The Influence of N and P on Maize Yield and Yield Components in Maize/Rice Mixture in the Northern Savanna Zone of Nigeria

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Abstract

Most recommended fertilizer rates available for crops in the northern savanna zone of Nigeria are for crops in monoculture. In order to be able to recommend to farmers the rates of nitrogen (N) and phosphorus (P) to be applied to maize and rice in an intercropping system to increase crop yields, a field experiment was conducted at the Samaru farm of the Institute for Agricultural Research (IAR), Nigeria (Lat. 11° 11' N and Long. 07° 38' E) at 680 m above sea level on a sandy loam soil in 1990 and 1992. Factorial combination of four levels of N (0, 60, 120 and 180 kg ha^{-1}) and three levels of P (0, 13.2 and 26.4 kg ha^{-1}) were laid out in a randomized complete block design (RCBD) with four replications. Yield components of maize such as ears/m^2 increased significantly ($P < 0.05$) with increasing levels of N and P but no significant changes were observed in shelling percentage and 100 seed weight of maize. The number of panicles/m^2 and number of tillers/plant were the yield components of rice that responded significantly ($P < 0.05$) with increasing levels of N and P. Threshing percent and 1000 seed weight of rice were not significantly affected by increasing levels of N and P. Grain yields of maize and rice increased significantly ($P < 0.05$) by raising the levels of N and P. The application of 13.2 kg P ha^{-1} at each level of N significantly ($P < 0.05$) increased maize and rice yields. However, the highest grain yields of both crops were obtained when 120 kg N ha^{-1} and 13.2 kg P ha^{-1} were applied.

Introduction

Intercropping, the practice of growing two or more crop species on the same piece of land in a cropping season, continues to be popular and persistent among peasant farmers in the developing world (Andrews & Kassam, 1976; Willey, 1979). Surveys conducted by Norman (1975) in the former Zaria Province of Northern Nigeria revealed that 82% of land grown to crops was under mixed cropping system. The advantages which encourage these farmers to practice this system are numerous. These include (i) a reduction in the spread of pest and diseases (IITA, 1977), (ii) insurance against total crop failure and stability of income (Abalu, 1977), (iii) efficient utilization of both factors above and under ground-resources by plants with different growth periods, heights, rooting systems and nutrient requirements. Maize is one of the most popular and widely consumed cereal in the West Africa sub-region (Langyintuo, 1997). Apart from the fact that the savanna environment has been proven suitable for production of the crop in these areas, there are other important reasons for popularizing maize in the midst of millet and sorghum.

Maize yields higher than all the cereals and responds better to fertilizers. Maize yields of 8–10 tonnes ha^{-1} have been obtained as against 4–5 tonnes ha^{-1} for improved millet and long duration sorghum (Kowal & Kassam, 1978). Even yields of maize in intercrops and yields after leguminous crops gave yields comparable to sole crops fertilized with 120 kg N ha^{-1} which was not the same with sorghum and millet (Nguimgo, Balasubramanian & Thê, 2001). Maize is also preferred to sorghum or millet due to the fact that maize ears are protected against insects and birds damage.

Though most peasant farmers in the sub-region do not consume rice regularly because of its high cost, surveys showed that most people prefer it to traditional staples like cassava and maize (IITA, 1992). However, rice is now more increasingly becoming a staple food crop in most West African countries but in others, the crop is limited to occasional preparations at funerals, weddings and for religious celebrations.

Both maize and rice have become important in the Nigerian goal for food sufficiency (Olu & Adepetu, 1984), and mixed cropping continues to be dominant and important system in northern Nigeria (Fisher, 1979) but not much work is done on fertilizer use to improve the yields of such crops in the system.

It has also been found that intercrop components suffer from competition for resources such as nutrients, water and light within the system (Nguimgo Balasubramanian & Thê, 2001). This means that efforts should be made to reduce the competition by supplying the system with the most limiting factors, such as nitrogen, to make the system more efficient. The recommended rates of N and P for the optimum grain yields of these crops in monocultural system in northern Nigeria have been found to be 120 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} for maize (Balasubramanian & Mokwunye, 1976) and 90 kg N ha^{-1} and 60 kg P_2O_5 ha^{-1} for rice, respectively (Nossa & Vergra, 1980).

