

**EFFECTS OF NITROGEN AND PHOSPHORUS FERTILIZATION
ON MAIZE/GROUNDNUT MIXTURE**

BY

YOHANNA MAMMA KWAGA

B.Sc. AGRIC. (ABU)

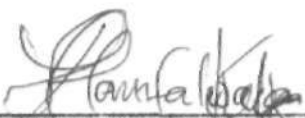
**A thesis submitted to the post-graduate school Ahmadu
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requirement for the degree of Master of Science in
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**DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA**

(JANUARY, 1994)

DECLARATION

I hereby declare that this thesis has been written by me, and that it is a record of my own research work. It has not been presented before in any previous application for a higher degree.


YOHANNA MAMMA KWAGA
(Candidate)

Date: 18-5-1994

The above declaration is confirmed.


DR. K.A. ELEMO
(Major Supervisor)

Date: 19 May 1994

CERTIFICATION

This thesis entitled "EFFECTS OF NITROGEN AND PHOSPHORUS FERTILIZATION ON MAIZE/GROUNDNUT MIXTURE" by Yohanna Mamma Kwaga meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.



DR. K.A. ELEMO
Chairman, Supervisory Committee



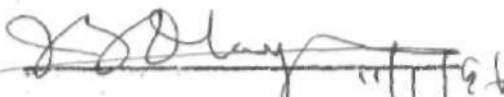
PROFESSOR S.T.O. LAGOKE
Member, Supervisory
Committee



PROFESSOR V. KUMAR
Member, Supervisory
Committee



PROFESSOR S.T.O. LAGOKE
Head, Department of
Agronomy



Dean Postgraduate School

Date: _____
AHMADU BELLO UNIVERSITY
ZARIA.

DEDICATION

This work is dedicated to El-Elyon for His
sustaining grace through out the course of the work.

ACKNOWLEDGEMENT

I wish to express my profound gratitude to my loving Heavenly Father for the immeasurable grace showered on me throughout the period of the project work. My deep appreciation goes to my major supervisor Dr. K.A. Elemo who assisted immensely in developing useful ideas and offered tireless guidance on the whole aspect of the work. I am greatly indebted to my other supervisors Professors S.T.O. Lagoke and V. Kumar for their counselling and invaluable suggestions made during the course of the work.

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ABSTRACT

A field trial was conducted in the 1991 wet season on the Research Farm of the Institute for Agricultural Research, Samaru, Zaria (11° 11'N, 7° 38'E, 658m above mean sea-level) located in the northern Guinea savanna ecological zone of Nigeria. The objective was to determine the effects of nitrogen and phosphorus on the productivity of maize and groundnut in mixture.

Five levels of nitrogen (0, 40, 80, 120 and 160 kg N/ha) laid out in mainplots and three levels of phosphorus (0, 26.4, 52.8 kg P/ha) in subplots were tested on the maize/groundnut mixture in all possible combinations in a split-plot design. Application of 40 kg N/ha significantly increased maize shelling percentage, stover yield, cob diameter, LAI at 13 WAP, plant and ear heights. Whereas application of 80 kg N/ha remarkably increased maize grain yield, 1000-grain weight and further increased stover yield and cob diameter. Maize kernel depth, cob length and cob number per plant increased with N level up to 80 kg N/ha. However application of 80 kg N/ha significantly reduced the number of days to 50% silking. Application of 26.4kgP/ha significantly increased maize stover yield, LAI at 13 V/AP, but resulted in shorter days to 50% silking. Increasing P level to 52.8 kg P/ha appreciably increased maize 1000-grain weight, cob diameter, plant and ear heights and further increased stover yield, but reduced days to 50% tasseling, However maize grain yield

bellling percentage, cob number per plant;, cob length, kernel depth, LAI at 10 WAP and percentage of lodged plants did not respond to P application.

Application of nitrogen to maize in the mixture indirectly depressed groundnut pod and kernel yields, ' Haulm yield and number of mature pods per Plant, were significantly reduced by the application of 40-120 kg N/ha. The groundnut LAI at 10 and 13 WAP were also remarkably reduced by the application of 120 kg N/ha. However nitrogen application had no significant effect on groundnut shelling percentage, 100-kernel weight, number of immature pods per plant, plant height and days to 60% flowering. Application of phosphorus did not affect groundnut except the LAI at 10 WAP that increased.

The highest LER of 1.35 and the highest cross returns less fertilizer cost was obtained from the application of 160 kg N/ha + 26.4 kg P/ha. Nevertheless application of 80 kg/ha + 0 kg P/hn was the lowest combined levels of N and P that gave significant increase in LER. Highest return per Nairn invested on fertilizer was obtained from the application of 40 kg N/h a with ou t phosphorus, followed by 80 kg N/ha + 0 kg P/ha. Given the condition of this study where there was appreciable soil P and considering the financial constraints of the small scale farmers who grow their crops mostly in mixture, application of 80 kg N/ha without P is most promising for the productivity of maize/groundnut mixture.

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INTRODUCTION

The bulk of food production in the Nigerian savanna is contributed by the small scale-farmers who grow crop mostly in mixtures. Nevertheless, past research efforts have been concentrated on sole cropping resulting in lack of available recommended practices for mixed crops.

Maize production has gained ground among farmers of the savanna zones of Nigeria where it is grown in mixture with other crops like groundnut and other legumes (Ologunde, 1983, 1987). Since efforts to encourage farmers in the ecology to shift from mixed cropping to sole cropping has been a futile attempt (Abalu and D'Silva, 1978) it is imperative to develop relevant technologies to cater for the crop mixtures.

Nitrogen and phosphorus are the two major nutrients limiting crop production in the savanna of Nigeria (Mokwunye, 1979). There is similarity in the phosphorus requirement of maize and groundnut (Enwezor et al., 1989) but great disparity exists in their nitrogen requirement. As a cereal, maize favourably responds to application of nitrogen for optimum grain production (Berger, 1962) whereas groundnut being a legume is able to meet its nitrogen requirement through symbiotic fixation. However high nitrogen may restrict nodulation (Mengel and Kirby, 1978) and consequently reduce kernel yield. Therefore

nitrogen application to maize/groundnut mixture should be done judiciously such that the high nitrogen requirement of maize is catered for without detriment to kernel production of groundnut.

There is paucity of information on the combined effects of nitrogen and phosphorus fertilizers on maize and groundnut mixture in the Nigerian savanna. This study was therefore conducted to determine the effects of nitrogen and phosphorus on the productivity of maize and groundnut in mixture.

Chapter 2

LITERATURE REVIEW

Most of the West-African savanna soils especially those north of latitude 7°N are low in organic matter and clay content which is mainly kaolinitic (Jones, 1974; Lombin, 1981). Consequently the soils are poorly buffered and rapidly lose their fertility under continuous cultivation. Therefore adequate fertilizer application is necessary in the ecology for a sustained crop yield where continuous cropping is practised.

2.1. Effect of Nitrogen Application on Maize

Maize production is limited by nitrogen deficiency more often than by any other nutrient element (Berger, 1962; Ologunde, 1983; Mbagwu, 1990). In a multi-locational study in the southern Guinea savanna of Nigeria, Agbede *et al.* (1991) reported that 90 and 120 kg N/ha gave the highest maize grain yield at three and five sites respectively. At another location in the same ecology, Ologunde and Ogunlela (1984) obtained the highest grain yield with 120 kg N/ha. Similar response was observed in the forest zone of Nigeria (Esechie, 1987) in Italy (Manino *et al.*, 1990) and in the northern Guinea savanna of Nigeria (Ologunde, 1983). At Tanzania Uriyo *et al.* (1977) reported linear increase in maize yield with increasing

nitrogen rates up to 120 kg N/ha. Positive maize yield response to increasing nitrogen rates up to 150 kg N/ha has been reported by Sharma (1973) and Lucas (1986). Nitrogen was also reported to increase 1000-grain weight and ears per plant of maize (Sharma, 1973; Prasad and Singh, 1990). Similarly nitrogen application was observed to increase maize ear length (Prusty et al., 1987; Prasad and Singh, 1990). Increase in plant and ear height of maize as a result of nitrogen application was recorded by Al-Rudha and Al-Younis (1978).

Several workers reported that higher nitrogen rate favoured early silking (Glover, 1953; Sharma, 1973; Al-Rudha and Al-Younis, 1978; Gangwar and Kalra, 1988; Prasad and Singh, 1990). In contrast Ologunde and Ogunlela (1984) and Ologunde and Ogunlela (1985) observed that higher nitrogen rates delayed silking. Thompson and Troeh (1978) remarked that plant must have N before it can synthesize cells, and that severe shortage of nitrogen could halt the process of growth and reproduction. Similarly Millar et al. (1958) reported that ample supply of nitrogen during the early growth stage of the plant may stimulate growth and result in earlier maturity, but that excess nitrogen throughout the growing season of plant frequently prolongs the growth period. Therefore it appears that severe shortage or excess supply of nitrogen could delay silking in maize.

