 kg ha^{-1} (N_3), which was however on par with 250 kg ha^{-1} (N_2) (Table. 1). Maize fertilized with 80 kg P_2O_5 ha^{-1} (P_3) during the first year and 60 kg P_2O_5 ha^{-1} (P_2) during the second year registered the higher phosphorus uptake, which was however on par with other phosphorus levels tried.

The effect of interaction on phosphorus uptake of maize upto 90 DAS was not significant during both the years of investigation.

Phosphorus uptake by stover

Phosphorus uptake of maize was significantly higher with the application of nitrogen at 300 kg ha^{-1} (N_3) (Table. 1). Application of phosphorus at 60 kg ha^{-1} (P_2) recorded higher phosphorus uptake but it was statistically superior over other phosphorus levels during the first year. During the second year, 60 kg P_2O_5 ha^{-1} (P_2) recorded significantly higher phosphorus uptake, which was however on par with 80 kg ha^{-1} (P_1).

Interaction among nitrogen and phosphorus levels was significant only during *kharif*, 2015 (Table. 2). During the second year, at 40 kg P_2O_5 ha^{-1} (P_1) level phosphorus uptake was significantly affected by different nitrogen levels significantly higher phosphorus uptake was recorded with 300 kg N ha^{-1}. At 60 kg P_2O_5 ha^{-1} (P_2) significantly higher phosphorus uptake was recorded with 300 kg N ha^{-1} (N_3) which was significantly superior over 250 kg N (N_2) but at par with 200 kg N ha^{-1} (N_1). At 80 kg P_2O_5 ha^{-1} (P_3) significantly higher phosphorus uptake was recorded with 250 kg N ha^{-1} (N_2) which was significantly superior over 200 kg N (N_1) but at par with 300 kg N ha^{-1} (N_3). At all the N levels N ha^{-1} (N_1), phosphorus uptake was significantly affected by different phosphorus levels and uptake was significantly higher with 60 kg P_2O_5 (P_2), 80 kg P_2O_5 (P_3) and 40 kg P_2O_5 ha^{-1} (P_1) at 200 kg N (N_1), 250 kg N (N_2) and 300 kg N ha^{-1} (N_3) respectively.

Phosphorus uptake by grain

Phosphorus uptake of maize grain was higher with the application of nitrogen at 300 kg ha^{-1} (N_3), which was significantly superior over 250 kg N ha^{-1} (N_2) which in turn was superior over 200 kg N ha^{-1} (N_1) during both the years of study (Table. 1). Phosphorus uptake of maize was higher with the application of phosphorus at 60 kg ha^{-1} (P_2), which was significantly superior over 80 kg P_2O_5 ha^{-1} (P_3) which intern was superior over 40 kg P_2O_5 ha^{-1} (P_1) during both the years of study.

Interaction among nitrogen and phosphorus levels existed during both the years of study (Table. 4). During the first year, at 40 kg P_2O_5 ha^{-1} (P_1) level phosphorus uptake was not affected by different nitrogen levels. But at 60 kg P_2O_5 ha^{-1} (P_2) significantly higher phosphorus uptake was recorded with 250 kg N ha^{-1} which was on par with 300 kg N ha^{-1} (N_3). At 80 kg P_2O_5 ha^{-1} (P_3) significantly higher phosphorus uptake was recorded with 300 kg N ha^{-1} (N_3) which was significantly superior over other lower N levels. At 200 kg N ha^{-1} (N_1), phosphorus uptake was not affected by different phosphorus levels. But at 250 kg N ha^{-1} (N_2) phosphorus uptake was significantly higher with 60 kg P_2O_5 ha^{-1} (P_2) which was statistically superior over other P levels. At 300 kg N ha^{-1} (N_3) phosphorus uptake was same with 60 kg (P_2) and 80 kg P_2O_5 ha^{-1} which in turn were statistically superior over 40 kg P_2O_5 ha^{-1} (P_1). During the second year at all phosphorus and nitrogen levels tested, P uptake was similar to that of the first year.

Nitrogen levels significantly influenced the uptake of phosphorus. The higher uptake of phosphorus was recorded with the application of nitrogen at 300 kg ha^{-1} (N_3) followed by 250 kg ha^{-1} (N_2) and 200 kg ha^{-1} (N_1). The increased uptake of phosphorus might be due to the fact that increased supply of nitrogen by applied fertilizer might have increased the root growth, leading to exploration of more soil volume for absorption of more nutrients. These results are in corroboration with the findings of Mala (2008) [11], Hussaini *et al.* (2008) [8], Gosavi and Thorat (2009) [5], Sunitha and Reddy (2012) [20], Mahajan *et al.* (2013) [10] and Sobhana *et al.* (2013) [18].

