Effect of nitrogen and phosphorus fertilization on maize/rice intercropping system at Samaru, northern Nigeria

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ABSTRACT

The generally low fertility status of the savanna soils requires the application of fertilizers to supply adequate amounts of nutrients needed by cereal crops to raise yields. The effect of nitrogen (N) and phosphorus (P) on grain yield, soil nitrogen and uptake of N and P by maize (*Zea mays* L.) and rice (*Oryza sativa* L.) in a mixed cropping system was studied in a field experiment at the Samaru Farm of the Institute for Agricultural Research in 1990 and 1992. Factorial combinations of four levels of N (0, 60, 120 and 180 kg N ha^{-1}) and three levels of P (0, 13.2 and 26.4 kg P ha^{-1}) were laid in a randomized complete block design with four replications. The number of tillers per rice plant increased significantly with increasing levels of N up to 180 kg N ha^{-1} while cobs/m^2 of maize increased only up to 60 kg N ha^{-1}, but the response of leaf area index (LAI) to increasing levels of N was not consistent. The significant increase in these variables as affected by P was only from 0 to 13.2 kg ha^{-1} However, the application of 13.2 kg P ha^{-1} at each level of N significantly ($P <$ 0.05) increased maize and rice yields, with the highest grain yields of both crops recorded when 120 kg N ha^{-1} and 13.2 kg P ha^{-1} were applied. Crude protein increased in maize and rice leaves with increasing levels of N up to 120 kg N ha^{-1}, but the effects of P on the variable was not consistent. Percent P in crop leaves was unaffected by the application of increasing levels of N and P, and no interaction effect was observed between the levels of N and P. Soil analysis after harvest showed that increasing levels of N and P increased the residual N and P in the soil. For sufficient supply of N and P to raise maize and rice yields, and to have reasonable residual amounts of these elements in the savanna soils at Samaru, the application of 120 kg N ha^{-1} and 13.2 kg P ha^{-1} seem adequate.

RÉSUMÉ

KOMBIOK, J. K. & ELEMO, K. A.: *Effet de fertilisation avec azote et phosphore sur le système de semailles de maïs - riz en lignes alternantes à Samaru au nord du Nigéria.* Le niveau bas de fertilité en général des sols de la savane exige l'application d'engrais chimique pour fournir les quantités adéquates d'élément nutritif exigées par les cultures de céréale pour élever les rendements. L'effet d'azote (A) et phosphore (P) sur le rendement de graine, l'azote du sol et la consommation de N et P par le maïs (*Zea mays* L.) et le riz (*Oryza sativa* L.) dans un système de cultures associées en mélange était étudié en une expérience sur le terrain menée aux champs de Samaru de l'Institute de Recherche d'agriculture en 1990 et 1992. Les combinaisons factorielles de quatre niveaux d' A (0, 60, 120, et 180 kg A ha^{-1}) et trois niveaux de P (0, 13.2 et 26.4 kg P ha^{-1}) étaient posées dans un dessin de bloc complet choisi au hasard avec quatre réplications. Le nombre de talles par plante du riz augmentait considérablement avec l'augmentation des niveaux d' A jusqu' à 180 kg A ha^{-1} alors que les épis/m^2 de maïs augmentaient seulement jusqu' à 60 kg A ha^{-1} la réaction de l'indice de surface foliaire (ISF) à l'augmentation des niveaux d'A n'était pas réguliere. Les augmentations considérables de ces variables comme influencées par P était de O à 13.2 kg P ha^{-1}. Toutefois, l'application de 13.2 kg P ha^{-1} à chaque niveau d' A augmentait considérablement ($P<$ 0.05) les rendements de maïs et de riz avec les rendements de grain de deux cultures obtenus lorsque 120 kg A ha^{-1} et 13.2 kg P ha^{-1} étaient appliqués. La protéine brute augmentait dans les feuilles de maïs et de riz avec l'augmentation des niveaux d'A jusqu' à 120 kg A ha^{-1} maïs les effets de P sur la variable n'était régulier. Le pourcentage de P en feuilles des cultures n'était pas influencé par l'application d'augmentation des niveaux d' A et P et il n'y avait pas d'effet d'interaction observé entre les niveaux d' A et P. Analyse de sol après la moisson montrait que l'augmentation des niveaux d' A et P

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augmentait A et P résiduaires dans le sol. Pour la provision suffisante d' A et P pour augmenter les rendements de maïs et de riz et pour avoir des quantités de residuaire raisonnable de ces éléments dans les sols de savane à Samaru, l'application de 120 kg A ha^{-1} et 13.2 kg P ha^{-1} semble être adéquat.