2.2 Effect of Phosphorus Application on Maize

The rate of phosphorus to be applied to maize crop for optimum yields depends on the phosphorus sorption capacity of the soil (Enwezor, 1979) as soils with higher sorption capacity require high level of P fertilization when they are P deficient. Furthermore, under conditions of low phosphorus buffering capacity and low inherent phosphorus, it is beneficial to apply large initial dose of phosphorus to the soil to build up the phosphorus adequately to sustain good yield for some years (Yost et al., 1979; Anonymous, 1988). Adepoju (1991) observed that application of 13.1 kg P/ha consistently gave optimum maize yield in a trial conducted in southern Nigeria. Where P levels have been built up under continuous cultivation 17.6 kg P/ha was reported to be sufficient for optimum maize production in the Nigerian savanna (Mokwunye, 1979). In a study conducted in India by Devarajan and Rajagopal (1978) 22kg P/ha was observed to be optimum for maize yield. Osiname (1979) reported increase in maize yield with increasing phosphorus level up to 80kg P/ha in the forest zone of Nigeria. Glover (1953) found that higher soil phosphorus resulted in earlier tasseling and silking in maize.

2.3 Effect of Nitrogen Application on Groundnut

Most legumes under optimum growth conditions such as high pH (7-8.5), high fertility level and right rhizobial strains meet their nitrogen requirement through symbiotic fixation (Ofori, 1975). Consequently nitrogen application on such soils is unnecessary. Singh and Balasubramanian (1978) recommended application of 5 to 10 kg N/ha to groundnut as starter dose on poor sandy soils. Similarly it has been reported that groundnut yield could be increased by the application of 10 to 20 kg N/ha (Chesney, 1975; Ofori, 1975; Venkateswarlu and Nath, 1989; Mahalle et al., 1991). Jana et al. (1990) observed that application of about 20 kg N/ha to groundnut did not only produce the highest economic returns but increased the number of pods per plant, kernels per pod and 100-kernel weight. Bhuiya and Choudhury (1974) observed that application of nitrogen increased protein content but decreased oil content of groundnut.

2.4 Effect of Phosphorus Application on Groundnut

Phosphorus plays a key role in the physiological process of root production, nodulation and N_2 -fixation in groundnut (Sanker et al., 1984). Chesney (1975) and Jain and Dikshit (1987) reported that groundnut yield increased with increasing phosphorus level up

to 13.2 kg P/ha. However Patil et al. (1979), Lal and Saran (1988), Reddy and Giri (1989) observed a similar increase up to 17.6 kg P/ha. Kayode (1987) found the optimum P level for groundnut production in the forest zone of Nigeria to be between 13.2 and 19.8 kg P/ha. In the Nigerian savanna application of 23.76 kg P/ha has been recommended for groundnut production (Enwezor et al., 1989).

Phosphorus has been found to increase groundnut 100-kernel weight, number of pods per plant and number of kernels per pod (Patil et al., 1979; Jana et al., 1990) and also the seed oil and protein content (Kayode, 1987; Lal and Saran 1988).

2.5 Effect of Nitrogen Application on Maize/Groundnut mixture

Literature is scanty on the effect of nitrogen application on maize and groundnut mixture. In an intercrop of legume and non-legume, the legume obtain most of its nitrogen requirement by symbiotic fixation, (Trenbath, 1976). The non-legume benefits more from the nitrogen application. In such a mixture there is a reduced competition for soil nitrogen (Black, 1968; Searle et al., 1981). Studies conducted in the Nigerian savanna showed that nitrogen application significantly increased maize yield in maize and groundnut mixture (Ologunde, 1983; Anonymous, 1984)

but showed no marked effect on the yield of groundnut. However, maize or groundnut in mixture have been observed to show no response to applied N as a result of the high status of the native soil N at Australia (Searle et al., 1981).

2.6 Planting Configuration

A study carried out in the northern Guinea savanna on the planting configuration of maize in mixture with groundnut showed that alternate single ridges performed best compared to within rows and alternate double rows arrangement (Anonymous, 1991).

Chapter 3

MATERIALS AND METHODS

3.1 Experimental site

The study was conducted in 1991 wet season on the farm of the Institute for Agricultural Research, Samaru ($11^{\circ} 11', 7^{\circ} 38' E$) in the northern Guinea savanna ecological zone of Nigeria. The rainfall pattern in the area is unimodal with its peak in the month of August. Rains in the area usually start by the middle of May and often end about the first week of October (Kowal and Knabe, 1972). The distribution of rainfall during the year of the experiment is presented in appendix 1.

3.2 Soil sampling and Analysis

The soil of the experimental area was sampled at 15 different points using tubular auger, on the day of the first fertilizer application. The collected samples were bulked and air-dried. The composite sample was then thoroughly mixed and sieved using 2mm mesh sieve before carrying out the physico-chemical analysis of the soil. The result of the analysis is presented in appendix 2.

3.3 Treatments and Experimental Design

The experiment consisted of 17 treatments which were a sole crop of maize (var. TZBSR-W) fertilized at the rate of 120 kg N/ha and 26.4 kg P/ha as well as sole groundnut (var. RRB) given 23.8 kg P/ha. The remaining 15 treatments comprising the mixture received five levels of nitrogen (0, 40, 80, 120, 160kg N/ha) combined in a factorial with three levels of phosphorus (0, 26.4, 52.8 kg P/ha) and laid out in split-plot design with nitrogen in main plot and phosphorus in sub-plot. Fertilizers were applied by side placement according to the rate for each treatment. Single superphosphate was used to supply phosphorus at 2 WAP to both maize and groundnut in all plots. However nitrogen was applied only to maize in the form of urea in equal split dosage at 2 and 6 WAP. The gross and net plots were eight and four rows respectively ridged 90cm apart. Both gross and net plots were 5m long giving plot sizes of 36m² and 18m² respectively.

3.4 Crop Establishment and Management

The experimental site was ploughed once, harrowed twice and ridged before planting. Both maize and groundnut were planted on 24 June, 1991, but groundnut was replanted about two weeks later as a result of

poor germination. The maize and groundnut were both planted in alternate single ridges in the mixture. In both the mixture and sole cropping intra-row spacing was 20cm on the ridges. Maize was thinned to two plants per stand in the mixture and one plant per stand in the sole crop at 2 weeks after planting (WAP) to maintain required sole crop density. Groundnut which was planted at two seeds per hill was not thinned. The plots were hoe weeded at 2, 6 and 8 WAP. Each crop was harvested after attaining the stage of physiological maturity.

3.5 Data Collection on Maize

3.5.1 Plant height of maize

The heights of ten maize plants were taken per plot at 12 WAP. The measurement was made from the ground level to the tip of the plant.

3.5.2 Days to 50% tasseling in maize

Days to 50% tasseling in maize was determined as number of days from planting to the time that 50% of maize plants in the net plot have tasseled.

3.5.3 Days to 50% silking in maize

Days to 50% silking in maize was calculated as number of days from planting to the time that 50% of maize plants in that net plot silked.

3.5.4 LAI of maize

The (LAI) of maize at 10 and 13 WAP were determined using two plants at each sampling from each plot. The product of the length and breadth of the widest portion of every leaf of the two plants were summed up and multiplied by 0.76 to get the leaf area for each plot. The factor 0.76 was obtained as the ratio of the estimated area of the leaf outline on graph paper to that of the product of its length and breadth at the widest portion. (McKee, 1964). The leaf area index was calculated by dividing the leaf area of the two plants by the ground area occupied by the two plants.

3.5.5. Ear height of maize

At harvest height from ground level to the first ear insertion was taken for ten maize plants in each plot to give the ear height of maize.

3.5.6 Lodging of maize plant

At harvest the number of maize plants that lodged in each net plot was taken and expressed as percentage of the number of maize plants in the plot.

3.5.7 Number of cobs per plant

Number of maize cobs per plant was the ratio of number of harvested cobs from each net plot to the number of maize plants in the plot.

3.5.8 Cob length

The cobs from each plot were arranged according to their length and ten were systematically sampled and their length measured.

3.5.9 Cob diameter

The diameter of ten systematically sampled cobs were taken per plot.

3.5.10 Kernel depth

Diameter of ten cobs were taken before and after shelling. The difference between each measurement was divided by two to give the kernel depth.

