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Nitrogen Management in Maize + Potato Inter Cropping System under Eastern Indo Gangetic Plains of Bihar

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ABSTRACT

A field experiment was conducted during winter season of 2010-11 and 2011-12 at Central Potato Research Station, Patna on sandy loam soil under irrigated condition in factorial randomized block design with four replications to find the suitable nitrogen management for maize intercropped with potato (1:1) in additive series having 100 percent population of both the crops. The tuber yield of potato and grain and straw yield of maize was significantly higher under sole cropping. Inter cropping reduced the potato tuber yield, maize grain and straw yield by 4.33, 8.12 and 12.79% respectively. However, intercropping of maize + potato increased the maize grain equivalent yield, net return, benefit: cost ratio and nutrient uptake increased with increase in N dose to maize crop. Application of 120 kg N/ha to maize resulted in significantly higher values of potato tuber yield, maize grain and stover yield, Maize grain equivalent yield, net return, benefit: cost ratio and nutrient uptake but was at par with 90 kg N /ha. Application of N to intercropped maize in two equal splits as ½ N at knee high stage and ½ N at tasseling recorded significantly higher values of growth and yield attributes of maize, maize grain and stover yield, Maize grain equivalent yield, net return, benefit: cost ratio and nutrient uptake, though it recorded lowest value of growth and yield attributes of potato as well as tuber yield of potato.

Keywords: Integrated Nitrogen Management, Intercropping, Potato, Maize

INTRODUCTION

India is the second largest potato producing country in the world after China, with annual production of 37.3 million tones from area of 1.83 million hectare. The projected potato production estimates for 2030 is 79 million tones from 2.55 million ha (Singh *et al*., 2015a). Intercropping of potato with compatible crops during winter season provides an opportunity to increase the potato acreage as well as production (Singh *et al*., 2013b). The inter and intra row spacing as well as time of planting and harvesting of potato can be easily adjusted without sacrificing much yield for successful inter-cropping systems, which is the only sustainable way of maintaining higher productivity because the farm holding are becoming smaller and smaller due to fragmentation with little scope for bringing additional land under cultivation (Singh *et al*., 2013a). Potato being a short duration crop with shallow root system leaves significant residual nutrients and other inputs which get utilised by the long duration inter-crops thereby increasing environmental sustainability. Bihar state ranks first in area and production of winter (*rabi*) maize in the country (Singh *et al*., 2015a). The area under winter maize is increasing rapidly mainly due to high productivity and relatively little risk involved. Winter maize is long duration (Six month) crop planted in rows 60 cm apart and takes first three months to pick up the growth. In view of such eco-system, there is ample scope to utilize the vacant wider inter row space during its initial slow growth period by introducing compatible short duration crop like potato for increased productivity and good returns (Singh and Singh, 2014). Inter-cropping of potato with maize crops gives stability to the system (Sinha *et al*., 1999).

Nutrient management in the intercropping system plays an important role in the productivity of the intercropping system (Singh *et al*., 2014 and Singh *et al*., 2013a). Both Potato and maize are very responsive to nutrient application and hence efficient management of nutrients is required to get profitable yield and

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return from the intercropping system (Singh, 2003). Nutrients especially nitrogen contribute significantly in improving the yield of maize crop. The haulm of potato which has very little economic value can be buried in the soil to act as green manure for maize after potato harvest. The efficiency with which a crop produces a harvestable product per unit of available nutrient varies with species. However the inter cropping system is still not understood adequately with that of sole cropping especially in terms of nutrient requirement and their use efficiency (Singh *et al*., 2013b). There is practically less information available on nutrient management in the intercropping of maize in potato. Hence, the present experiment was conducted to find the suitable nitrogen management for maize intercropped with potato in additive series.