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Introduction

The two most important nutrient elements required for cereal production are nitrogen and phosphorus. However, these are also the most commonly deficient nutrients in the savanna soils which have very low organic matter content (Schmidt & Frey, 1988). The build-up of organic matter in this ecological zone is also prevented by annual burning of crop residues or their removal for various uses such as for fuel, animal feed, and for building purposes. This results in the exposure of the soil to the long dry season characterised by wind erosion, and also to running water during the early rains of the wet season.

The production of staple food crops of the savanna zone, which are mainly cereals such as maize (*Zea mays*), rice (*Oryza sativa*), millet (*Pennisetum americanum*) and sorghum (*Sorghum bicolor*) to feed the increasing population is, therefore, faced with low soil fertility problems. Maize, sorghum and millet are produced on upland soils, either in sole or mixed with legumes such as cowpea (*Vigna unguiculata*) and soybean (*Glycine max*), with the aim of improving the fertility status of the soil. Even though rice is also produced mostly as a sole crop in the valleys (*fadamas*) in northern Nigeria, it is sometimes intercropped with maize on the upland (Elemo, 1989).

The advantages derived from mixed cropping might have compelled peasant farmers in this zone to intensify the practice. These include precautions against uncertainty and income stability (Abalu, 1977), increase in total productivity (Rahat & Singh, 1979), and a reduction of pest and disease infestations (IITA, 1975). Mixed cropping has, therefore, remained dominant and persistent among the small-scale farmers of the northern savanna zone of West Africa (Andrews & Kassam, 1976; Willey, 1979; Fisher, 1979). This calls for further studies into the system to improve the productivity of component crops. Work done on maize/rice mixtures so far has shown that alternating one row of maize with five rows of rice produced component crop yields that were comparable to sole maize and rice (Elemo, 1989). On evaluating intercropping in maize and rice in relation to grain yield by combining traditional and recommended practices, Moura & Lodi (1983) found significant increases in sole and intercrop up to 120 kg N ha^{-1} and 60 kg P ha^{-1}.

Literature on work done in the area of applying different levels of fertilizers to improve yields in mixed cropping systems on the low fertility soils of the northern savanna zone is scanty. Farmers in the zone who can, therefore, secure funds to purchase fertilizers to increase yields in mixed cropping systems are faced with the problem of the amounts of N and P to be applied, since all available fertilizer recommendations are for sole cropping systems.

Therefore, the objective of this study was to find out the levels at which N and P would be applied to increase the yields of the component crops in maize/rice intercropping system and improve soil fertility for the benefit of subsequent crops. The specific objectives were as follows:

(i) to assess the effect of different levels of N and P on the yield of maize and rice in a mixed cropping system; and

(ii) to study the effect of N and P fertilization on nutrient uptake and residual soil N and P after crop harvest.

Materials and methods

Study site

A field experiment was conducted at the Institute for Agricultural Research Farm, Samaru (Latitude 11° 11'N and Longitude 07° 38'E) at 680 m above sea level in the northern savanna zone of Nigeria, in the 1990 and 1992 wet seasons.

Samaru and its environs experience a mono modal pattern of rainfall with an average of 1,200 mm mostly between May and October. The total rainfall measured during the experimental periods was 229.9 mm in 1990 and 295.6 mm in 1992. The climate is warm semi-arid with temperatures ranging from a minimum of 16 °C in December to a maximum of more than 50 °C in September. It has a grassland vegetation with shrubs interspersed with economic trees such as the shea (*Butyrospermum parkii*) and dawa dawa (*Parkia biglobosa*).

