THE EFFECT OF NITROGEN AND PLANT POPULATION ON MAIZE (Zen mnyo L.) PERFORMANCE IN THE NORTHERN GUINEA SAVANNA OF NIGERIA

BY

GODFREY MONIBORITSE AMORUWA

A thesis submitted to the Postgraduate School,
Ahmadu Bello University
in partial fulfillment of the requirements for
the Degree of Master of Science in Agronomy

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY
ZARIA, NIGERIA

JUNE, 1985

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.

GODFREY M. AMORUWA
(Candidate)

Date: 8/JULY/1985

The above declaration is confirmed.

O. O. OLOGUNDE
(Major Supervisor)

Date: 15/JULY/1985

CERTIFICATION

This thesis entitled 'THE EFFECT OF NITROGEN AND PLANT POPULATION ON MAIZE (*Zea mays* L.) PERFORMANCE IN THE NORTHERN GUINEA SAVANNA OF NIGERIA' by Godfrey Moniboritse AMORUWA 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. O. O. OLOGUNDE
Chairman, Supervisory Committee

DR. V. B. OGUNLELA
Member, Supervisory Committee

DR. L. SINGH
Member, Supervisory Committee

PROF. J. Y. YAYOCK
Head, Department of Agronomy

PROF. G. E. OSUIDE
Dean, Postgraduate School

Date: ....4/xi/85....

AHMADU BELLO UNIVERSITY
ZARIA

DEDICATION

To

Alhaji Mohammed Shaaba Lafiagi, the General Manager of Nigerian Sugar Company, Bacita, without whom this work could not have materialised.

ACKNOWLEDGEMENTS

I wish to express my sincere appreciation and gratitude to my Major Supervisor, Dr. G. O. Olagunde and other supervisory Committee members - Dr. L. Singh and Dr. V. B. Ogunlela, for guidance during the course of this study. This work benefited immensely from their advice, motivation and constructive criticisms during the field work and preparation of this Thesis.

Sincere appreciation is extended to the Head, Professor J. Y. Yayock and staff of the Agronomy Department, for their encouragement, assistance and constructive criticisms.

Also gratefully acknowledged are Mr. Nana and the technical staff of the soil and plant analytical laboratory of the National Cereal Research Institute, Moor Plantation, Ibadan, who helped in the analysis of the soil and leaf samples.

The author extends sincere appreciation to his wife - Tosan, for her love, understanding, help and patience in the course of this study, and to Mr. C. O. Egeolu, for the excellent job done in typing this Thesis.

ABSTRACT

The response of maize cv. 096 to five nitrogen rates (0, 50, 100, 150 and 200 kg N/ha) and three plant population levels (25,000, 50,000 and 75,000 plants/ha) was investigated during the 1983 wet season at Samaru. The investigation revealed that grain yield increased significantly with increase in nitrogen application up to the 150 kg N/ha rate and a non-significant increase resulted from further increase in the rate of nitrogen to 200 kg/ha. Length of ear, ear diameter, number of kernels per ear, kernel depth, weight per 1,000 kernels and number of ears per plant increased by 98.6, 37.0, 149.2, 52.5, 64.5 and 145.4 per cent, respectively, with increase in N from 0 to 200 kg/ha. Increasing N rates from 0 to 200 kg/ha delayed days to 50 per cent tasselling and silking by 12.3 and 15.6 days, respectively.

A slight but non-significant decrease in grain yield was observed with increase in plant population from 25,000 to 50,000 plants/ha. A significant decrease in grain yield resulted from further increase in plant population from 50,000 to 75,000 plants/ha. This result indicated that under low rainfall condition as recorded for this trial, it would be adequate to use a planting density that is on the low side in order to maintain reliable production. Number of kernels per ear, length of ear, ear diameter, kernel depth and number of ears per plant decreased significantly with each 25,000 plants/ha increase in

plant population from 25,000 to 75,000 plants/ha. Days to 50 per cent tasselling and silking was 2.0 and 3.6 days earlier when the plant population was raised from 25,000 to 75,000 plants/ha, respectively.