MATERIALS AND METHODS

A field experiment was conducted at Central Potato Research Station, Patna on sandy loam soil under irrigated condition during winter season of 2010-11 and 2011-12. The soil of experimental plot was neutral in reaction having pH 7.3, low in organic carbon (0.37%), having the availability of N (157.8 kg/ha), P (11.6 kg/ ha) and K (179.4 kg K /ha) at medium ranges. The experiment was laid out in factorial randomized block design with four replications. The experiment consisting 11 treatments had 2 sole crop *viz*. sole potato and sole maize and 9 treatment combinations comprised of three rates of N application to maize (*viz*. 120, 90 & 60 kg N / ha) and three schedules of N application (*viz*. S_1 = ½ N at the time of planting + ¼ N at knee high stage + ¼ at tasselling stage, S_2 = ⅓N at the time of planting and ⅓N at knee high stage + ⅓at tasselling stage, S_3 = No N at planting + ½ N at knee high stage and ½ N at tasselling) applied to maize intercropped with potato (1:1) in additive series having 100 percent population of both the crops. Maize and potato in sole as well as in intercropping system was planted at uniform row distance of 60 cm. The plant-to-plant distance was kept at 20 cm for both potato and maize in the entire planting pattern. Well-sprouted tuber of potato cv. K. Ashoka having 40-50 gm size was planted at the rate 2.5 to 3.0 tones/ha during third week of November and was dehaulmed at the maturity 85 days after planting and harvested during second week of February. Seeds of hybrid maize cv. Pinnacle @ 20-Kg/ha was sown immediately on the next day after potato planting and harvested at maturity in the third week of May. In inter cropping system, potato was planted on ridges 60 cm apart and maize was sown at the base of the potato ridges. The Recommended dose of fertilizer used for potato was 150 kg N, 26.2 kg P and 83 kg K/ha applied in both sole and inter cropping system. Full phosphorus and potassium and half of N was applied before planting as basal and rest half of N was top dressed 25-30 days after planting in the potato rows. Recommended dose of fertilizer applied to sole stand of winter maize was120 kg N, 26.2 kg P and 66.4 kg K/ha. In sole as well as in intercropped maize, full recommended dose of phosphorus and potassium was applied before planting as basal. In sole stand half of N was applied before planting as basal and rest half of N was top dressed in two equal splits at knee high and tasselling stage while in intercropping system nitrogen was applied as per the treatments. The sources of N, P and K were urea, single super phosphate and muriate of potash. In the inter cropping system the haulm of the potato crop was chopped and applied in between the rows of maize and was buried in soil during the earthing up of maize. Earthing up of maize was done immediately after the harvest of potato along with the top dressing of nitrogen. Potato produced 11.92 to 12.65 and 12.24 to 12.96 tones/ ha of haulm biomass having N content of.0.26 and 0.25 % and this added 30.98 to 34.6 and 30.6 to 32.4 Kg N /ha in inter cropping treatments during 2010-11 and 2011-12, respectively. Recommended package of practices were followed for raising potato and maize crop.

Observations were recorded on growth attributes at different stages, yield and yield components at maturity of the crops. The two year experimental data were pooled and subjected to statistical. The N, P and K content of potato and maize was determined by modified micro Kjeldahl, Vandomolybdate spectro photometry and flame photometer methods. The prevailing market price of maize grain(Rs. 8.4/Kg), maize stalk(Rs.100/q) potato tuber (Rs. 4.0/kg) were taken for calculating the gross return accrued from the system and the maize equivalent yield for statistical analysis. Price of different commodities taken for economics of potato production are, potato seed@ Rs 1000/q, Maize seed @ Rs 150/kg, N @ Rs10.92/ kg, P_2O_5 @ Rs 21.60/kg, K_2O @ Rs7.72/kg and other cultivation charge@ Rs 35000/ha for potato and Rs18000 thousand for intercropped maize and Rs 24000 for sole maize.