Even though work done on the production of maize and rice in a mixed cropping system showed that alternating one row of maize with five rows of rice proved promising in producing component crop yields that are comparable to sole crop yields (Elemo, 1990), little work has been done to establish the rates of fertilizers to be applied to the system to increase yields of component crops. Farmers in northern Nigeria, therefore, rely on rates of fertilizers meant for sole crops to fertilize crop mixtures. This necessitated the studies of N and P levels on maize and rice that can give optimum grain yields in an intercrop system. Specifically the study was established to determine the levels at which N and P applied to maize/rice mixture would give optimum grain yield and yield components of maize and rice in an intercropping system.

Materials and methods

A field experiment was conducted at the Institute for Agricultural Research (IAR) farm, Samaru (lat. 11° 11' N and long. 07° 38' E) at 680 m above sea level in 1990 and 1992 cropping seasons.

Samaru is within the northern Guinea savanna ecological zone of Nigeria with an average mono modal rainfall of about 1200 mm. The climate is warm semi-arid with temperatures ranging from 16 °C (Decem-ber) to about 50 °C in September annually. The vegetation of the area is grassland interspersed with non-canopy forming shrubs and trees.

The soil texture is sandy loam and it is classified as Orthic luvisol (FAO, 1977). Soil characterization of the site in 1990 showed a *p*H of 4.7 in calcium chloride ($CaCl_2$) solution. Other chemical properties were 0.021% N, 0.6% organic carbon, 23.18 p.p.m. available P and 90 mg kg^{-1} K.

The treatments were composed of all possible combinations of four levels of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and three levels of P (0, 13.2 and 26.4 kg P ha^{-1}) in a randomized complete block design with four replications. The gross plot size was 40.5 m^2 (8.1 m × 5 m^2) and a net plot 27 m^2 (5 × 5.4 m^2). The site was disc-ploughed and ridged at 90 cm apart by a tractor-mounted ridger for the planting of maize. Every other ridge was then flattened, levelled and raked to a fine tilth where the rice component was planted.

Maize (cv. TZBSR), a late maturing variety (120 days) resistant to streak with white grain (IITA, 1975) and rice (cv. ITA 257), an early maturing variety (90–100 days), blast resistant and low shattering (IITA, 1981) were the test crops. Maize was planted three seeds per hole on ridges at 1.8 m by 0.2 m and later thinned to 2 plants per stand, 2 weeks after planting, to maintain a plant population of 55,555 plants ha^{-1}.

Rice, on the other hand, was planted six per hole at 30 cm × 30 cm which was also later thinned to two plants per hill to meet the recommended rice plant population of 222,222 plants ha^{-1}. The plant arrangements were, therefore, alternate with one row of maize alternating five rows of rice and the mixture was the additive model since both maize and rice were held at 100%.

Fertilizer application was by band placement in split application for N, with half the amount of urea (as source of N) applied 2 weeks after planting and second dose, 7 weeks after planting. Phosphorus was applied as single super phosphate at a single dose 2 weeks after planting and covered with soil. Five hoe weeding operations were carried out at 2, 4, 6, 9 and 12 weeks after planting in order to maintain a weed-free environment.

Maize was harvested later than rice in both years by hand while rice was harvested by the use of a sickle. Rice and maize were harvested on the 6th and 15th October in 1990, respectively, while in 1992, harvesting was done on the 7th and 21st of October for rice and maize, respectively. The harvested ears of maize and panicles of rice from the net plots were shelled and threshed, respectively, sun-dried and winnowed. The grains were then weighed before converting each crop into per hectare bases. Other data taken included 100-grain weight of maize, 1000-grain weight of rice, number of tillers per plant for rice, shelling and threshing percentages for maize and rice, respectively.

Analysis of variance was done to test the treatment effect for significance using the F-test as described by Cox & Cochran (1967). The effects of N and P and their interactions were compared using standard errors (SE+).