3.5.11 Grain yield of maize

The cobs of each net plot were shelled, weighed and converted to yield per hectare.

3.5.12 Shelling percentage of maize

The shelling per cent of maize for each plot was calculated as follows:

$$\text{Shelling per cent (\%)} = \frac{\text{Grain weight after shelling}}{\text{Cob weight (before shelling)}} \times 100$$

3.5.13 1000-grain weight of maize

After shelling, 1000 grains were counted from per plot and weighed.

3.5.14 Stover yield of maize

The weight of ten sun-dried maize stover from each plot was taken. This was multiplied by number of maize plants in the plot divided by ten and then converted to yield per hectare.

3.6 Data Collection on Groundnut

3.6.1 Plant height of Groundnut

The heights of ten groundnut plants were taken per plot at 12 WAP. The measurement was done from the ground level to the tip of the plant.

3.6.2 LAI of Groundnut

The leaf area index (LAI) of groundnut at 10 and 13 WAP was determined using two plants at each sampling from each plot. The leaves from the two plants were removed, piled up and ran through with a cork borer of 1 cm diameter. The number of complete disks formed were counted. The disks and the remaining leaf parts were oven-dried at about 70°C for about 24 hours in separate envelopes and weighed. The leaf area was calculated from the relationship of the average weight of the leaf disks to the total leaf weight (McKee, 1964) and the LAI calculated as follows:

$$LA = \frac{a + b}{c} \times d$$

Where LA = Leaf area (cm^2)

a = dry weight of oven-dried leaf disks (g)

b = Weight of the remaining oven-dried leaf parts (g)

c = Mean dry weight of leaf disks

d = Disk area (cm^2)

$$\text{LAI} = \frac{\text{LA}}{y}$$

Where y = Ground area occupied by the two plants.

3.6.3 Days to 50% flowering in groundnut

Days to 50% flowering in groundnut was number of days from planting to the time that 50% of plants in the net plot have flowered.

3.6.4 Number of mature pods per plant

At harvest, a sample of ten groundnut plants was taken from each plot and the number of mature pods were counted. The mean of the count gave the pods per plant.

3.6.5 Number of immature pods per plant

The number of immature pods and pegs were counted from a sample of ten groundnut plants from each plot at harvest. The mean gave the number of immature pods per plant.

3.6.6 Pod yield of groundnut

The weight of dry groundnut pods from each net plot was measured and converted to yield per hectare.

3.6.7 Shelling percentage of groundnut

After drying of the ^{mature} groundnut pods two handfulls of the pods were taken from the yield of each plot and weighed before and after shelling. The shelling percentage was determined as follows:

$$\text{Shelling per cent (\%)} = \frac{\text{Kernel weight (shelled)}}{\text{pod weight (unshelled)}} \times 100$$

3.6.8 Kernel yield of groundnut

Kernel yield of groundnut was weight of pods from each net plot multiplied by its shelling percentage and then converted to yield per hectare.

3.6.9 100-kernel weight of groundnut

After shelling 100 kernels were counted from the yield of each plot and weighed.

3.6.10 Haulm yield of groundnut

Ten sun-dried haulms of groundnut from each plot were weighed. The weight was multiplied by number of groundnut plants in the plot divided by ten and then converted to yield per hectare.

3.7. Land Equivalent Ratio

Land equivalent ratio (LER) was used to ascertain the yield advantage of the mixture over sole cropping. The LER for both crops were summed to get the combined LER. The LER was computed as follows:

$$\text{Maize LER} = \frac{\text{Grain yield of maize in mixture}}{\text{Grain yield of sole maize}}$$

$$\text{Groundnut LER} = \frac{\text{Kernel yield of groundnut in mixture}}{\text{Kernel yield of sole groundnut}}$$

$$\text{Combined LER} = \text{LER maize} + \text{LER groundnut}$$

3.8. Economic Returns

The returns of each crop was based on its retail price at Samaru local market at harvest in 1991. The gross returns less fertilizer cost was calculated as the combined returns of the two crops minus the cost of fertilizer in the same local market at the time of planting.

3.9 Statistical Analysis

Data collected were subjected to analysis of variance and the treatment means were compared using Duncan Multiple Range Test (DMRT) at 5% level of probability. Although the treatments were laid out in split-plot design for the mixtures, it was necessary to use Randomized complete Block Design (RCBD) for the analysis involving the sole crops. This was because

the sole crops were not part of the split-plot layout, but were only grown alongside of each replication. Correlation was run for yield and yield attributes of both crops.

Chapter 4

RESULTS

4.1 Grain Yield, Shelling Percentage,
1000-grain weight and Stover Yield
of Maize

4.1.1. Grain yield of maize

Nitrogen applied at 40kg N/ha had no significant effect on maize grain yield (Table 1). However increasing the N level to 80 kg N/ha significantly increased the grain yield . While a further rise to 120 and 160 kg N/ha no longer had significant effect on the grain yield. There was no significant effect of P or its interaction with N on the grain yield of maize.

As expected sole maize outyielded all treatments of the mixture that received less than 120 kg N/ha including those without P at 120 and 160 kg N/ha and that fertilized with 26.4 kg P/ha at 120 kg N/ha. However it was statistically at par with the treatment that received 120 kg N/ha + 52.8 kg P/ha and those fertilized with P at 160 kg N/ha.

4.1.2 Shelling percentage of maize

Application of 40 kg N/ha significantly raised the shelling percentage of maize (Table 1) but higher nitrogen level did not significantly improve the shelling percentage. The main effect of phosphorus

Table 1: Influence of nitrogen and phosphorus applied to maize (TZBSR-W) in mixture with groundnut (GB) on grain yield, shelling percentage, 1000-grain weight and stover yield of maize at Sessu, 1991 wet season.

Treatment	Grain yield (kg/ha)*	Shelling percentage*	1000-grain weight (g)*	Stover yield (kg/ha)*
<u>Nitrogen (kg N/ha)</u>				
0	285b	73.95b	131.4b	1270c
40	768b	76.38a	148.8ab	2632b
80	1477a	77.76a	157.1a	3455ab
120	1628a	77.21a	161.2a	3714a
160	1695a	76.50a	165.1a	3289ab
SE $\pm$	216.3	0.581	6.95	260.7
<u>Phosphorus (kg P/ha)</u>				
0	1094	76.68	148.8b	2461c
26.4	1138	76.07	151.2b	2831b
52.8	1279	76.34	158.2a	3324a
SE $\pm$	80.3	0.564	2.33	114.9
	ns	ns		
<u>Interaction</u>				
N X P	ns	ns	ns	ns

*Means followed by the same letter(s) in each treatment group are not significantly different at 5% level of probability using DMRT.

ns = Not significant at 5% level of probability.

Table 2: Grain yield of maize (TZBSR-W) in mixture with groundnut (RRB) under different N and P rates applied to maize and sole crop at Samaru, 1991 wet season.

Maize treatment		Grain yield (kg/ha)*
<u>N</u> (kg/ha)	<u>P</u> (kg/ha)	
0	0	193e
0	26.4	370e
0	52.8	292e
40	0	823cde
40	26.4	633de
40	52.8	847cde
80	0	1567bc
80	26.4	1220bcd
80	52.8	1644bc
120	0	1482bc
120	26.4	1610bc
120	52.8	1791ab
160	0	1402bcd
160	26.4	1859ab
160	52.8	1823ab
Sole maize (check)**		2557a
(124 kgN + 26.4 kg P/ha)		
SE $\pm$		252.6

*Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using DMRT.

and its interaction with nitrogen had no significant influence on the shelling percentage of maize.

4.1.3 The 1000-grain weight of maize

The 1000-grain weight of maize did not respond to the application of 40 kg N/ha (Table 1). However application of 80 to 160 kg N/ha gave a significantly higher 1000-grain weight than the no nitrogen treatment. The 40 to 160 kgN levels were statistically similar. Application of 26.4 kg P/ha had no appreciable effect on the 1000-grain weight of maize. Nevertheless increasing the P level to 52.8 kg P/ha resulted in a significantly higher 1000-grain weight than at 0 and 26.4 kg P/ha. No significant effect of nitrogen and phosphorus interaction was observed on the 1000-grain weight of maize.

4.1.4 Stover yield of maize

Stover yield of maize was significantly increased by the application of 40 kg N/ha (Table 1). Among the higher N rates, only application of 120 kg N/ha gave further increase in stover yield. The nitrogen levels from 80 to 160 kg N were statistically at par. There was progressive increase in maize stover yield with increasing P levels from 0 to 52.8 kg P/ha. The interaction effect of N and P on stover yield was not significant.