Increase in N application significantly increased the concentration of N, K, Mg and Mn in the ear leaf. Plant population had no significant effect on the ear leaf content of N, P, K, Ca, Mg, Mn, Zn, Cu and Fe.

Maximum grain yield was associated with 2.16 per cent N in the ear leaf. The relationship of grain yield to per cent N in the ear leaf was significant (r = 0.518).

TABLE OF CONTENTS

Chapter		Page
	Declaration	ii
	Certification	iii
	Dedication	iv
	Acknowledgements	v
	Abstract	vi
	Table of Contents	viii
	List of Tables	xii
	List of Figures	xiv
	Abbreviation	xv
	List of Appendices	xvi
1	INTRODUCTION	1
2	LITERATURE REVIEW	4
2.1	Nitrogen	4
2.1.1	Nitrogen rate, growth and yield	4
2.1.2	Nitrogen and yield components	8
2.2	Plant Population	9
2.3	Nutrient Element Concentration in the Ear Leaf	14
2.4	Relationship between Nutrient Concentration and Yield	17
3	MATERIALS AND METHODS	20
3.1	Experimental Site	20
3.2	Soil Samples	20

Chapter		Page
3.3	Treatments	20
3.3.1	Nitrogen	20
3.3.2	Plant population	22
3.4	Plot Size	22
3.5	Planting	22
3.6	Weed Control	23
3.7	Observations	23
3.7.1	Leaf samples	23
3.8	Experimental Design and Statistical Analysis	24
4	RESULTS	25
4.1	Grain Yield and Yield Components	25
4.1.1	Grain yield	25
4.1.2	Number of kernels per ear	25
4.1.3	Length of ear	26
4.1.4	Ear diameter	29
4.1.5	Weight per 1,000 kernels	29
4.1.6	Kernel depth	30
4.1.7	Number of ears per plant	30
4.2	Morphorlogical Characters	31
4.2.1	Plant height at tassel	31
4.2.2	Ear height	34
4.2.3	Number of leaves per plant	34
4.2.4	Days to 50 per cent tasselling	35
4.2.5	Days to 50 per cent silking	36

Chapter		Page
4.2.6	Ear leaf area, total leaf area per plant and leaf area index	36
4.2.7	Dry matter yield at tassel	40
4.2.8	Dry matter yield at harvest	43
4.2.9	Stover weight	43
4.3	Grain to Stover Ratio	45
4.4	Shelling Percentage	46
4.4.1	Number of barren stalks per plot	49
4.5	Nutrient Element Concentrations in the Ear Leaf	50
4.5.1	Nitrogen	53
4.5.2	Phosphorus	53
4.5.3	Potassium	53
4.5.4	Calcium	54
4.5.5	Magnesium	54
4.5.6	Manganese	55
4.5.7	Zinc, copper and iron	55
4.6	Simple Correlation Studies	56
4.7	Relationship between Ear Leaf Nutrient Content and Grain Yield	59
4.8	Relation of Grain Yield to Nitrogen Concentration in the Ear Leaf	61
5	DISCUSSIONS	64
5.1	Nitrogen	64
5.2	Plant Population	60

Chapter		Page
5.3	Nitrogen and Population Interaction	72
5.4	Nutrient Element Concentrations in the Ear Leaf	773
5.4.1	Nitrogen	73
5.4.2	Phosphorus	74
5.4.3	Potassium	74
5.4.4	Other nutrient elements	75
5.5	Relationship between Ear Leaf Nitrogen Concentration and Grain Yield	76
5.5.1	Critical N per cent of the ear leaf	77
5.6	Correlation Studies	70
6	SUMMARY AND CONCLUSIONS	00
	LITERATURE CITED	84
	APPENDIX	93
	BIOGRAPHY	94