Initial soil characterization of the experimental site in 1990 showed a *p*H of 4.7 in 0.01 M calcium chloride ($CaCl_2$) solution. Other chemical properties of the soil were N (0.21%), organic carbon (0.9 %), available P (23.18 ppm), and K (90 mg/kg). The soil textural class is sandy loam with 56 % sand, 38 % silt and 6 % clay, while the classification of the soil at the site in Samaru, Zaria is the Orthic luvisol (FAO, 1977).

The land is gentle sloping (about 2 %) and has been under crop cultivation for 10 years before the experiment started. Crops cultivated on the land have been cereals such as maize, millet, and sorghum, and legumes (soybean and cowpea) in sole cropping systems.

Experiment

Land preparation

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; the rice was then planted in five rows on the flat alternating each ridge of maize. The mixture was the additive model as maize was held at 100 per cent with about 66 per cent rice added to it.

Planting materials and planting

Maize (cv: TZB-SR), 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 used in the experiment. Both crops were planted from 18th to19th June 1990, while in 1992, they were planted between 30th June and 2nd July.

Fertilizer application and weed control

The treatments included combinations of four levels of N (0, 60, 120 and 180 kg N ha^{-1}) and three levels of P (0, 13.2 and 26.4 kg P ha^{-1}), giving a total of 12 treatments laid in a completely randomized block design with four replications. The gross plot size was 40.5 m^2 (8.1 m × 5 m), and a net plot size of 27 m^2 (5 m × 5.4 m) for final yield assessment.

Fertilizer was applied by band placement. Nitrogen was split applied, half of the urea (N) was applied 2 weeks after planting and the other half was applied 7 weeks after planting of crops. Single super phosphate (P) was applied as a single dose at 2 weeks after planting. The fertilizers were covered.

Five hoe-weeding operations were administered at 2, 4, 6, 9 and 12 weeks after planting.

Harvesting

Each year, the net plot consisting of three ridges of maize and two bands of five rows of rice each was harvested and yield was assessed. Rice and maize were harvested on 6th and 15th October 1990, respectively. Rice and maize were harvested again on 7th and 21st October 1992, respectively.

Data collection

Leaf area index (LAI) at tasselling (maize) and at booting (rice). The length (L) and breadth (B) at the widest portion of each of the leaves of the five randomly selected plants of maize and rice per plot were measured and multiplied (L × B) to determine the leaf areas. The leaf area was multiplied by 0.8 for maize and 0.75 for rice. The leaf area index was then calculated as the ratio of the total leaf area of each crop plant sampled and the land area covered by each plant (Watson, 1952).

Number of cobs/m². The number of cobs of maize in each net plot (27 m^2) was recorded before harvest and converted to per square metre basis.

Grain yield of maize and rice. The harvested ears of maize from the net plots were shelled and panicles of rice were also threshed, sun dried to 13 per cent moisture content, and winnowed. The grains of maize and rice (paddy) were then weighed and the plot yield data converted into yield per hectare.

Number of tillers/plant. The number of tillers produced per plant of rice was counted. Five hills were randomly selected per plot and the number of plants counted per hill. With the knowledge that each hill was planted to two, these were subtracted from each hill. The remaining number of plants left per hill was summed up and the average calculated; this represented the number of tillers/plant.

Soil analysis. Composite soil sample was collected before planting. After harvesting each year, soil samples were collected from each plot and analysed for N and P in the Soil Science Laboratory of the Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria.

Plant analysis. Nitrogen and phosphorus contents in the leaves of maize and rice were determined at tasselling and booting, respectively, in each plot. Percent N in leaves of maize and rice was converted into crude protein content by multiplying by 6.25.

Data analysis. Analysis of variance was applied to test the treatment effect for significance, using the F-test (Cox & Cochran, 1967). The effect of N and P and their interactions were compared, using standard errors (SE).