4.2 Number of Cobs per plant, Cob Length, Cob diameter and Kernel Depth of Maize

4.2.1. Number of cobs per plant

Number of maize cobs per plant increased with increasing nitrogen rates from 0 to 80 kg N/ha (Table 3) subsequent increase in nitrogen level did not significantly affect the number of cobs per plant. The main effect of P and the interaction effect of N and P on the number of cobs per plant were not significant.

4.2.2 Cob length of maize

Cob length of maize increased with increasing nitrogen levels from 0 to 80 kg N/ha (Table 3). Further increase in N level had no marked increase on cob length. There was no significant effect of phosphorus or its interaction with N on maize cob length.

4.2.3 Cob diameter of maize

Nitrogen application remarkably increased cob diameter of maize when N rate was increased from 0 to 40 kg N/ha (Table 3). Raising the N level to 80 kg N/ha gave no further increase in cob diameter. Although the 120 and 160 kg N/ha treatments gave comparable cob diameter to 80 kg N/ha, yet they produced significantly larger cob diameter than 0 and

Table 3: Effects of nitrogen and phosphorus applied to maize (TZBSR-W) in mixture with groundnut (RRB) on number of maize cobs per plant, cob length, cob diameter and kernel depth at Samaru, 1991 wet season.

Treatment	Number of cobs per plant (no)*	Cob length (cm)*	Cob diameter (mm)*	Kernel depth (mm)*
<u>Nitrogen (kg N/ha)</u>				
0	0.26c	7.23c	29.23c	5.13c
40	0.52b	9.13b	34.95b	6.14b
80	0.75a	10.72a	37.22ab	6.63a
120	0.74a	11.11a	36.77a	6.90a
160	0.73a	11.46a	39.37a	7.05a
SE $\pm$	0.049	0.339	0.945	0.240
<u>Phosphorus (kg P/ha)</u>				
0	0.58	9.66	34.92b	6.26
26.4	0.60	9.71	35.43b	6.45
52.8	0.62	10.43	37.30a	6.40
SE $\pm$	0.029	0.28	0.537	0.168
	ns	ns		ns
<u>Interaction</u>				
N X P	ns	ns	ns	ns

*Means followed by the same letter(s) in each treatment group are not significantly different at 5% level of probability using DMRT.

ns = Not significant at 5% level of probability.

40 kg N levels. Application of 26.4 kg P/ha gave similar cob diameter to no phosphorus treatment. Nevertheless application of 52.8 kg P/ha gave a significantly larger cob diameter than both 0 and 26.4 kg P rates. The N and P interaction had no significant effect on the cob diameter of maize.

4.2.4 Kernel depth of maize

Kernel depth of maize increased with increasing nitrogen level from 0 to 80 kg N/ha (Table 3). Subsequent increase in N level did not significantly affect kernel depth. Phosphorus application and its interaction with N had no significant effect on the kernel depth of maize.

4.3 Plant Height, Ear Height and Leaf Area Index of Maize

4.3.1 Plant height of maize

Application of 40 kg N/ha resulted in a significantly taller maize plants at 12 WAP compared to 0 kg N rate (Table 4). Further increase in N level had no significant effect on the plant height. Application of 26.4 kg P/ha had no significant effect on maize plant height. However raising the P level to 52.8 kg P/ha resulted in a significantly taller maize plants than no phosphorus treatment but statistically at par with 26.4 kg P rate. Nitrogen and phosphorus interaction had no significant effect on maize plant height.

Table 4: Influence of nitrogen and phosphorus applied to maize (TZBSR-W) in mixture with groundnut (RRB) on maize plant and ear height and leaf area indice (LAI) at Samaru, 1991 wet season.

Treatment	Plant ht. at 12 WAP (cm)*	Ear ht. at harvest (cm)*	LAI at 10 WAP*	LAI at 13 WAP*
<u>Nitrogen (kg N/ha)</u>				
0	105.3b	44.8b	1.17b	0.67b
40	169.3a	65.1a	1.56ab	1.35a
80	176.0a	71.8a	1.83ab	1.36a
120	179.3a	69.8a	1.85ab	1.55a
160	169.31	65.3a	2.03a	1.43a
SE $\pm$	7.55	3.42	0.215	0.124
<u>Phosphorus (kg P/ha)</u>				
0	150.9b	58.1b	1.60	1.03b
26.4	161.8ab	62.8b	1.84	1.41a
52.8	166.9a	69.0a	1.73	1.37a
SE $\pm$	3.97	1.86	0.133	0.102
			ns	
<u>Interaction</u>				
N X P	ns	ns	ns	ns

*Means followed by the same letter(s) in each treatment group are not significantly different at 5% level of probability using DMRT.

ns = Not significant at 5% level of probability.

WAP= Weeks after planting.

4.3.2 Ear height of maize at harvest

Ear height of maize at harvest responded to the application of 40 kg N/ha (Table 4). Subsequent increase in N level had no significant effect on the ear height. Application of 26.4 kg P/ha did not affect the ear height of maize. However increasing P level to 52.8 kg P/ha remarkably increased the ear height. The interaction effect of nitrogen and phosphorus were not significant on the ear height of maize.

4.3.3 Leaf Area Index (LAI) of maize at 10 WAP

Increasing nitrogen level from 0 to 120 kg N/ha had not marked effect on maize LAI at 10 WAP (Table 4). However application of 160 kg N/ha gave a significantly higher LAI than 0 nitrogen treatment but statistically similar LAI to the remaining N rates. The main effect of P and the interaction effect of N and P on LAI at 10 WAP were not significant.

4.3.4 Leaf Area Index (LAI) of maize at 13 WAP

Significant increase in the LAI of maize at 13 WAP was only observed when N level was increased from 0 to 40 kg N/ha (Table 4). Further increase in N level did not significantly influence the LAI. Increasing P level from 0 to 26.4 kg P/ha significantly raised the LAI at 13 WAP. Subsequent increase in P

level had no significant effect on the LAI. Nitrogen interaction with phosphorus had no marked effect on the LAI at 13 WAP.

4.4 Days to 50 Per cent Tasseling, Silking and Percentage of Lodged plants of Maize

4.4.1 Days to 50% tasseling in maize

Nitrogen application had no significant effect on the number of days to 50 per cent tasseling in maize (Table 5). Application of 26.4 kg P/ha had no significant effect on number of days to 50 tasseling. However further rise in P level to 52.8 kg P/ha resulted in earlier tasseling in maize than no phosphorus treatment, but similar time of tasseling with 26.4 kg P rate. Nitrogen and phosphorus interaction had no significant effect on the time of tasseling.

4.4.2 Days to 50% silking in maize

Nitrogen application had no significant effect on days to 50% silking in maize when N level was increased from 0 to 40 kg N/ha (Table 5). However increasing N rate to 80 kg N/ha resulted in earlier silking than no nitrogen treatment. Nevertheless the 80 kg N rate had similar time of silking with the remaining N rates. Application of 26.4 kg P/ha

Table 5: Effects of nitrogen and phosphorus applied to maize (TZBSR-W) in mixture with groundnut (RRB) on days to 50 percent tasseling and silking and percentage lodged plants at Samaru, 1991 wet season.

Treatment	Days to 50 percent tasseling (days)*	Days to 50 percent silking (days)*	Percentage lodged plant at harvest*
<u>Nitrogen (kg N/ha)</u>			
0	70.50	82.67a	42.4
40	69.17	77.58ab	51.0
80	69.17	74.83b	42.3
120	70.00	75.33b	32.8
160	70.17	76.83ab	42.9
SE $\pm$	0.918	1.40	6.40
	ns		ns
<u>Phosphorus (kg P/ha)</u>			
0	70.45a	79.59a	39.5
26.4	69.85ab	77.00b	43.2
52.8	69.10b	75.76b	44.2
SE $\pm$	0.383	0.522	2.65
			ns
<u>Interaction</u>			
N X P	ns	ns	ns

*Means followed by the same letter(s) in each treatment group are not significantly different at 5% level of probability using DMRT.

ns = Not significant at 5% level of probability.

resulted in shorter days to 50 per cent silking than no phosphorus treatment. Increasing P level to 52.8 kg P/ha had no significant effect on the time of silking. Nitrogen and phosphorus interaction had no appreciable effect on the time of silking.

4.4.3 Percentage of lodged maize plants at harvest

Nitrogen application had no significant effect on the percentage of lodged maize plants at harvest (Table 5). Similarly the main effect of P and the interaction of N and P had no marked effect on the percentage lodged plants at harvest.