LIST OF TABLES

Table		Page
3.1	The Physico-chemical properties of the soil collected up to a depth of 20cm from the experimental site at Samaru, 1983	21
4.1	The effect of nitrogen and plant population on grain yield and yield components of maize at Samaru, 1983	27
4.2	The effect of nitrogen and plant population on some morphological characters of maize at Samaru, 1983	33
4.3	The effect of nitrogen and plant population on the ear leaf area, leaf area per plant and leaf area index of maize at Samaru, 1983 ...	37
4.4	The effect of nitrogen and plant population on stover weight, grain to stover ratio, dry matter yield at tassel and at harvest of maize at Samaru, 1983	42
4.5	The effect of nitrogen and plant population on shelling percentage and number of barren stalks per plot of maize at Samaru, 1983	48
4.6	The effect of interaction between nitrogen and plant population on the shelling percentage of maize at Samaru, 1983	50

Table		Page
4.7	The effect of nitrogen and plant population on nutrient element concentrations in the ear leaf of maize at tassel at Samaru, 1983	52
4.8	The effect of interactions between nitrogen and plant population on Zn (ppm) concentrations in the ear leaf of maize at Samaru, 1983 ...	57
4.9	The effect of interactions between nitrogen and plant population on Fe (ppm) concentrations in the ear leaf of maize at Samaru, 1983 ...	57
4.10	Simple correlation coefficients for the relationships between selected variables and grain yield of maize grown at different plant population and nitrogen rates	58
4.11	Simple correlation coefficients for the relationships between grain yield and ear leaf nutrient content of maize at tassel ...	60

LIST OF FIGURES

Figure		Page
4.1	Interaction between nitrogen and population on the ear length of maize at Samaru, 1983	20
4.2	Interaction between nitrogen and population on the number of ears per plant of maize at Samaru, 1983	32
4.3	Interaction between nitrogen and population on the ear leaf area (cm^2) of maize at Samaru, 1983	39
4.4	Interaction between nitrogen and population on the leaf area index of maize at Samaru, 1983	41
4.5	Interaction between nitrogen and population on the dry matter yield of maize at tassel at Samaru, 1983	44
4.6	Interaction between nitrogen and population on grain to stover ratio of maize at Samaru, 1983	47
4.7	Interaction between nitrogen and population on the number of barren stalks per plot of maize at Samaru, 1983	51
4.8	Relationship between grain yield and nitrogen concentration in the ear leaf of maize at Samaru, 1983	62
4.9	Relationship between increase in ear leaf nitrogen content and increase in grain yield over control of maize at Samaru, 1983	63

ABBREVIATIONS

a.i	.....	active ingredient
cv	.....	cultivar
C.V.	.....	Coefficient of variability
g	.....	grams
ha	.....	hectare
kg	.....	kilogram
IAR	.....	Institute for Agricultural Research
LSD	.....	Least significant difference
NS	.....	Not significant
Tr	.....	Trace
N	.....	Nitrogen
P	.....	Phosphorus
K	.....	Potassium
Ca	.....	Calcium
Mg	.....	Magnesium
Mn	.....	Manganese
Fe	.....	Iron
Zn	.....	Zinc
Cu	.....	Copper

LIST OF APPENDICES

Appendix		Page
A	Daily rainfall (mm) during the crop season at Samaru, 1983	93

Chapter 1

INTRODUCTION

The maize grain industry in Nigeria has expanded rapidly since the mid-1970s. The estimated annual production is about 1.55 million metric tonnes from about 1.66 million hectares of small peasant holdings (F.A.O., 1980). Virtually all the grains produced are used for human consumption with a very small proportion being used for livestock feed.

In Nigeria, the traditional areas for maize production had hitherto been in the rain forest ecological zone, where two crops of maize can be grown in a year. However, it has been reported that the savanna zones of northern Nigeria have the greatest potential for maize production because of the higher solar radiation (Kassam et al., 1975). This potential can, however, be realised with increased levels of fertilizer application (Norman et al., 1976), since most savanna soils are known to be deficient in native soil nitrogen (Jones, 1973) and phosphorus (Bache and Rogers, 1970; Mokwunye, 1974). With the rapid expansion of the poultry and livestock industries and the higher grain demand created by increased human population and availability of fertilizers, maize production is now expanding rapidly to the savanna ecological zone.