Results

Maize grain yield

Grain yield of maize increased significantly (P = 0.01) with increasing levels of N up to 120 kg N ha^{-1} in 1990 and 1992 (Fig. 1). The increase in maize grain yield from 0 to 120 kg N ha^{-1} was 3582 kg ha^{-1} in 1990 and 4238 kg ha^{-1} in 1992, representing increases of about 738 and 718 per cent, respectively (Fig. 1). However, increasing N level above 120 kg N ha^{-1} did not increase maize grain yield significantly. The effect of P levels on maize grain yield showed significant yield increases of 157 and 296 kg ha^{-1} only up to 13.2 kg P ha^{-1} in 1990 and 1992, respectively. Increasing P levels beyond this had no yield advantage (Fig. 1).

At N levels of 0 and 60 kg ha^{-1}, a significant increasing effect on maize grain yield was observed as levels of P increased, while at 120 and 180 kg N ha^{-1}, the effect on maize grain yield with increasing P levels was not significant in both years. The increase in maize grain yield on applying N and P was highest when 120 kg N ha^{-1} and 13.2 kg P ha^{-1} were applied in 1992, giving grain yield of 6093 kg ha^{-1}; but in 1990, the grain yield of 4228 kg ha^{-1} was not significantly different from what was

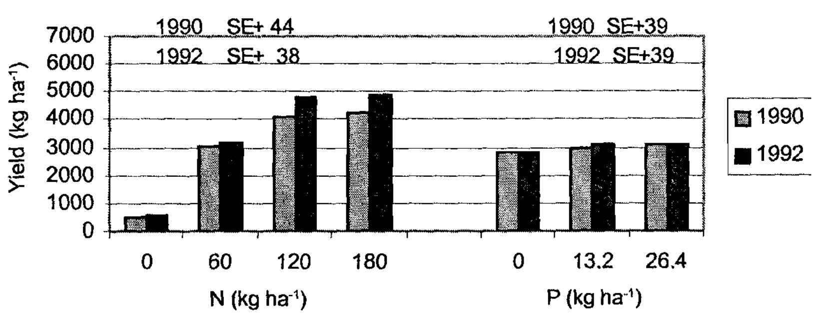

Fig. 1. Effect of N and P on maize grain yield in 1990 and 1992.

recorded when the same quantity of N was applied with no P (Fig. 2a and 2b).

Number of cobs/m²

Number of cobs per square metre increased significantly ($P<0.05$) as levels of N increased, but only up to 60 kg N ha^{-1} in both years (Table 1). The increases were estimated as 14 per cent in 1990 and 167 per cent in 1992. The increase in the number of cobs per square metre on applying increasing levels of P was significant up to 26.4 kg P ha^{-1} in both years (Table 1). It was observed that the percent increases with increasing levels of P from 0 to 26.4 kg P ha^{-1} in both years were the same (22 %).

LAI of maize at tasselling

Leaf area index of maize was observed to be influenced significantly ($P < 0.05$) by levels of N and P. When N was increased from 0 to 180 kg ha^{-1}, the corresponding increase in LAI of 1.36 in 1990 was significant; but in 1992, the decrease in LAI beyond 120 kg ha^{-1} was significant (Table 1). The effect of P on LAI in both years showed that increasing P levels from 0 to 13.2 kg ha^{-1} increased LAI by 1 in 1990 and 0.44 in 1992, but beyond 13.2 kg ha^{-1}, it did not significantly affect the variable (Table 1).

Crude protein in maize leaves at maturity

Crude protein of maize did not increase from 0 to 60 kg N ha^{-1}, and from 120 to 180 kg N ha^{-1}. An increase in crude protein of 8.38 and 6.81 per cent was recorded when N rate was increased from 60 to 120 kg ha^{-1} in 1990 and 1992, respectively (Table 2). However, the effect of P levels on crude protein content of maize in both years was not significant (Table 2).