Phosphorus uptake of maize was higher with the application of phosphorus at 60 kg ha^{-1} (P_2) which was significantly superior over 80 kg P_2O_5 ha^{-1} (P_3) which intern was superior over 40 kg P_2O_5 ha^{-1} (P_1). Similar results of P uptake at moderate level of phosphorus application were obtained by Sharma *et al.* (2009) [17] and Nsanzabaganwa *et al.* (2014) [12].

Significant interaction among N and P levels was observed during the second year in the straw and in both the years in the grain. The treatment N_3P_1 (300 kg N + 40 kg P_2O_5 ha^{-1}) recorded the highest phosphorus uptake in the straw while N_2P_2 (250 kg N + 60 kg P_2O_5 ha^{-1}) registered significantly highest P uptake by grain. Similar results of P uptake up to certain dose were recorded by Nsanzabaganwa *et al.* (2014) [12].

Yield

Grain Yield

During the first year, application of 300 kg N ha^{-1} (N_3) resulted in higher grain yield, which was statistically superior to other N levels (Table. 5). During the second year nitrogen applied at 300 kg ha^{-1} (N_3) resulted in highest grain yield, which was statistically on par with that of 250 kg N ha^{-1} (N_2). This might be due to favourable effect at higher nitrogen level leading to better crop growth and increase in yield attributes which was reflected in kernel yield of maize. In physiological terms, the grain yield of maize was largely governed by source and sink relationships as it is directly related to nitrogen. These results are in accordance with the findings of Nsanzabaganwa *et al.*, (2014) [12], Om *et al.*, (2014) and Thimmappa *et al.*, (2014) [21]. The lowest grain yield was associated with 200 kg N ha^{-1} (N_1) during both the years. Maize supplied with 60 kg P_2O_5 ha^{-1} (P_2) resulted in higher grain yield, which was however statistically on par with 80 kg P_2O_5 ha^{-1} (P_3). Significantly lowest grain yield was obtained with 40 kg P_2O_5 ha^{-1} (P_1) in the first year. Similar trend was observed during the second year but all the three phosphorus levels recorded statistically on par values of grain yield. Grain yield of maize increased significantly up to 60 kg P_2O_5 ha^{-1}. Further increase in P from 60 to 80 kg P_2O_5 ha^{-1}, failed to record statistical significance.

Increase in grain yield up to certain level of phosphorus was directly related to the vegetative and reproductive growth phases of the crop and attributes to complex phenomenon of phosphorus utilization in plant metabolism. Similar results were obtained by Araei and Mojaddam (2014) [2] and Nsanzabaganwa *et al.*, (2014) [12]. Highest grain yield of maize was recorded with N_2P_2 (250 kg N + 60 kg P_2O_5 ha^{-1}) which was statistically superior over lower levels of N and P, while on par with the higher levels (Table. 6). The balanced nitrogen and phosphorus levels might have helped in efficient absorption and utilization of other required plant nutrients which ultimately increased the grain yield. Similar results were obtained by Jaliya *et al.*, (2008) [9] and Abera *et al.*, (2009) [1].

Table 1: Uptake of phosphorus (kg ha^{-1}) by *kharif* maize at different stages as influenced by nitrogen and phosphorus levels

	30 DAS		60 DAS		90 DAS		Stover Uptake		Grain Uptake	
Treatments	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**	**2014**	**2015**
Nitrogen levels (kg ha^{-1})										
N_1: 200	7.5	6.2	44.5	39.6	60.0	64.4	22.2	27.5	40.6	43.9
N_2: 250	9.1	6.3	56.1	54.8	73.2	71.5	26.1	33.7	47.2	50.1
N_3: 300	11.7	9.1	69.0	56.0	77.4	82.8	30.7	41.0	52.2	54.5
SEm±	0.78	0.83	3.80	3.28	4.02	4.56	1.41	1.38	1.06	1.11
CD (P = 0.05)	2.3	2.5	11.4	9.8	12.1	13.7	4.2	4.1	3.2	3.3
Phosphorus levels (kg ha^{-1})										
P_1: 40	9.0	6.9	53.5	48.2	64.1	64.6	22.4	31.1	40.0	43.3
P_2: 60	10.0	8.6	58.4	53.2	67.9	72.5	30.7	36.5	54.1	56.2
P_3: 80	9.3	6.2	57.6	48.3	78.7	66.5	25.8	34.6	45.9	49.0
SEm±	0.78	0.83	3.80	3.28	4.02	4.56	1.41	1.38	1.06	1.11
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	4.2	4.1	3.2	3.3
Interaction										
SEm±	1.35	1.44	6.59	5.67	6.97	7.90	2.44	2.38	1.83	1.92
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS	7.1	5.5	5.7