But due to the traditional farming practice of bush burning which destroys part of native nitrogen in the savanna soils, and the relatively high requirements of nutrients by

maize, judicious application of nitrogen fertilizer has become necessary in order to attain and maintain high yields.

With better fertilization, soil management and adequate supply of soil moisture, high plant density would be required to provide the number of stands required for maximum grain yield. When plant population falls below the optimum level, all other inputs of production would fail to produce the desired effect on yield. However, an increase in plant population above the optimum for a crop brings about a decrease in grain yield of the individual plants. This reduction in yield is due among other factors to mutual interference and increased environmental stress resulting from greater competition among plants.

Hitherto, little has been reported on the effect of nitrogen rates and plant population on maize in the northern Guinea savanna zone of Nigeria. Most of the recent studies on the effect of nitrogen rates and plant population on maize in Nigeria have been conducted in the rain forest and southern Guinea savanna zones of the country (Agboola and Kayode, 1971; Ologunde and Ogunlela, 1983; Ologunde and Ogunlela, 1984), where the soil fertility and rain distribution are more favourable than in the northern Guinea savanna.

The present study was, therefore, undertaken with the following objectives:

1. To investigate the direct effect of nitrogen rate

application, leads to an increase in grain yield, but at a diminishing rate. In India, Singh et al. (1978) demonstrated that increasing the rate of nitrogen from 0 to 60 kg N/ha significantly increased grain yield; but yield differences between 60 and 90 kg N/ha, were not significant. Such significant increase in grain yield was attributed to significant increase in almost all yield contributing characters, especially number of cobs/ha, grain weight/cob, grains/cob, cob length and grains/row. Similar observations have earlier been made by Shukla and Bhardwaj, (1976) and Verma and Singh (1976). However, if the native soil fertility is very high, a non-significant response to applied nitrogen would be observed (Douglas et al., 1972; Reyes et al., 1972; Steele et al., 1982).

Nigeria, many researchers have reported positive yield responses of maize to application of nitrogen fertilizer. Goldsworthy, (1967) reported response of maize to nitrogen fertilization and recommended a rate of 65 kg N/ha for maximum yield throughout the savanna area. However, more recent work at Samaru has shown that improved varieties of maize will respond to nitrogen levels at least twice as high when grown under good levels of management (Jones, 1973). In field trials at Samaru, Balasubramanian et al. (1978) observed that increasing application of nitrogen at various rates up to 120 kg N/ha resulted in increase in grain yield. They noted that further increase in the rate of nitrogen to 180 kg/ha

resulted in yield depression. Ologunde and Ogunlela (1904) reported that the optimum nitrogen rate for maize at Mokwa and Omu-Aran lies between 100 and 150 kg N/ha with yield depression being observed beyond 150 kg N/ha. They suggested a revision of the nitrogen recommendation for maize in the southern Guinea savanna from the present 65 kg N/ha to 120 kg N/ha in order to allow for greater nitrogen requirements of improved higher yielding varieties now grown.

The response of maize to nitrogen fertilizer is known to be related to the level of soil organic matter, the total N content of the soil, the texture of the soil and the variety of maize used. Generally, maize planted in sandy loam soil performed better than those planted in loamy sand at all levels of nitrogen applied (Singh et al., 1979). This was due to the ability of the sandy loam to retain more moisture per unit volume and the better physical environment compared to the loamy sand. Brown (1966) in Malawi found no economic response of maize to nitrogen on sandy clay loam soils with nitrogen content being greater than 0.20 per cent, and on sandy loam and sandy soils with nitrogen content greater than 0.15 per cent. Jenny (1930) had earlier reported positive correlation between maize yield and total soil N.