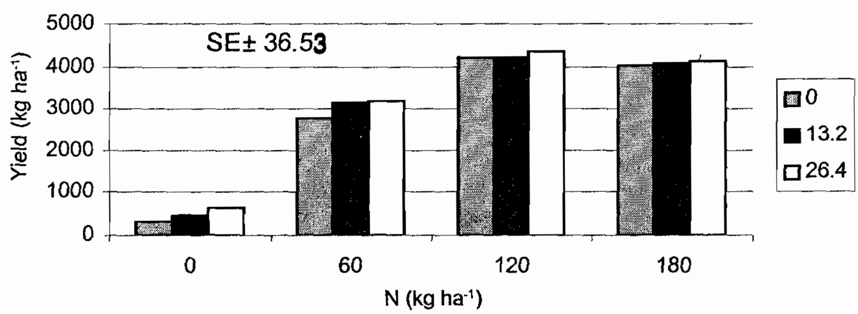

Fig. 2a. The interaction of N and P on maize grain yield in 1990.

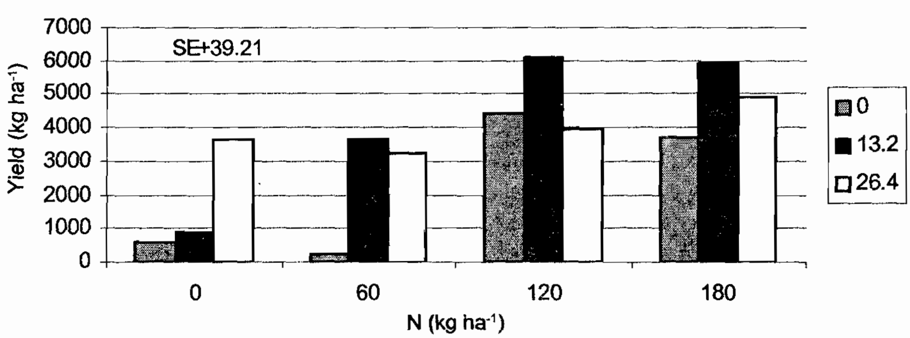

Fig. 2b. The interaction of N and P on maize grain yield in 1992.

TABLE 1

Effect of N and P on Cobs/m² and LAI of Maize at Tasselling

N level (kg ha⁻¹)	1990 Cobs/m²	1992 Cobs/m²	1990 LAI	1992 LAI
0	7	3	2.98	3.61
60	8	8	3.59	5.39
120	8	8	3.62	6.33
180	8	8	4.34	5.52
SE+	0.33	0.32	0.10	0.05
P level				
0	7	7	3.58	4.92
13.2	8	8	4.58	5.36
26.4	9	9	4.65	5.35
SE+	0.32	30	0.08	0.04
N × P interaction	NS	NS	NS	NS

NS=Not significant

TABLE 2

Effect of N and P on Percent Crude Protein and Percent P in Maize at Maturity

Treatment	*Crude protein in maize (%)*		*P in maize (%)*	
N level (kg ha⁻¹)	*1990*	*1992*	*1990*	*1992*
0	7.88	9.88	0.21	0.15
60	7.06	9.94	0.21	0.16
120	15.44	16.75	0.23	0.16
180	17.31	16.63	0.24	0.21
SE+	2.25	1.38	0.04	0.03
P level (kg ha⁻¹)				
0	13.81	13.19	0.24	0.17
13.2	14.63	12.44	0.24	0.18
26.4	15.13	12.25	0.26	0.18
SE+	1.93	1.37	0.03	0.03
N × P interaction	NS	NS	NS	NS

Percent P in maize leaves at maturity

The percent P in maize leaves increased by 0.02 when N level was raised to 120 kg N ha^{-1} in 1990, and by 0.06 to 180 kg N ha^{-1}in 1992; but these increases were not significantly different among treatments (Table 2). With P application, however, the difference in percent P of maize at maturity was not significant (Table 2).

Grain yield of rice

The application of N up to 120 kg ha^{-1} increased rice yield significantly ($P < 0.05$) by 1414 kg ha^{-1} in 1990, and by 1398 kg ha^{-1} in 1992; thereafter, increases in N did not result in any significant increase in yield (Fig. 3). The significant increase in yield due to increasing P application was 1621 kg ha^{-1} in 1990 and 186 kg ha^{-1} in 1992. The increase was from 0 to 13.2 kg N ha^{-1}. Increasing P levels after 13.2 kg P ha^{-1} in 1990 reduced rice yield significantly ($P < 0.05$) while in 1992, beyond that level, the difference in yield was not significant.