Results

Grain yield of maize

Maize grain yield increased significantly (P = 0.01) in both years as levels of N increased (Table 1). In 1990 the increase in grain yield of maize was significant up to 180 kg N ha^{-1}, while in 1992 there was no yield advantage beyond 120 kg N ha^{-1} (Table 1). The effect of P levels on maize yield showed that there was no significant increase in grain yield of maize beyond 13.2 kg P ha^{-1} in 1992 but in 1990 the increase in grain yield due to P was significant up to highest P level of 26.4 kg P ha^{-1} (Table 1).

TABLE 1

Effect of N and P on maize grain yield (kg ha^{-1}), shelling percent (%), ears/m^{2+} and 100-seed weight (g) of maize in 1990 and 1992

Treatments	*Grain yield*		*Shelling*	*Ears/m^2*		*100-seed wt*	
(N levels kg ha^{-1})	*1990*	*1992*	*1992*	*1990*	*1992*	*1990*	*1992*
0	485	590	76.00	6.6	3.0	15	21
60	3053	3167	76.04	7.6	7.7	16	22
120	4067	4827	76.56	8.2	7.9	19	22
180	4263	4835	76.00	8.2	7.8	20	0.51

SE±	44	38	0.61	0.33	0.32	0.5	
P levels (kg ha^{-1})							
01	2829	2834	75.85	6.9	6.7	18	22
3.2	2986	3130	76.14	7.7	7.8	17	23
26.4	3085	3100	76.47	7.8	7.9	18	22
SE±	39	39	0.53	0.32	0.30	0.22	0.56
Interaction	**	**	NS	**	**	NS	NS

**Significant at 1% level of probability NS—Not significant

There was positive and significant interaction effect of N and P on maize yield in both years (Tables 2a and 2b). In 1990,

TABLE 2a

Interaction of N and P levels on grain yield of maize (kg ha^{-1}) in 1990

N (kg ha^{-1})	*P (kg ha^{-1})*		
	0	13.2	26.4
0	303	485	666
60	2786	3162	3211
120	4209	4228	4362
180	4038	4368	4392
SE+	36.53		

increasing N levels from 0–180 kg ha^{-1} gave significant ($P < 0.05$) increases in maize grain yields as P levels also increased up to 26.4 kg P ha^{-1} (Table 2a). However, in 1992, grain yields increased significantly ($P < 0.05$) with increasing levels of N and P up to 120 and 13.2 kg ha^{-1}, respectively, with a significant ($P < 0.05$) decline in yield at P level of 26.4 kg ha^{-1} at all levels of N (Table 2b).

TABLE 2b

Interaction of N and P on grain yield of maize (kg ha^{-1}) in 1992

N (kg ha^{-1})	*P (kg ha^{-1})*		
	0	13.2	26.4
0	537	870	3631
60	2667	3630	3204
120	4444	6093	3944
180	3689	5926	4889
SE+	39.21		

Shelling Percentage

Results obtained in 1992 on maize shelling percentage (taken for only 1 year) revealed that neither increasing levels of N nor P significantly influenced shelling percentage. There was no interaction effect of N and P on shelling percentage too (Table 1).

Number of ears/m^2

Number of ears/m^2 increased significantly ($P < 0.05$) with increasing levels of N from 60 to 120 kg N ha^{-1} in both years (Table 1). The increase in the number of ears per square meter due to P application levels also showed significance only up to 13.2 kg P ha^{-1} but not beyond (Table 1).

In 1990, the interaction of N and P on ear number showed that at all levels of N, except at 180 kg N ha^{-1}, there was no significant influence with increasing levels of P. However, at 180 kg N ha^{-1} ear number increased when P levels increased up to 13.2 kg P ha^{-1} (Table 3a). In 1992, increasing levels of N significantly increased ear number at 13.2 kg P ha^{-1} and 26.4 kg P ha^{-1} but not at 0 kg P ha^{-1} (Table 3b). With increasing levels of P, the increase in ear number was only significant at 60 kg N ha^{-1}.