4.5 Pod and Kernel Yields, Shelling Percentage and 100-kernel weight of Groundnut

4.5.1 Pod yield of groundnut

The plots where no nitrogen was applied to maize gave a significantly higher pod yield of groundnut than where N application was made (Table 6). All plots where the maize received nitrogen gave pod yields that were statistically at par. There was no significant effect of P or its interaction with N on the pod yield of groundnut.

4.5.2 Kernel Yield of groundnut

Application of 40 to 160 kg N/ha to maize in the mixture significantly depressed the kernel yield of groundnut (Table 6). Phosphorus application had no

Table 6: Influence of nitrogen and phosphorus applied to maize (TZBSR-W) in mixture with groundnut (RRB) on pod and kernel yields, shelling percentage and 100-kernel weight of the groundnut at Samaru, 1991 wet season.

Treatment	Kernel yield (kg/ha)*	Pod yield (kg/ha)*	Shelling percentage*	100- Kernel weight (g)*
<u>Nitrogen (kg N/ha)</u>				
0	391a	549a	71.28	36.10
40	305b	423b	72.08	35.77
80	290b	393b	73.85	36.83
120	302b	414b	73.10	36.21
160	324b	443b	73.46	37.70
SE $\pm$	24.8	32.08	0.945	1.013
			ns	ns
<u>Phosphorus (kg P/ha)</u>				
0	316	436	72.61	35.87
26.4	329	452	72.91	36.74
52.8	323	445	72.74	36.94
SE $\pm$	12.4	17.48	0.732	0.359
	ns	ns	ns	ns
<u>Interaction</u>				
N X P	ns	ns	ns	ns

*Means followed by the same letter(s) in each treatment group are not significantly different at 5% level of probability using DMRT.

ns = Not significant at 5% level of probability.

marked effect on the kernel yield. Similarly effect of N and P interaction on the kernel yield was not significant. Sole groundnut gave a significantly higher yield than any of the groundnut yield in the mixtures (Table 7).

4.5.3 Shelling percentage of groundnut

Shelling percentage of groundnut did not respond to the application of N to maize in the mixture (Table 6). Similarly application of phosphorus and the interaction of N and P showed no significant effect on the shelling percentage of groundnut.

4.5.4 The 100-kernel weight of groundnut

The 100-kernel weight of groundnut was not significantly affected by the application of nitrogen to maize in the mixture (Table 6). Similar trend was observed with the application of phosphorus. The interaction of N and P also had no marked effect on the 100-kernel weight of groundnut.

4.6 Haulm Yield, Number of Mature and Immature Pods per plant and Days to 50 per cent Flowering in Groundnut

4.6.1 Haulm yield of groundnut

Application of 40 to 120 kg N/ha to maize in the mixture significantly depressed the haulm yield of

Table 7: Kernel yield of groundnut (RRB) in mixture with maize (TZBSR-W) under different N and P rates applied to maize and sole crop at Samaru, 1991 wet season.

Treatment		Kernel yield (kg/ha)*
<u>N</u> (kg/ha)	<u>P</u> (kg/ha)	
0	0	380bc
0	26.4	370bc
0	52.8	422b
40	0	281c
40	26.4	315bc
40	52.8	318bc
80	0	277c
80	26.4	309c
80	52.8	285c
120	0	306c
120	26.4	328bc
120	52.8	274c
160	0	336bc
160	26.4	321bc
160	52.8	316bc
Sole groundnut (check)** (23.76 kg P/ha)		566a
SE _±		32.3

*Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using DMRT.

groundnut (Table 8). While the 160 kg N/ha gave haulm yield that was statistically at par with all that of other treatments. Phosphorus application had no appreciable effect on the haulm yield. Similarly N and P interaction had no significant effect on the haulm yield.

4.6.2 Number of mature pods per plant of groundnut

There was a significant decrease in number of mature pods per plant of groundnut at harvest when 40 kg N/ha was applied to maize in the mixture (Table 8). Further increase in N level showed no marked effect on the pod number. However the 160 kg N/ha treatment gave similar number of pods to that of no nitrogen treatment. Main effect of phosphorus and the interaction effect of N and P were not significant on number of mature pods.

4.6.3 Number of Immature Pods per Plant of Groundnut

Nitrogen applied to maize in the mixture did not affect number of immature pods per plant of groundnut (Table 8). Similarly application of phosphorus and the interaction of N and P had no significant effect on the number of immature pods.

Table 8: Haulm yield, number of mature and immature pods per plant and days to 50 per cent flowering of groundnut (RRB) in mixture with maize (TZBSR-W) under different N and P rates applied to maize at Samaru, 1991 wet season.

Treatment	Haulm yield (kg/ha)*	Number of mature pods per plant at harvest (no)*	Number of immature pods per plant (no)*	Days to 50 per cent flowering (days)*
<u>Nitrogen (kg N/ha)</u>				
0	355a	15.08a	11.08	33.92
40	266b	11.08b	11.42	33.75
80	269b	11.42b	10.92	33.67
120	269b	11.42b	10.92	33.58
160	308ab	13.75ab	11.50	33.58
SE $\pm$	26.7	0.825	0.858	0.194
			ns	ns
<u>Phosphorus (kg P/ha)</u>				
0	306	12.75	11.80	33.50
26.4	282	12.60	10.80	33.95
52.8	293	12.30	10.90	33.65
SE $\pm$	17.9	0.654	0.548	0.185
	ns	ns	ns	ns
<u>Interaction</u>				
N X P	ns	ns	ns	ns

*Means followed by the same letter(s) in each treatment group are not significantly different at 5% level of probability using DMRT.

ns = Not significant at 5% level of probability.

4.6.4 Days to 50% flowering in groundnut

Days to 50% flowering in groundnut was not significantly affected by the application of nitrogen to maize in the mixture (Table 8). Similar trend was observed with the application of phosphorus. The interaction of N and P also had no appreciable effect on the time of flowering in groundnut.

4.7 Plant Height and Leaf Area Index (LAI) of Groundnut

4.7.1 Plant Height of groundnut at 12 WAP

Groundnut plant height at 12 WAP was not significantly influenced by the application of nitrogen to maize in the mixture (Table 9). Main effect of phosphorus and the interaction effect of N and P had no marked effect on the plant height.

4.7.2 Leaf area index (LAI) of groundnut at 10 WAP

Application of 40 kg N/ha to maize in the mixture had no remarkable effect on groundnut LAI at 10 WAP (Table 9). However application of 80 and 120 kg N/ha gave a significantly lower LAI than no nitrogen treatment, but gave similar LAI to that of 160 kgN rate. Application of 26.4 kg P/ha gave comparable LAI at 10 WAP to that of no phosphorus. However higher rate of 52.8 kg P/ha gave a significantly higher LAI than no phosphorus treatment but statistically at par with 26.4 kg P rate. Interaction effect of N and P on LAI at 10 WAP was not significant.

Table 9: Plant height and leaf area indice (LAI) of groundnut (RRB) in mixture with maize (PZB30-9) under different N and P rates applied to maize at Samaru, 1991 wet season.

Treatment	Plant height at 12 WAP (cm)*	LAI at 10 WAP*	LAI at 13 WAP*
<u>Nitrogen (kg N/ha)</u>			
0	39.5	0.71a	0.30a
40	40.1	0.57ab	0.31a
80	40.1	0.49b	0.28ab
120	41.6	0.51b	0.29b
160	42.2	0.54ab	0.27ab
SE $\pm$	1.54	0.054	0.025
	ns		
<u>Phosphorus (kg P/ha)</u>			
0	39.9	0.50b	0.30
26.4	40.8	0.58ab	0.23
52.8	41.4	0.66a	0.29
SE $\pm$	0.51	0.043	0.027
	ns		ns
<u>Interaction</u>			
N X P	ns	ns	ns

*Means followed by the same letter(s) in each treatment group are not significantly different at 5% level of probability using DMRT.

ns = Not significant at 5% level of probability.

WAP= Weeks after planting.

4.7.3 Leaf Area Index (LAI) of groundnut at 13 WAP

Groundnut LAI at 13 WAP was not significantly affected by the application of 40 and 80 kg N/ha to maize in the mixture (Table 9). Increasing N rate to 120 kg N/ha gave a significantly higher LAI than no nitrogen treatment but similar to all the other N rates. Main effect of phosphorus and N and P interaction were not significant on LAI at 13 WAP.

4.8 Correlation

4.8.1 Association among maize characters

The relationships between maize yield and yield components are shown in Table 10. Maize yield was positively correlated with 1000-grain weight, shelling percentage, length and diameter of cob, kernel depth, number of cobs per plant, stover yield LAI at 10 and 13 WAP ($r=0.6496, 0.5470, 0.8388, 0.7595, 0.8353, 0.7623, 0.5286, 0.5073$ respectively), but negatively related with days to 50% tasseling and silking ($-0.7103, -0.4656$ respectively). With the exception of days to 50% tasseling and silking, all the other characters were positively related to each other but negatively related to the time of tasseling and silking. However days to 50% tasseling and silking were positively related to each other.