Table 2: Phosphorus uptake (kg ha^{-1}) by *kharif* maize stover as influenced by interaction of nitrogen and phosphorus levels during 2015

	P_1	P_2	P_3	Mean
N_1	19.8	35.6	27.0	27.5
N_2	27.6	32.3	41.1	33.7
N_3	46.0	41.5	35.5	41.0
Mean	31.1	36.5	34.6	
SEm±		2.38		
CD (P = 0.05)		7.1		

Table 3: Phosphorus uptake (kg ha^{-1}) by *kharif* maize grain as influenced by interaction of nitrogen and phosphorus levels Interaction between N and P levels in 2014

	P_1	P_2	P_3	Mean
N_1	38.5	43.5	39.9	40.6
N_2	40.0	61.3	40.3	47.2
N_3	41.6	57.5	57.5	52.2
Mean	40.0	54.1	45.9	
SEm±		1.83		
CD (P = 0.05)		5.5		

Table 4: Interaction between N and P levels in 2015

	P_1	P_2	P_3	Mean
N_1	43.1	46.4	42.7	43.9
N_2	42.5	63.9	43.3	50.1
N_3	44.3	58.4	60.9	54.5
Mean	43.3	56.2	49.0	
SEm±		1.92		
CD (P = 0.05)		5.7		

Table 5: Grain and stover yield (kg ha^{-1}) of maize as influenced by nitrogen and phosphorus levels during *kharif* season

Treatments	Grain yield		Stover yield	
	2014	2015	2014	2015
Nitrogen levels (kg ha^{-1})				
N_1: 200	6885	8170	7997	10951
N_2: 250	7832	9116	8961	12186
N_3: 300	8231	9146	9277	12517
SEm±	124.4	125.5	252.9	402.3
CD (P=0.05)	373	376	758	1206
Phosphorus levels (kg ha^{-1})				
P_1: 40	7271	8714	8491	12003
P_2: 60	7983	8936	9387	13240
P_3: 80	7693	8781	8357	11844
SEm±	124.4	125.5	252.9	402.3
CD (P=0.05)	373	NS	758	1206
Interaction				
SEm±	215.4	217.3	438.0	696.8
CD (P=0.05)	NS	651	NS	NS

Table 6: Grain yield (kg ha^{-1}) of maize as influenced by interaction between nitrogen and phosphorus levels during *kharif*, 2015

	P_1	P_2	P_3	Mean
N_1	8071	8319	8120	8170
N_2	8986	9307	9055	9116
N_3	9087	9183	9169	9146
Mean	8714	8936	8781	
SEm±		217.3		
CD (P = 0.05)		651		