TABLE 3a

Interaction of N and P on number of (ears/m²) of maize 1990

N (kg ha^{-1})	P (kg ha^{-1}) 0	13.2	26.4
0	6.00	6.00	7.50
60	6.50	8.00	8.25
120	7.75	7.75	9.00
180	7.50	8.75	10.00
SE+	0.58		

TABLE 3b

Interaction of N and P levels on the number of ears/m² in 1992

N (kg ha^{-1})	P (kg ha^{-1}) 0	13.2	26.4
0	7.00	7.00	8.75
60	7.50	9.00	9.25
120	8.75	8.75	10.00
180	8.50	9.75	11.00
SE+	0.68		

100-seed weight

Hundred grain weight of maize was found not to be significantly affected by levels of N in 1992 but in 1990 there was a significant increase in grain weight up to 180 kg N ha^{-1} with no significant difference in weight between 60 kg N ha^{-1} and 0 kg N ha^{-1} treatments (Table 1). In both years, increasing levels of P had no significant influence on grain weight of maize. There was no interaction effect of N and P on 100-grain weight in both years (Table 1).

Grain yield of rice

In both years, grain yield of rice increased significantly ($P < 0.05$) with increasing levels of N (Table 4). The application of N up to 120 N ha^{-1} increased yield of rice significantly ($P < 0.05$) after which further increases never resulted into any significant increase in yield. The increase in the rice grain yield due to P application was significant ($P < 0.05$) only up to 13.2 kg P ha^{-1}.

At both higher levels of N (120 and 180 kg N ha^{-1}) there was interaction of N and P when both were increased (Table 5a). Increasing P levels from 0 to 13.2 kg P ha^{-1} increased rice yields significantly in both years with the highest yield obtained at 120 kg N ha^{-1} and 13.2 kg P ha^{-1}. In both years, increasing the levels of N at 0 kg P ha^{-1} did not increase rice yield significantly (Tables 5a and 5a). Also, increasing P levels never had any significant effect on the yield of rice at 0 kg N ha^{-1}. However, increasing N from 60 to 180 kg ha^{-1} resulted in significant increases in rice yield. At both 13.2 and 26.4 kg ha^{-1} of P, there were significant increases in rice yield with increasing levels of N but the highest yield was recorded when 120 kg N ha^{-1} and 13.2 kg P ha^{-1} were applied in both years (Table 5a and 5b).

Threshing percent

Threshing percentage was neither significantly affected by neither increasing levels of N nor P (Table 4).

TABLE 4

Effect of N and P Levels on grain yield, threshing percent and 1000-seed weight of rice in 1990 and 1992

Treatments (N levels kg ha^{-1})	Grain yield (kg ha^{-1}) 1990	1992	Shelling % 1992	1000-seed weight (g) 1990	1992
0	742	930	69.00	29.98	30.16
60	1608	1836	69.77	30.03	30.61
120	2156	2328	69.23	30.06	30.63
180	2206	2416	69.81	30.02	30.24
SE±	64	56	0.65	0.52	0.54

P levels (kg ha^{-1})					
0	328	1755	70.13	29.32	30.50
13.2	13.2	1941	68.64	29.77	29.80
26.4	1654	1937	69.58	30.06	30.03
SE±	55	34	0.56	0.50	0.52
Interaction	*	*	NS	NS	NS

NS- Not significant * - Significant at 5% probability

TABLE 5a

Interaction of N and P levels on grain yield (kg ha^{-1}) of rice in 1990

N (kg ha^{-1})	*P (kg ha^{-1})*		
	0	*13.2*	*26.4*
0	715	776	733
60	1677	1796	1633
120	1234	2749	2181
180	1684	1679	1904
SE+	35.39		

TABLE 5b

Interaction of N and P on grain yield (kg ha^{-1}) of rice in 1992

N (kg ha^{-1})	*P (kg ha^{-1})*		
	0	*13.2*	*26.4*
0	1013	848	929
60	1656	2152	1702
120	2162	2990	2112
180	2053	2710	2205
SE+	44.10		

1000-grain weight of rice

There was no significant change in 1000-seed weight with increasing levels of N and P levels (Table 4). The interaction between N and P on 1000-seed weight also did not attain any level of significance.

Number of panicles/m^2

The number of panicles increased significantly ($P > 0.05$) with levels of N in similar manner in both years (Table 6). In each year there was a significant response to N to the highest level of 180 kg N ha^{-1}. However, increasing P beyond 13.2 kg P ha^{-1} had no significant effect on panicle number (Table 6). No interaction effect on panicle number per square metre was observed in both years by N and P.