Table 10: Correlation matrix for maize plant characters.

	V ₁	V ₂	V ₃	V ₄	V ₅	V ₆	V ₇	V ₈	V ₉	V ₁₀	V ₁₁	V ₁₂
V ₁	1.0000											
V ₂	0.6496**	1.0000										
V ₃	0.5470**	0.4209**	1.0000									
V ₄	0.8223**	0.6463**	0.3643**	1.0000								
V ₅	0.8388**	0.6723**	0.4645**	0.8192**	1.0000							
V ₆	0.7595**	0.4918**	0.4869**	0.6278**	0.8337**	1.0000						
V ₇	0.8353**	0.4482**	0.4891**	0.6058**	0.7020**	0.6881**	1.0000					
V ₈	0.7623**	0.4443**	0.4498**	0.6842**	0.7400**	0.6360**	0.6838**	1.0000				
V ₉	0.5286**	0.3956**	0.3278**	0.4695**	0.4194**	0.3532**	0.4583**	0.3027*	1.0000			
V ₁₀	0.5073**	0.2575*	0.1376	0.4118**	0.4584**	0.3755**	0.4118**	0.4853**	0.3918**	1.0000		
V ₁₁	0.7102**	-0.6984**	-0.4475**	-0.6102**	-0.7042**	-0.6015**	-0.4437**	-0.6758**	0.3802**	-0.4088**	1.0000	
V ₁₂	0.656**	-0.2836*	-0.3414**	-0.1953	-0.3751**	-0.3443**	-0.4875**	-0.3996**	-0.3953**	-0.3009*	0.7188**	1.0000

V ₁	=	Grain yield	V ₅	=	Cob diameter	V ₉	=	LAI at 10 WAP
V ₂	=	1,000 grain weight	V ₆	=	Kernel depth	V ₁₀	=	LAI at 13 WAP
V ₃	=	Shelling percentage	V ₇	=	Number of cobs/plant	V ₁₁	=	Days to 50% silking
V ₄	=	Cob length	V ₈	=	Stover yield	V ₁₂	=	Days to 50% tasseling

*Significant at 5% level of probability

**Significant at 1% level of probability

WAP = Weeks after planting.

4.8.2 Association among groundnut characters

The relationship between groundnut character and yield attributes are presented in Table 11. The result has shown that groundnut kernel yield was positively associated with pod and haulm yields, LAI at 10 and 13 WAP and number of mature pods per plant ($r = 0.9912, 0.5695, 0.4411, 0.2792, 0.6263$, respectively). The 100-kernel weight was positively associated with groundnut shellin, percentage ($r = 0.5436$). Similarly, pod yield was positively correlated with number of mature pods per plant, haulm yield and LAI at 10 and 13 WAP ($r = 0.6381, 0.5855, 0.4189, 0.2902$, respectively). Groundnut haulm yield was positively correlated with number of pods per plant ($r = 0.5075$) but negatively correlated to number of days to 50% flowering ($r = -0.3804$).

4.9 Land Equivalent Ration (LER)

The data on land equivalent ratio (LER) are shown in Table 12. Fertilizer application to mixtures at the rate of 160 kg N/ha + 26.4 kg P/ha, 160 kg N/ha + 52.8 kg P/ha and 120 kg N/ha + 52.8 kg P/ha resulted in maize LER comparable to that of sole maize. Groundnut LER was significantly higher for sole groundnut than any of the fertilizer combinations in the mixtures.

Table 11: Correlation matrix for groundnut plant characters.

	S ₁	S ₂	S ₃	S ₄	S ₅	S ₆	S ₇	S ₈	S ₉
S ₁	1.0000								
S ₂	0.2052	1.0000							
S ₃	0.9912**	0.1289	1.0000						
S ₄	-0.0603	0.5486**	0.1903	1.0000					
S ₅	0.5695**	0.0230	0.5855**	-0.1600	1.0000				
S ₆	0.4411**	0.1951	0.4189**	0.0796	0.1351	1.0000			
S ₇	0.2792*	0.1274	0.2902*	0.1320	0.1154	0.1510	1.0000		
S ₈	0.6263**	-0.0271	0.6381**	-0.1509	-0.5705**	0.0895	0.0938	1.0000	
S ₉	-0.1547	0.1686	-0.1766	0.1400	-0.3804**	-0.1271	-0.0443	-0.0115	1.0000
S ₁	= Kernel yield								
S ₂	= 100-kernel weight								
S ₃	= Pod yield								
S ₄	= Shelling percentage								
S ₅	= Haulm yield								
S ₆	= LAI at 10 WAP								
S ₇	= LAI at 13 WAP								
S ₈	= Number of mature pods/plant								
S ₉	= Days to 50% flowering								

*Significant at 5% level of probability

**Significant at 1% level of probability

WAP = Weeks after planting.

Table 12: Land equivalent ratio (LER) of maize (TZBSR-W) and groundnut (RRB) grown in mixture at different nitrogen and phosphorus rates at Samaru, 1991 wet season.

Treatment		Maize (LER)	Groundnut (LER)	Combined (LER)
<u>N</u> <u>(kg /ha)</u>	<u>P</u> <u>(kg /ha)</u>			
0	0	0.07e	0.69bc	0.76f
0	26.4	0.17de	0.67bcd	0.84d-f
0	52.8	0.12e	0.76b	0.88ef
40	0	0.33cde	0.50cd	0.83ef
40	26.4	0.25de	0.56cd	0.81ef
40	52.8	0.34cde	0.56cd	0.90b-f
80	0	0.61bc	0.48d	1.09a-f
80	26.4	0.48bcd	0.55cd	1.03a-f
80	52.8	0.64bc	0.51cd	1.15a-e
120	0	0.59bc	0.55cd	1.14a-e
120	26.4	0.65bc	0.58bcd	1.23a-c
120	52.8	0.72ab	0.49cd	1.21a-d
160	0	0.58bc	0.60bcd	1.18a-e
160	26.4	0.78ab	0.57bcd	1.35a
160	52.8	0.73ab	0.56cd	1.29ab
Sole maize		1.00a	-	1.00a-f
Sole groundnut		-	1.00a	1.00a-f
SE $\pm$		0.100	0.059	0.11

*Means followed by the same letter in a column are not significantly different at 5% level of probability using DMRT.

The result from the combined LER showed that all the fertilizer combinations had LER Comparable to those of the sole crops, while 160 kg N/ha + 26.4 kg P/ha gave the highest value of 1.35. The combined LER for all the fertilizer treatments of 80 to 160 kg N/ha with various P combinations were comparable to the highest obtained in the trial. Application of 120 kg N/ha resulted in higher combined LER than corresponding P levels without nitrogen.

4.10 Economic Returns

The estimated returns for each of the treatments as enterprise are presented in Table 13. Revenue generated from sole maize was comparable to that from maize of the best three treatments in the mixtures; which are 160 kg N/ha + 26.4 kg P/ha, 160 kg N/ha + 52.8 kg P/ha and 120 kg N/ha + 52.8 kg P/ha. However it gave a significantly higher revenue than that of the remaining treatments in the mixtures. Revenue obtained from sole groundnut was considerably higher than that from groundnut from any of the treatments in the mixtures. Highest combined revenue was obtained from 160 kg N/ha combined with 26.4 kg P/ha. Fertilizer application of 80 to 160 kg N/ha gave comparable combined revenue to sole maize. Application of 40 kg N/ha without P gave a significantly higher returns per Naira cost of fertilizer than any of the

Table 13: Gross returns, fertilizer cost, returns per naira invested on fertilizer and gross returns less fertilizer cost of maize and groundnut enterprises grown in mixture at Samaru, 1991 wet season.