RESULTS AND DISCUSSION

Potato Performance

The tuber yield of potato was highest in sole stands due to absence of intercrop competition in sole stand. Inter cropping of maize in potato reduced the potato tuber

yield by 4.33 %. The reduction in tuber yield of potato could be attributed to competition offered by the inter crop for various growth resources as growth attributes of potato viz. plant height and number of leaves/plant etc. showed decreasing trend under intercropping system (Table 1). The yield and number of large (>75g) and medium (50-75g) grade tuber was significantly higher in sole cropping while that of small (25-50g) and very small (<25g) grade tuber was less in sole cropped potato than intercropped potato. As a result the tuber yield decreased in intercropping. Similar decrease in tuber yield of potato due to maize intercropping was reported by Singh and Lal (2010) and Bharti *et al.* (2007). In the intercropping system, tuber yield of potato differed significantly due to rate and time of nitrogen application treatments to maize. Potato tuber yield increased with increase in N dose to maize crop. Application of 120 kg N/ha to maize resulted in significantly higher tuber yield of Potato (24.7 t/ha) over 60 kg N /ha (23.3 t/ha) but was at par with 90 kg N /ha (24.0 t/ha). These results are in agreement with the findings of Singh (2003) and Jha *et al.* (1999). Application of N to intercropped maize in three splits ½ N at the time of planting + ¼ N at knee high stage + ¼ at tasselling stage recorded highest potato tuber yield while application of N in two equal splits as ½ N at knee high stage and ½ N at tasselling recorded lowest tuber yield of potato. This behavior of tuber yield may be due to dominant and vigorous growth profile of potato after germination and low growth profile of the maize in the beginning, as such a part of N applied to maize as basal dose might have been utilized by the potato crop for vegetative growth and yield, since growth attributes viz. plant height, number of leaves /plant etc. and yield attributes such as number and yield of large and medium grade tuber decreased significantly due to decreasing N rates.

Maize Performance

Pooled data of two years indicated that grain and straw yield of maize was significantly higher under sole cropping (6.28 and 8.44 t/ha) than intercropping system (5.77 and 7.36 t/ha). There were 8.12 and 12.79% decrease in grain and straw yield of maize, respectively due to intercropping of potato (Table 2). The reduction

Table 1: Influence of rate and time of nitrogen application to maize on growth and yield attributes of potato in potato + maize intercropping system

Treatment	Plant height (cm)	Stem / plant	Leaves/ plant	Grade wise tuber yield (t/ha)				Grade wise tuber number (X 10^3/ ha)			
				>75g	50-75g	25-50g	<25g	>75g	50-75g	25-50g	<25g
Cropping system											
Sole	86.4	4.1	106.7	8.37	10.84	3.78	2.05	68.6	169.4	102.2	113.9
Intercropped	75.0	4.2	98.3	5.5	9.0	6.4	3.0	49.6	141.9	163.8	169.1
SEm ±	4.04	1.1	6.06	0.33	0.55	0.44	0.94	1.53	5.29	6.17	8.84
CD (P=0.05)	8.5	NS	12.8	0.7	1.2	0.9	NS	3.2	11.2	13.0	18.6
Nitrogen dose											
60 kg/ha	65.7	4.2	85.2	5.05	7.36	6.99	3.86	45.7	114.7	178.0	214.3
90 kg/ha	76.8	4.4	99.4	5.61	9.23	6.73	2.44	50.7	146.3	172.3	135.7
120 kg/ha	82.4	4.1	110.2	5.95	10.55	5.37	2.83	52.3	164.8	141.0	157.2
SEm ±	2.5	0.9	3.7	0.2	0.3	0.3	0.78	0.9	3.3	3.8	5.4
CD(P=0.05)	7.4	NS	11.1	0.6	1.0	0.8	NS	2.8	9.7	11.3	16.2
Nitrogen application schedule											
S_1	82.6	4.1	108.6	7.13	9.50	5.96	2.56	62.8	147.5	156.4	142.2
S_2	75.2	4.2	98.1	5.27	8.65	6.67	3.29	47.4	137.0	172.2	182.8
S_3	67.2	4.2	88.1	4.20	9.00	6.46	3.28	38.6	141.4	162.7	182.2
SEm ±	2.5	0.9	3.7	0.2	0.3	0.3	0.78	0.9	3.3	3.8	5.4
CD(P=0.05)	7.4	NS	11.1	0.6	1.0	0.8	NS	2.8	9.7	11.3	16.2