TABLE 6

Effect of N and P levels on particles/m^2 and number of tillers/plant in 1990 and 1992

Treatments	*Number of panicles/m^2*	*Number of tillers/plant*		
N-(kg ha^{-1})	*1990*	*1992*	*1990*	*1992*
0	83	43	4	3
60	122	90	6	5
120	133	183	8	9
180	168	194	1a	11
SE±	4.34	3.95	0.4	0.4
P levels (kg ha^{-1})				

0	110	117	6	6
13.2	130	132	7	7
26.4	142	133	7	7
SE±	4.16	3.65	0.4	0.4
Interaction (N x P)	NS	NS	NS	NS

NS - Not significant

Number of tillers per plant

Significant increase in the number of tillers was observed when N levels were increased in both years (Table 6). Increasing P levels up to 13.2 kg P ha^{-1} gave significant number of tillers but not above this level. No interaction effect of N and P were observed for the 2 years on the number of tillers per plant.

Discussion

The increase of some of the parameters of maize such as grain yield and 100-seed weight with increasing N levels up to 180 kg N ha^{-1} in 1990 was attributed to the initial low N and P content of the soil in the first year of the study. However, the response of grain yield to increasing levels of N and P up to 120 kg N ha^{-1} and 13.2 kg P ha^{-1}, respectively, with no yield advantage after these levels in 1992 could be due to the residual effect of N and P application in the previous year's fertilization. This is similar to earlier work done by Balasubbramanian & Mokwunye (1976) that showed significant increase in grain yield of maize with N levels only up to 120 kg N ha^{-1} after which there was a decline in yield. This was confirmed by Ologunde & Ogunlela (1984) where they found N rate for maize to lie between 100 and 120 kg N ha^{-1}. In a similar experiment Lonhard-Bony & Nemeth (1989) and McPhilips (1989) found significantly higher grain yield of maize at 13.2 kg P ha^{-1} than at lower or higher rates of P. With a wide range of levels of N and on different tillage systems, Mullins, Alley & Reeves (1998) found 112 kg N ha^{-1} to be the peak of both grain and silage yields of maize.

Rice grain yield also increased significantly with N and P up to 120 kg N ha^{-1} and 13.2 kg P ha^{-1} after which there was no yield advantage with further increases. The upward trend of rice grain yield as the application of N increases is consistent with the results reported by Sanchez (1976), Stifel (1989) and Kang & Balasubramanian (1990). The number of panicles per square meter and number of tillers per plant increased significantly with levels of N and P. Saisong, Gloving & Southain (1970) identified these characters to be the two most important characters affected by N and P. It could, therefore, be explained that the significant increase in the grain yield of rice with increasing levels of N and P was due to the positive effect on yield by these characters. This is not different from the findings of Nossa & Vergra (1980) that the significant increase in grain yield in three varieties of rice was due to the increase in these characters with increasing levels of N and P.

Even though seed weight is one of the components of yield of both rice and maize there was no significant increase in 100-seed weight of maize and 1000-seed weight of maize and rice, respectively, with increasing levels of N and P. The non-significant effect of N and P levels on these plant characters suggests that the effect of fertilizers rather goes to increase the yield through increased number of ears and panicles/m^2. This result is in conformity with that of Chang (1976) and Matsushina (1976) who also identified seed weight as one of the most important yield components of rice but it never responded to levels of N and P. The findings of Agboola & Kayode (1981) that the application of N and P had no effect on shelling and threshing percentages confirm the results of this study but disagrees with that of Ologunde & Ogunlela (1984) who reported significant increases with lower rates of N but decreasing at higher rates. Horrocks & Zuber (1970), however, concluded that the differences in the response of N and P observed on shelling percent could be attributed to the method used, location, cultivar and cultural practices.

Conclusion

The significant increases in components of yield such as ear/m^2 for maize, number of tillers/plant and panicles/m^2 for rice with increasing levels of N and P contributed to the significant increases in the total grain yield of maize and rice. In few cases, some of the crop parameters responded to the last levels of N and P in the first year. However, in most cases including grain yields, increased only up to 120 kg N ha^{-1} and 13.2 kg P ha^{-1} in the second year of experimentation suggesting that these levels would be adequate for the production of maize intercropped with rice in the savanna ecological zone of Nigeria.

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