At both higher levels of N (120 and 180 kg N ha^{-1}), interaction with increasing levels of P was observed. Increasing P levels from 0 to 13.2 kg P ha^{-1} increased rice yields significantly in both years. The highest yield of 2749 kg ha^{-1} in 1990 and 2990 kg ha^{-1} in 1992 were recorded when 120 kg N ha^{-1} and 13.2 kg P ha^{-1} were applied in both years (Fig. 4a and 4b).

Number of tillers per plant

Significant increases of six tillers per rice plant in 1990 and eight tillers per plant in 1992 were observed when N levels were increased from 0 to 180 kg N ha^{-1} (Fig. 5). Increasing P levels up to 13.2 kg P ha^{-1} resulted in significant number of tillers in both years, but above this level the number of tillers per plant of rice was the same. No interaction effect of N and P was observed on the number of tillers per rice plant in both years.

Leaf area index of rice

The significant increase in LAI of about 2.96 was recorded when N was increased from 0 to 180 kg N ha^{-1} in 1990, but in 1992, increasing N levels beyond 120 kg N ha^{-1} rather resulted in insignificant lower LAI (Table 3). Significant higher LAI was recorded at the highest level of 26.4 kg P ha^{-1} in 1990, but increasing P level above 13.2 kg P ha^{-1} never recorded any significant LAI in 1992 (Table 3). No interaction effect of N and P on LAI of rice was observed in both years.

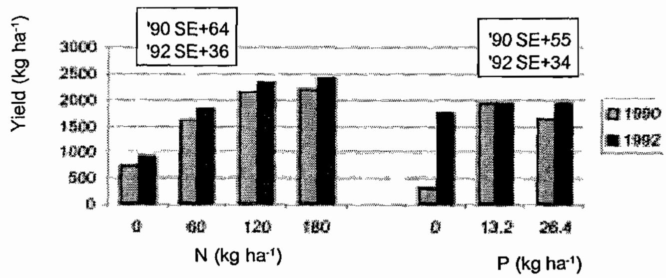

Fig. 3. Effect of N and P on rice grain yield in 1990 and 1992.

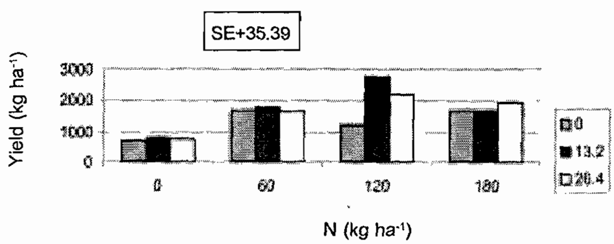

Fig. 4a. The interaction of N and P on rice grain yield in 1990.

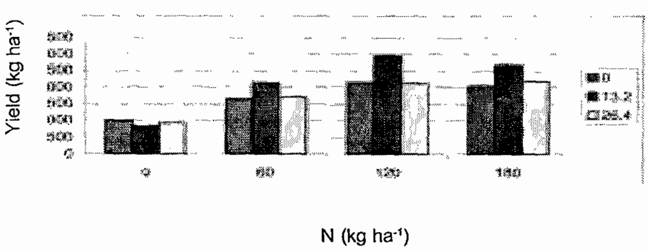

Fig. 4b. The interaction of N and P on rice grain yield in 1992.