S_1 = ½ N at the time of planting and ¼ N at knee high stage + ¼ at tasselling stage,

S_2 = ⅓N at the time of planting and ⅓N at knee high stage + ⅓at tasselling stage,

S_3 = No N at planting + ½ N at knee high stage and ½ N at tasselling

Table 2: Influence of rate and time of nitrogen application on growth and yield attributes of maize in potato + maize intercropping system

treatment	Plant height (cm)	Stem girth (mm)	Cobs / plant	Length of cob (cm)	**Girth of cob (cm)**	**Grains / cob**	**Test weight (g)**
Cropping system							
Sole	168.6	18.6	1.6	17.9	15.2	440.3	216.2
Intercropped	149.1	15	1.5	15.4	12.6	417.5	214.5
SEm ±	7.75	1.20	0.0	0.76	0.72	10.04	2.8
CD (P=0.05)	16.3	2.5	0.0	1.6	1.5	21.2	NS
Nitrogen dose							
60 kg/ha	131.5	12.4	1.4	13.4	10.8	391	212.9
90 kg/ha	152.8	15.7	1.5	15.8	13	415.7	214.1
120 kg/ha	162.9	16.9	1.6	17	14.1	445.7	216.6
SEm ±	4.8	0.7	0.0	0.5	0.4	6.2	1.9
CD(P=0.05)	14.2	2.2	NS	1.4	1.3	18.4	NS
Nitrogen application schedule							
S_1	163.2	13.4	1.58	14.8	11.6	400.9	216.6
S_2	152.1	14.8	1.51	15.3	12.9	419.7	214.8
S_3	132.1	16.7	1.52	16.1	13.4	431.9	212.2
SEm ±	4.8	0.7	0.0	0.5	0.4	6.2	1.9
CD(P=0.05)	14.2	2.2	NS	1.4	1.3	18.4	NS

S_1 = ½ N at the time of planting and ¼ N at knee high stage + ¼ at tasselling stage,

S_2 = ⅓N at the time of planting and ⅓N at knee high stage + ⅓at tasselling stage,

S_3 = No N at planting + ½ N at knee high stage and ½ N at tasselling

in grain and straw yield of maize could be attributed to competition offered by the inter crop of potato for various growth resources as growth and yield attributes of maize viz. plant height and plant girth, cob length and grains/cob showed decreasing trend under intercropping system. Similar decrease in grain and straw yield of maize due to potato intercropping was reported by Jha *et al.* (1999) and Sinha *et al.* (1999). Grain and Stover yield of maize increased significantly with increase in rate of N application. Application of 120 kg N /ha recorded significantly higher grain and Stover yield (6.13 and 8.06 t/ha respectively) compared to 60 kg N/ha (5.18 and 6.44 t/ha respectively) but it was at par with 90 kg N/ha (6.02 and 7.57 t/ha, respectively) and the latter treatment in turn was also significantly superior to application of to 60 kg N/ha. It indicated that application of 90 kg N /ha to maize will save 30 kg N / ha. Yield attributing character of maize viz. cob length, cob girth and grains/cob, followed similar trend. Higher grain and Stover yield at higher levels of N fertilizer could be attributed to enhanced vegetative growth (viz. plant height, stem girth etc.) and yield attributes (grains/cob) as N promotes growth, enhanced synthesis and accumulation of proteins, amino acids and enzymes which are responsible for cell division and cell elongation (Verma, 1991). These results are in agreement with the findings of Jha *et al.* (1999) and Sinha *et al.* (1999). Application of N to maize in two splits as ½ N at knee high stage and ½ N at tasselling recorded highest grain yield of maize while application of N in three splits ½ N at the time of planting + ¼ N at knee high stage + ¼ at tasselling stage to maize recorded lowest grain yield. This may be attributed to acceleration in growth of maize with favorable temperature in mid February after harvest of potato, and the higher dose of nitrogen applied at this time boosted the growth and yield attributes of maize crop and ultimately yield.