Treatment	Gross Maize value in Naira (#)*	Gross Groundnut Value in Naira (#)*	Combined value in Naira (#)*	Fertilizer cost in Naira (#)*	Returns per Naira invested on fertilizer (#)*	Gross returns less fertilizer cost @ (#)*
(Kg N/ha) (kg P/ha)						
0 0	374.91e	2223.87bc	2598.78f	-	-	2598.78bc
0 26.4	718.29e	2182.85bc	2901.14f	433.22	6.70def	2467.92c
0 52.8	566.00e	2469.99b	3035.99ef	866.44	3.50g	2169.55d
40 0	1591.11cd	1648.13c	3245.24c-f	156.40	20.75a	3088.84abc
40 26.4	1228.02d	1845.90bc	3073.92d-f	589.62	5.22efg	2484.30c
40 52.8	1642.21cd	1860.55bc	3502.76b-f	1022.84	3.43g	2479.92c
80 0	3039.50bc	1624.69c	4664.19a-e	312.80	14.91b	4351.38a
80 26.4	2366.80bcd	1807.81c	4174.61a-f	746.02	5.60d-g	3428.59abc
80 52.8	3188.88bc	1667.17c	4856.05a-c	1179.24	4.12fg	3676.81abc
120 0	2875.08bc	1793.16c	4668.24a-e	469.20	9.95c	4199.04ab
120 26.4	3123.40bc	1919.15bc	5042.55ab	902.42	5.59d-g	4140.13ab
120 52.8	3475.03ab	1602.71c	5077.74ab	1335.64	3.80fg	3742.10abc
160 0	2720.37bcd	1970.43bc	4690.80a-d	625.60	7.50cde	4065.19abc
160 26.4	3605.98ab	1882.53bc	5488.51a	1058.82	5.18efg	4429.68a
160 52.8	3535.65ab	1845.83bc	5384.48a	1492.04	3.61fg	3892.44abc
Sole maize	4961.07a	-	4961.07ab	302.42	5.50d-g	4058.65abc
Sole groundnut	-	5315.33a	5315.33c-f	369.90	8.50cd	2923.93abc
SE ±	468.11	135.10	496.54	-	0.95	486.90

+Cash value was based on the retail price of each produce at harvest at Samaru local market.

Cash value for maize was #5.00 per measure (#1.94/kg) and for groundnut #13.00 per measure (#13.55/kg).

@Nitrogen costed #90.00 per urea bag (#3.91/kgN) and phosphorus costed #65.00 per single super phosphate bag (#16.41/kg P).

*Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using F_{0.05}.

treatments. The highest returns less fertilizer cost was realised from 160 kg N/ha + 26.4 kg P/ha. However the returns was similar to that of both sole crops, mixtures fertilized with 80 to 160 kg N/ha and that treated with 40kg N/ha without P. Groundnut haulm was not costed in the study.

Chapter 5

5.1 Effects of Nitrogen on Maize and Groundnut

Maize yield and yield components responded positively to nitrogen application. The significant effect of nitrogen on the maize characters (grain yield, shelling percentage, 1000 - grain weight, stover yield, number of cobs, length and diameter of cob, kernel depth, plant and ear height, LAI and days to 50 per cent silking) can be attributed to the low inherent total nitrogen content of the soil (0.04% nitrogen) which is below critical level where response to nitrogen is expected according to the classification of soil fertility by Ewczor et al. (1989).

Despite the low level of native nitrogen of the soil, maize shelling percentage, 100 - grain weight, plant and ear heights, LAI and days to 50% silking did not respond to nitrogen application higher than 40.kg N/ha. However high N rates increased grain and stover yields, number of cobs, kernel depth, length and diameter of cob. This may be due to low C:N ratio (19:1). At narrow C:N ratio there is less immobilization of added nitrogen by soil microbes. Consequently there is greater availability of added N for plant uptake. Therefore under such conditions high nitrogen dose is not required to effect significant response in plant

characters. Whereas under conditions of high C:N ratio high dosage of nitrogen is needed to cater for the amount to be immobilized by microbes and that required for plant productivity before significant response to nitrogen application can be observed.

Grain yield of maize only increased with the application of 80 kg N/ha, while stover yield was increased by the application of 40 kg N/ha. The lack of response of maize grain yield to the low nitrogen rate of 40 kg N/ha could be that the dosage is not high enough to sustain the crop through vegetative stage and effect significant response in grain yield. Application of nitrogen dose higher than 40 kg N/ha was probably sufficient for both vegetative and grain production to allow for significant response in grain yield. The lack of significant response of maize grain yield to N rates higher than 80 kg N/ha implies that the optimum N level for maize grain production in the maize and groundnut mixture has been attained. This is consistent with results from the southern Guinea savanna of Nigeria where maize grain yield in a maize and groundnut mixture did not respond to nitrogen level higher than 90 kg N/ha (Anonymous, 1984). In contrast Searle et al. (1981) in Australia, did not observe significant response in maize grain yield to

nitrogen application in maize/groundnut mixture. The observed differences in the response to N could be attributed to variation in the native N status of the different soils, as the soil of the study in Australia was considered to be sufficient in N.

The positive effect of nitrogen application on maize shelling percentage and 1000-grain weight indicate that nitrogen is essential for the production of large sized grains (Mengel and Kirby, 1978). This confirms the works of Ologunde and Ogunlela (1984) and Prasad and Singh (1990) who observed that nitrogen increased 1000-grain weight of maize.

The increase in maize cob length and diameter, kernel depth and number of cobs per plant with N application observed in this trial agrees with the findings of Prusty et al. (1987), and Prasad and Singh (1990) who earlier reported similar observations with N application to maize. It shows that nitrogen application enhances cob bearing and production of large sized cobs.

The taller plants and higher ears obtained with nitrogen application confirms the report of Al-Rudha and Al-Younis (1978) and Mengel and Kirby (1978) who observed that nitrogen application increased maize plant height. Such response is to be expected since

N deficiency results in stunted plant (Ishizuka, 1971). Invariably maize plant and ear heights are closely associated. The positive effect of N on maize LAI at both 10 and 13 WAP indicates that nitrogen is important for the production of large sized leaves and hence in increasing the photosynthetic capacity of the leaves which could result in greater production of assimilates for grain and vegetative production.

Nitrogen application reduced the days to 50% silking in maize. There are conflicting reports on the effect of nitrogen on the silking time of maize. Ologunde et al. (1985) observed that nitrogen increased days to 50% silking. However other workers (Sharma, 1973; Al-Rudha and Al-Younis, 1978; Gangwar and Kalra, 1988; Prasad and Singh, 1990) reported that nitrogen application resulted in earlier silking in maize. The conflicting results may be attributed to variation in the N status of the different soils. Black (1968) reported that application of 45 kg N/ha resulted in earlier maturity where maize was markedly deficient in N. He further remarked that when N is slightly deficient it had no effect on earliness to maturity. It is possible that in the present study insufficient available nitrogen for the use of maize at the low nitrogen level might have adversely affected the production of reproductive

cells. According to Thompson and Troeh (1973) plant must have adequate N before it can synthesize new cells and that shortage of nitrogen could halt the process of growth and reproduction. Also Ishizuka (1971) remarked that shortage of nitrogen inhibits cell division, resulting in slow emergence of silk. On the other hand, nitrogen application delays silking leading to late maturity (Miller et al., 1958).

Groundnut only responded to the application of 40 kg N/ha to maize in the mixture. Higher nitrogen rates had no further effect on groundnut characters except for LAI at 10 and 13 WAP which responded to the application of 120 kg N/ha. Nitrogen depressed both pod and kernel yields of groundnut. This agrees with the report of Searle, et al. (1931) who observed that nitrogen depressed groundnut yield in a maize/groundnut mixture. Since in this study, maize and groundnut were planted on separate ridges and that nitrogen was only applied to maize, the effect of nitrogen application was not direct on groundnut. The observed effect is probably due to the indirect effect of N in fostering vegetative growth of maize plants resulting in the shading of groundnut plant in the lower canopy. This explains why the no nitrogen treatment which had the least maize LAI outyielded the nitrogen fertilized treatments.

The shading effect was probably responsible for the apparent depression of groundnut kernel, pod and

haulm yields, number of pods per plant, LAI at 10 and 13 WAP to nitrogen application. Therefore the reduction of photosynthesis at the lower canopy as a result of the shading is the likely cause of depression in the above-mentioned groundnut characters when N was applied to maize in the mixture.

5.2 Effects of phosphorus on maize and Groundnut

Among the yield components of maize P application only significantly affected 1000-grain weight and cob diameter of maize. According to Mengel and Kirby (1978) the amount of P fertilizer required by a crop depends on the level of P in the soil solution and the P buffering capacity of the soil. Therefore the lack of response of maize grain yield and most yield attributes to P application is probably due to the medium level of P (10.77 ppm) in the soil of the experimental site. The positive response of 1000-grain weight and cob diameter of maize to P application indicates that phosphorus is essential for the improvement of the size of maize grains and cobs. This agrees with the remarks made by Mengel and Kirby (1978) that phosphorus principally affects the development of grain.