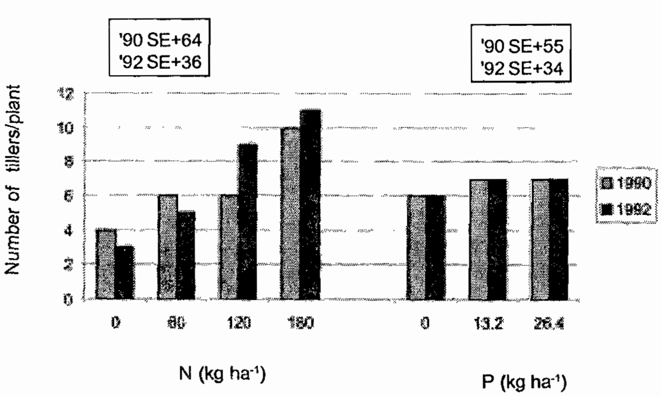

Fig. 5. Effect of N and P on the number of tillers in 1990 and 1992.

TABLE 3

Effect of N and P on LAI of Rice at Maturity in 1990 and 1992

Treatment	*LAI*	
N level (kg ha⁻¹)	*1990*	*1992*
0	1.40	1.40
60	2.10	2.85
120	3.27	3.45
180	4.32	4.36
SE+	0.04	0.04
P level (kg ha⁻¹)		
0	2.70	2.73
13.2	2.74	2.93
26.4	2.76	3.96
SE+	0.21	0.04
N × P interaction	NS	NS

NS=Not significant

TABLE 4

Effect of N and P Levels on Percent Crude Protein and Percent P in Rice Leaves at Maturity in 1990 and 1992

Treatment	*Crude protein in rice leaves (%)*		*P in rice leaves (%)*	
N level (kg ha⁻¹)	*1990*	*1992*	*1990*	*1992*
0	5.56	5.31	0.15	0.17
60	11.25	8.38	0.17	0.17
120	16.38	9.38	0.17	0.23
180	17.50	9.88	0.18	0.23
SE+	1.19	1.06	0.04	0.04
P level (kg ha⁻¹)				
0	12.44	9.06	0.16	0.15
13.2	16.50	8.75	0.18	0.21
26.4	13.00	8.94	0.21	0.19
SE+	1.00	0.94	0.03	0.03
N × P interaction	NS	NS	NS	NS

NS=Not significant

Crude protein in rice leaves at maturity

In 1990, the effect of applying increasing levels of N on crude protein content in rice leaves showed a significant increase of 10.86 per cent up to 120 kg ha^{-1}; but in 1992, the significant increase of 3.09 per cent was observed only when 60 kg ha^{-1} was applied (Table 4). On the effect of P, crude protein increased significantly with increasing levels of P up to 13.2 kg N ha^{-1}, resulting in an increase of 4.06 per cent in 1990, while in 1992, P had no influence on crude protein in rice leaves at crop maturity (Table 4).

Percent P in rice leaves at maturity

The application of N did not significantly increase the percent P by 0.03 in rice leaves (Table 4). With the application of P levels, percent P was highest at 26.4 kg P ha^{-1} (0.21%) in 1990 and at 13.2 kg P ha^{-1} in 1992 (Table 4).

Percent N in the soil at harvest

Percent N determined in the soil immediately after crop harvest indicated that increasing N levels increased the residual N significantly ($P < 0.05$) by 0.037 per cent in 1990, and 0.032 per cent in 1992 in the soil to the last level of N of 180 kg ha^{-1} (Table 5). While each level of N significantly increased soil N up to 180 kg ha^{-1} in both years, the difference in soil residual N between 60 and 120 kg N ha^{-1} levels in 1992 was not significant.

In 1990, even though increasing P levels up to 13.2 kg P ha^{-1} increased residual N in the soil, it was insignificant; but in 1992, the reduction in soil N after 13.2 kg P ha^{-1} was significant (Table 5).

P content in the soil at harvest

Significant effects were observed on the content of P in the soil after crop harvest with increasing levels of N in both years (Table 5). Also, the application of increased P levels resulted in the corresponding significant increase in soil residual P of 2.97 and 4.33 per cent in 1990 and 1992, respectively, up to the last level of P of 26.4 kg ha^{-1} (Table 5).