MAIZE GRAIN EQUIVALENT YIELD

The maize grain equivalent yield (MGEY) differed significantly due to cropping system (Table 3) and it was significantly higher with maize+ potato inter cropping (17.2 t/ha) than sole crop of potato (11.92 t/ ha) and maize (6.28 t/ha). The results corroborate the findings of Singh *et al.* (2002) and Jha *et al.* (2000). High

MGEY owing to maize+ potato intercropping system is attributed to high gross income obtained because of combined additional yield of maize and potato. The highest MGEY of 17.89 t/ha was obtained with 120 Kg N/ ha to maize crop which was at par to application of 90 kg N/ha (17.45 t/ha) but significantly superior to 60 kg N /ha (16.25 t/ha). Application of N to intercropped maize in two equal splits as ½ N at knee high stage and ½ N at tasselling recorded highest MGEY while application of N in three splits ½ N at the time of planting + ¼ N at knee high stage + ¼ at tasselling stage recorded lowest MGEY. This was due to significantly higher maize grain yield obtained with application of N to intercropped maize in two equal splits as ½ N at knee high stage and ½ N at tasselling stage as compared to rest of the N application schedules. The results corroborate the findings of Jha *et al*. (2000) and Singh (2003).

NUTRIENT UPTAKE

The N, P and K uptake differed significantly due to cropping system (Table 3) and it was significantly higher with maize+ potato inter cropping than sole crop of potato and maize. The results corroborate the findings of Singh *et al*. (2002) and Jha *et al*. (2000). High N, P and K uptake owing to maize+ potato intercropping system is attributed to high gross biomass yield obtained because of combined yield of maize and potato. The highest N, P and K uptake was obtained with application of 120 Kg N/ha to maize crop which was at par to application of 90 kg N/ha but significantly superior to 60 kg N /ha. Application of N to intercropped maize in two equal splits as ½ N at knee high stage and ½ N at tasselling though recorded highest N, P and K uptake, however, all the three schedules of N application viz. S_1, S_2 and S_3 were at par.

NTERACTION EFFECT

Interaction effect was noticeable in potato tuber yield, maize grain yield, maize grain equivalent yield and grains/cob of maize (Table 4). There was significant

Table 3: Influence of rate and time of nitrogen application to maize on yield, economics and nutrient uptake in potato + maize intercropping system

Treatment	Maize grain yield (t/ha)	Stover yield (t/ha)	Tuber yield (t/ha)	MGEY (t/ha)	Net return (Rs/ha)	B:C ratio	Recovery		Nutrient uptake (kg/ha)		
							potato	maize	N	P	K
Cropping system											
Sole potato	-	-	25.04	11.92	37160	1.59	100	-	108.9	13.6	118.6
Sole maize	6.28	8.24	-	6.28	17752	1.51	-	100	110.6	20.5	98.7
intercropped	5.77	7.67	24.0	17.20	54713	1.61	95.81	91.88	203.1	31.9	202.1
SEm ±	0.18	0.43	0.62	0.64	-	-	-	-	-	-	-
CD (P=0.05)	0.35	0.86	1.3	1.29	-	-	-	-	-	-	-
Nitrogen dose											
60 kg/ha	5.18	7.04	23.26	16.25	48022	1.54	92.89	82.45	191.97	30.62	191.73
90 kg/ha	6.02	8.17	24.01	17.45	56824	1.63	95.89	95.80	203.89	32.28	204.69
120 kg/ha	6.13	8.66	24.70	17.89	59292	1.65	98.64	97.61	213.56	32.92	209.97
SEm ±	0.09	0.23	0.38	0.34	-	-	-	-	2.87	0.71	2.56
CD(P=0.05)	0.28	0.68	1.14	1.02	-	-	-	-	8.54	2.11	7.64
Nitrogen application schedule											
S_1	4.97	7.69	25.15	16.95	52613	1.59	100.4	79.14	200.61	32.51	201.63
S_2	5.73	7.99	23.88	17.10	53921	1.60	95.37	91.24	200.09	31.38	200.73
S_3	6.62	8.21	22.94	17.54	57605	1.64	91.61	105.4	208.72	31.93	204.02
SEm ±	0.09	0.23	0.38	0.34	-	-	-	-	2.87	0.71	2.56
CD(P=0.05)	0.28	0.68	1.14	NS	-	-	-	-	NS	NS	NS

S_1 = ½ N at the time of planting and ¼ N at knee high stage + ¼ at tasselling stage,
S_2 = ⅓N at the time of planting and ⅓N at knee high stage + ⅓at tasselling stage,
S_3 = No N at planting + ½ N at knee high stage and ½ N at tasselling
MGEY= maize grain equivalent yield.