The general response in the maize growth characters to P application shows that maize growth characters gave

greater response to P than yield characters in this study. The significant response of stover yield, plant and ear heights of maize to the application of P show that phosphorus application improves the size and height of maize plants. The positive effect of P on stover and plant height should be expected since P deficiency results in thin and stunted plants (Mengel and Kirby, 1978; Thompson and Troeh, 1978). It therefore confirms that P is essential for cell division (Millar et al., 1958), thereby playing significant role in increasing plant size and height. The effect of P on maize LAI at 10 and 13 WAP implies that P is essential for the production of large size maize leaves thereby conferring better photosynthetic capacity.

Effect of phosphorus application on groundnut was only observed on LAI at 10 WAP. This general lack of response of groundnut characters to P implies that the P level in the soil of the trial site was sufficient to meet the P requirement of groundnut.

5.3: Yield advantage of Maize/Groundnut mixture as affected by Nitrogen and Phosphorus Application

The combined LER for the mixtures and sole crops of maize and groundnut did not show any significant yield advantage of growing the crops in

mixture compared to the sole crops. It means that irrespective of the fertilizer combinations applied to the mixtures, growing either maize or groundnut as sole with recommended N and P of 120 - 26.4 kg/ha (N, P) and 23.8 kg P/ha for maize and groundnut respectively is as good as any of the mixtures. However farmers consider sole cropping as being risky. This lack of observed yield advantage despite high level of N and P fertilization can be attributed to the high LER of groundnut in the mixtures even when no fertilizer was applied. However among the mixtures application of 80 kg N/ha without phosphorus appears to be sufficient.

5.4 Economic returns of maize/ground mixture

The combined revenue has shown that similar revenue can be realised from sole maize as that of the best in the mixtures, and better returns than that of the mixtures without nitrogen fertilizer and combinations of 40 kg N/ha with P at 0 and 26.4 kg/ha. However revenue obtained from sole groundnut was significantly lower than that of the mixtures that received 120 and 160 kg N/ha with exception of those that were not fertilized with P. The differences between the revenue generation capacity of the sole crops can be attributed to the high yield of maize than groundnut.

Considering the gross returns, application of 80 kg N/ha without P gave the optimum returns.

However in view of the continuous increase in the cost of fertilizer and its scarcity over the past decade, it is pertinent to include the cost of fertilizer in assessing the profitability of the accrued revenue from the produce. Since it is the most important variable cost for the production of the mixture especially for the small scale farmers. This category of farmers whose crop production is mainly in mixtures don't have the strong financial base to foot the high fertilizer cost that goes with high fertilizer dosage to crops even if it is more profitable. In this respect the fertilizer rate that gives a high returns per Naira invested on fertilizer may be more impressive to such farmers. The highest returns per Naira invested on fertilizer was obtained from the application of 40 kg N/ha without P, followed by 80 kg N/ha without P. The comined LER has shown that application of 80 kg N/ha + 0 kg P/ha was the lowest fertilizer combination that gave comparable value to the highest LER. Therefore considering the economic returns, the combined LER and the medium level of available soil phosphorus in this study, application of 80 kg N/ha without phosphorus appears to be most impressive for the maize/groundnut mixture.

5.5 Implication of soil analytical data

Soil analytical data showed the potassium level of the soil of the trial site to be 0.09 meq/100g of soil. This is below the critical level of 0.20 meq/100g of soil according to soil

classification by Enwezor et al. (1989). Potassium deficiency leads to poor cob formation (Miller et al., 1958). It was not possible for the trial to receive a blanket application of potassium due to non - availability. Perhaps this was responsible for the low maize yield reported in this trial.

Chapter 6

SUMMARY AND CONCLUSION

The field trial was conducted in the 1991 wet season on the farm of the Institute for Agricultural Research, Samaru ($11^{\circ} 11'N$, $7^{\circ} 38'E$) in the northern Guinea savanna ecological zone of Nigeria.

Five levels of nitrogen (0, 40, 80, 120, 160 kg N/ha) and three rates of phosphorus (0, 26.4, 52.8 kg P/ha) which were the main plots and sub-plots treatments respectively were applied in various possible combinations and replicated four times. In each replicate sole maize and sole groundnut were grown for yield comparison.

Applied nitrogen had significant effect on maize yield and yield attributes viz., shelling percentage, 1000-grain weight, length and diameter of cob, kernel depth and number of cobs per plant. Maize grain yield was significantly increased when level of applied nitrogen reached 80 kg N/ha. Further increase in N had no significant effect on maize yield. Number of cobs per plant, cob length and kernel depth increased significantly with increasing nitrogen level up to 80 kg N/ha. However marked increase in maize shelling percentage and growth characters such as plant and ear heights, and leaf area index were only observed when N level was raised from 0 to 40 kg N/ha.

Phosphorus significantly increased maize 1000-grain weight, cob diameter, plant and ear heights when applied at 52.8 kg P/ha. Stover yield increased with increasing phosphorus rate up to 52.8 kg P/ha. Nitrogen and phosphorus interaction had no significant effect on any of the maize parameters.

Nitrogen application to maize in the mixture resulted in depression of both pods and kernel yields of groundnut probably due to the shading caused by vigorous maize plants. Phosphorus only increased groundnut LAI at 10 WAP. Nitrogen and phosphorus interaction had no significant effect on any of the groundnut characters.

Maize grain yield was positively correlated with 1000-grain weight, shelling percentage, length and diameter of cobs, kernel depth, number of cobs per plant, stover yield and LAI at 10 and 13 WAP, but negatively related with days to 50% tasseling and silking. Kernel yield of groundnut was positively associated with pod, and haulm yields, LAI at 10 and 13 WAP and number of mature pods per plant.

The highest combined LER of 1.35 was obtained from the application of 160 kg N/ha + 26.4 kg P/ha. However none of the fertilizer combinations in the mixture gave higher LER than each of the sole crops. Application of 40 kg N/ha without phosphorus gave the

highest returns per Naira invested on fertilizer, followed by 80 kg N/ha + 0 kg P/ha. Furthermore application of 80 kg N/ha + 0 kg P/ha was the lowest fertilizer combination that effected significant increased in combined LER. Therefore considering the LER, economic returns and the medium level of native soil P in the present study application of 80 kg N/ha without phosphorus appears to be sufficient for the productivity of maize/groundnut mixture.

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Appendix 1: Rainfall distribution in Samaru for the year 1991 (mm)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Days												
1-10				11.0	42.0	22.1	71.0	56.9	20.0	28.7		
11-20			44.7	8.7	63.1	7.5	22.7	103.2	25.1			
21-31				28.1	137.9	57.4	95.9	168.9	6.1			
Total			44.7	47.8	243.0	87.0	189.6	329.0	51.2	28.7		

Source: Meteorological Unit, Institute for Agricultural Research, Samaru
Zaria, Nigeria.

Appendix 2: Physico-chemical properties of the
0-20 cm depth of the soil at the
experimental site.

<u>Physical property</u>	<u>Value</u>
Sand (%)	51
Silt (%)	40
Clay (%)	9
Textural Class	Sandy loam
<u>Chemical property</u>	
pH (H ₂ O)	5.7
pH (0.01M CaCl ₂)	5.1
Organic carbon (%)	0.4
Total nitrogen (%)	0.04
Available phosphorus (ppm)(Bray - 1)	10.77
Calcium meq/100g of soil	0.01
Potassium Meq/100g of soil	0.09
Magnesium Meq/100g of soil	0.39
Sodium Meq/100g of soil	0.10
CEC Meq/100g of soil	5.2

BIOGRAPHY

NAME : Yohanna Mamma Kwaga
DATE OF BIRTH : 5 MARCH, 1957
BUSINESS ADDRESS : Adamawa Agricultural
 Development Programme
 P.O. Box 956, Yola,
 Adamawa State.
HOME ADDRESS : EYN Church Likuni,
 Michika L.G.A.
 Adamawa State.

PREVIOUS QUALIFICATION

<u>Institutions Attended</u>	<u>From</u>	<u>To</u>	<u>Cert/Diploma/Degree</u>
Vilegwa Primary School, Michika.	1966	1971	First School Leaving Certificate
King's College, Lagos	1972	1976	W.A.S.C.
School of Basic Studies, Ahmadu Bello University, Zaria.	1976	1977	I.J.M.B.
Ahmadu Bello University, Zaria.	1977	1981	B.Sc. (Agriculture)

POST(s) HELD SINCE THE AWARD OF FIRST DEGREE

<u>Organization</u>	<u>From</u>	<u>To</u>	<u>Position</u>
Ewarat Community College, Dadur, Langtang.	1981	1982	Teacher (NYSC)
Ministry of Agriculture Adamawa State.	1982	1994	Research Officer

YEAR OF ADMISSION FOR POST-GRADUATE STUDIES: 1991

Admission Number: M.Sc./AGRIC/3232/1990-91