TABLE 5

Effect of N and P on Percent N and Content of P in the Soil after Harvest in 1990 and 1992

Treatment	N content in the soil at harvest		P content in the soil at harvest	
	1990	1992	1990	1992
N level (kg ha^{-1})	(%)		ppm	
0	0.021	0.030	10.69	9.75
60	0.027	0.051	10.44	9.50
120	0.039	0.052	10.89	10.06
180	0.058	0.062	10.99	9.10
SE+	0.004	0.005	0.19	0.18
P level (kg ha^{-1})				
0	0.035	0.050	8.86	6.56
13.2	0.036	0.059	10.82	8.85
26.4	0.038	0.045	11.83	10.89
SE+	0.007	0.004	0.17	0.16
N × P interaction	NS	NS	NS	NS

NS=Not significant

Discussion

A significant upward trend of maize and rice grain yields is observed as the application of N increases up to 120 kg N ha^{-1}; this is consistent with the results reported by Sanchez (1976), Stifel (1989), and Kang & Balasubramanian (1990). The number of panicles per square metre and number of tillers per plant have been recognised by many workers as the two most important characters of rice influenced by N and P. The significant increases in grain yield of rice with increasing N and P were caused by the positive effect of these elements.

Maize grain yield in both years did not show any significant increase above N level of 120 kg ha^{-1} and P level of 13.2 kg ha^{-1}. This agrees with the findings of Balasubramanian & Mokwunye (1976), as they observed significant yield increase of maize up to 120 kg N ha^{-1}, after which further increases had no yield advantage. This was also later confirmed by Olugunde & Ogunlela (1984) when they found that N rate for optimum maize yield was between 100 and 150 kg N ha^{-1}. The number of ears or cobs per square metre also increased with increasing levels of P up to 13.2 kg ha^{-1} as well as increasing levels of N which eventually increased maize yield significantly (Lonhard-Bony & Nemeth, 1989; McPhilips, 1989).

The significant increase in plant proteins of maize and rice with increasing levels of N and P was much expected. This is because the contents of N and P in crop plants vary according to the supply of these elements (Pierre, Aldrich & Martin, 1974). The non-significant difference in crude proteins observed among P levels could be due to the high P level in the soil before planting of crops. Apart from water, light and carbon dioxide, N and P are very essential for plant growth and development. Plant growth is highly correlated with the amount of N and P absorbed (Gasser & Williams, 1967).

Being constituents of chlorophyll, the more the plants absorb N and P, the better and faster the plant proteins and amino acids are synthesized; thus, aiding the plant to grow and develop.

The increase in N and P uptake with increasing levels of these elements could, therefore, be responsible for the subsequent higher grain yields recorded. Seartz & Sterger (1965), Bayo (1979), Jokelia & Randall (1989), and Castro & Gomez (1990) also found that increase in accumulation of N and P in maize and rice tissues led to significant grain yield increases.

The application of increasing levels of N and P significantly increased soil N and P. The significant increase in any element in the soil as a result of applying increasing levels may be due to a higher amount of the element in the soil than required by plants. With high levels of fertilizer application, when the nutrient requirements of plants are met, excess would be left in the soil if not leached. This could have been so in this trial, considering the amounts of N and P applied and the quantities of these elements determined in the soil before planting of the crops. Several reports have confirmed higher residual N and P in the soil with increasing levels of these elements. Stabetorp & Lyngstad (1988) found significantly lower percent

N in plots with 120 kg N ha^{-1} than in plots with 180 kg N ha^{-1}, while Ivanov & Dimitrov (1989) also reported unnecessarily higher residual P in the soil after applying 180 kg P ha^{-1} than 120 kg P ha^{-1}.

Conclusion

In this study, maize and rice grain yields in both years showed no yield advantage when N and P application increased beyond 120 kg N ha^{-1} and 13.2 kg P ha^{-1}, respectively. The quantities of the elements left in the soil at crop harvest after applying these rates are high enough to be used as starter fertilizer for subsequent cereal crops. These are already the recommended rates for the economic production of maize in sole cropping systems in the savanna zone of Nigeria. Therefore, considering the high cost of N and P fertilizers and the risk of unfavourable weather conditions such as erratic rainfall that can result in crop failure, the application of 120 kg N ha^{-1} and 13.2 kg P ha^{-1} would be adequate.

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