Table 4: Interaction effect of rate and time of nitrogen application on potato tuber, maize grain yield, maize grain equivalent yield and grains/cob of maize in potato + maize intercropping system

	TUBER YIELD			maize grain yield			MGEY			grains/cob		
	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3	S_1	S_2	S_3
60 kg/ha	23.69	23.24	22.84	4.38	5.13	6.02	15.66	16.20	16.90	389.6	386.4	397
90 kg/ha	25.28	23.73	23.02	5.17	6.07	6.81	17.20	17.37	17.77	388.7	418.5	440
120 kg/ha	26.47	24.68	22.95	5.37	5.99	7.03	17.98	17.74	17.96	424.3	454.2	458.6
SEm ±	0.66			0.16			0.59			10.7		
CD(P=0.05)	1.88			0.44			1.68			30.6		

increase in Potato tuber yield due to rise in N level to 120 kg N/ha in treatment S_1only. Considering time of application under same level of N, it was found that at 60 kg/ha, treatments S_1, S_2 and S_3 were similar while at 90 kg N/ha treatment S_1 was significantly superior over treatment S_3 but at par with treatment S_2. At 120 kg N/ha, treatment S_1 was significantly superior over treatments S_3 and S_2 both. Similar trend was noticed in MGEY. There was significant increase in number of grains/cob due to rise in N levels in treatment S_2 only. However same trend was obtained up to 90 kg N/ha in case of treatment S_3 and in treatment S_1 there was no difference in number of grains/cob due to N levels. Considering time of application under same level of N, it was found that at 60 kg/ha, treatments S_1, S_2 and S_3 were similar while at 90 kg N/ha treatment S_3 was significantly superior over treatments S_1 and S_2. At 120 kg N/ha treatments S_3 and S_2 were similar and both showed superiority over treatment S_1.

ECONOMICS

Both the net monetary return and benefit: cost ratio were significantly higher with maize + potato intercropping (Rs 54713/ha and 1.61, respectively) compared to sole crop of maize (Rs 17752 /ha and 1.51, respectively) and sole potato (Rs 37160/ha and 1.59, respectively). This was attributed to higher gross return realized because of additional yield of potato/maize which also fetched higher price in the market. The result confirms the findings reported by Singh and Lal (2010). Bharti *et al.* (2007) also reported higher monetary return and benefit: cost ratio with maize+ potato inter cropping over sole cropping of maize or potato. Application of 120 kg N/ha resulted in higher monetary return (Rs59292/ha) and benefit: cost ratio (1.65) than 60 kg N /ha but it was comparable to 90 kg N/ha. Jha *et al.* (2000) and Singh *et al.* (2002) also reported higher monetary return and benefit: cost ratio with increasing nitrogen application to maize + potato inters cropping system. Highest net return and B:C ratio was obtained in the inter cropping system where nitrogen was applied in two splits as ½ N at knee high stage and ½ N at tasselling stage to maize crop.

CONCLUSION

Based on the results of two years it was concluded that Intercropping of maize in potato was highly remunerative. In potato + maize intercropping system potato crop should be fertilized with full recommended dose of N (150 kg/ha), P (26.2 kg/ha) and K (83 kg/ha) while in the maize crop N may be applied @ 90 Kg /ha in two splits, ½ N at knee high stage and ½ N at tasselling stage apart from full recommended dose of P (26.2 kg/ha) and K (66.4 kg/ha) for higher yield and net return and would economies 30 kg nitrogen/ha in the intercropping system.

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