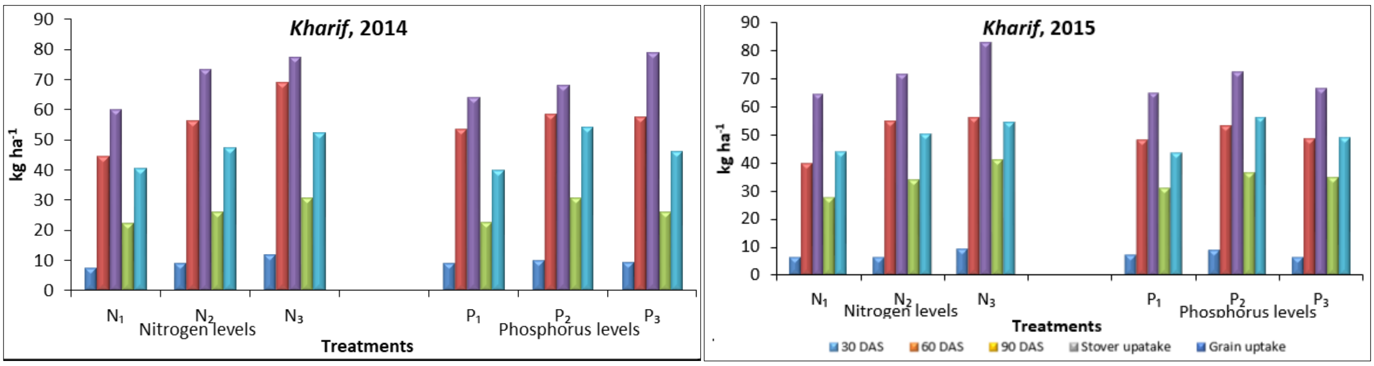

Fig 1: Uptake of phosphorus (kg ha^{-1}) by *kharif* maize as influenced by nitrogen and phosphorus levels

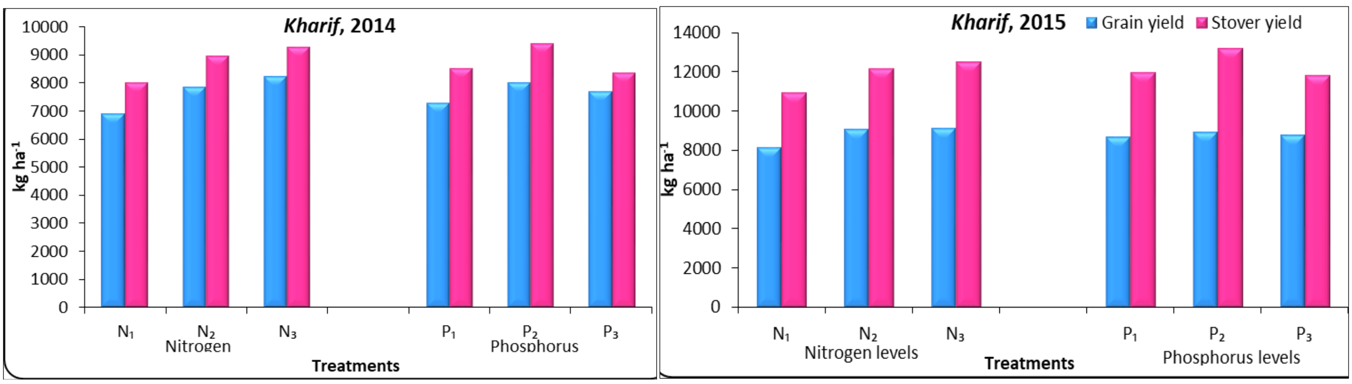

Fig 2: Grain and stover yield (kg ha^{-1}) of maize as influenced by nitrogen and phosphorus levels during *kharif.*

Stover yield

During both the instances of study, stover yield differed significantly due to the nitrogen levels. The higher stover yield was recorded with 300 kg N ha^{-1} (N_3), which was however on par with that obtained with 250 kg N ha^{-1} (N_2) and significantly higher than 200 kg N ha^{-1} (N_1). The lowest stover yield was obtained with 200 kg N ha^{-1} (N_1) (Table. 4).

Graded phosphorus levels influenced the stover yield of maize with distinct disparity between the levels tried. The higher stover yield of maize was obtained; when the crop was supplied with 60 kg P_2O_5 ha^{-1} (P_2) followed by 40 kg P_2O_5 ha^{-1} (P_1) with significant disparity between them. The lowest stover yield was resulted with the phosphorus level of 80 kg P_2O_5 ha^{-1} (P_3) during both the years of study. Interaction effect could not be traced among nitrogen and phosphorus levels tried during both the years of study.

Stover yield of maize increased significantly with increase in nitrogen levels from 200 to 300 kg N ha^{-1}. Increased stover yield with increase in nitrogen level could be attributed to adequate nutrient supply, which in turn improved growth parameters like plant height, leaf area index and dry matter production which resulted in higher stover yield. These results are agreement with the findings of Srikanth *et al.* (2009) [19], Reddy *et al.* (2012) [14], Hoshang (2012) [6] and Om *et al.* (2014) [13].

Stover yield of maize increased significantly up to 60 kgP_2O_5 ha^{-1}. Further increase in phosphorus from 60 to 80 kg P_2O_5 ha^{-1}, decreased the stover yield. Higher straw yield at medium phosphorus level could be attributed to adequate and balanced nutrient supply over higher and lower levels tested. Similar results were obtained by Arunkumar *et al.* (2007) [3], Araei and Mojaddam (2014) [2] and Nsanzabaganwa *et al.* (2014) [12].

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