Variable dry matter yield responses to increments in nitrogen fertilization rates have been reported in the literature. Increase in dry matter yield in response to increased nitrogen fertilization was reported by Bishop et al.

(1972), Jones (1973), Mikhail and Shalaby (1979) and Hamissa et al. (1979), but some researchers have reported little or no response (Dickson, 1968; Douglas et al., 1972) or have found depressions in dry matter yield with rates greater than 700 kg N/ha (Powell and Webb, 1972).

Gagro (1978) in Yugoslavia observed an increase of 21.7cm in plant height when nitrogen rate applied to maize cultivar Pan 280 was increased from 0 to 200 kg N/ha. Similarly, Mohammed et al. (1978) in Somalia found significant increase in plant height with increased levels of nitrogen application. On the other hand, Reyes et al. (1972) in Mexico, observed that plant height was not significantly affected by increasing levels of applied nitrogen from 0 to 200 kg/ha. They attributed this to the high native soil fertility of the experimental site.

Gagro (1978) also reported an increase in ear height with increase in levels of nitrogen application. He recorded an increase of 13.6cm when the levels of nitrogen were increased from 0 to 200 kg N/ha. A similar observation had earlier been reported by Bolton (1971).

Nitrogen has been known to affect the number of days to 50 per cent tasselling and silking. Rathore et al. (1976) observed that nitrogen application increased the number of days to tasselling. While Ologunde (1974) observed a decrease in the number of days to 50 per cent tasselling with increasing

nitrogen levels, Salem and Aly (1979) reported increased in the number of days to maize silking with nitrogen application. Conversely, however, Sharma (1973) observed that increasing the rate of applied nitrogen decreased the number of days to 50 per cent silking. The variable response in number of days to 50 per cent tasselling and silking to increments in nitrogen fertilization should be attributed to location effect, the variety used, and the prevailing climatic conditions.

2.1.2 Nitrogen and yield components

Many researchers have studied the effects of nitrogen rates on the yield components of maize. Singh et al. (1970) observed significant increase in kernel weight, number of kernels per ear and ear length with increase in the levels of nitrogen application from 0 to 60 kg/ha, with these attributes producing 37.3, 52.2 and 33.3 per cent increases, respectively. Increasing the nitrogen rate to 90 kg/ha failed to produce any further significant increase. Krantz and Chandler (1951) found increases of 17 and 41 per cent in the average ear size and number, respectively, when the level of nitrogen was increased from 20 to 190 kg/ha. Ologunde (1974) found that ear weight, number of kernels per ear, weight per 1,000 kernels, length of ear, kernel depth, ear diameter and number of ears per plant increased by 35.5, 26.8, 5.6, 19.6, 6.0, 7.0 and 13.0 per cent, respectively, when the nitrogen level was raised from 0 to 336 kg/ha.

Horrocks and Zuber (1970) observed increase in shelling percentage with increase in applied nitrogen, especially at high levels of nitrogen application of 135 to 269 kg/ha. Conflicting result was obtained by Ologunde and Ogunlela (1984), who found that shelling percentage was increased by low rate of nitrogen and decreased by high nitrogen rate. However, Agboola and Kayode (1981) observed that nitrogen had no effect on shelling percentage in maize. The differential response in shelling percentage to applied N observed by different workers might be due to the methods of determination, the year, location, date of planting, the cultivars and cultural practices (Horrocks and Zuber, 1970).

2.2 Plant Population

The number of maize plants per hectare resulting from varying either the planting rate within the row or the distance between rows has a marked influence on nutrition, growth and yield. The effects of plant density on maize yield and other agronomic characters have been intensively studied. Shubeck and Caldwell (1955) reviewed literature on maize population and planting studies conducted prior to 1950 in Minnesota and concluded that increasing number of maize plants per unit area resulted in increase in yield up to a point, which depended upon soil type, amount of sunlight, native soil fertility, the fertilizer used, and the moisture supply. Drowney (1971) reviewing plant density/yield relations in maize concluded that the optimal plant density for maize hybrid lies

approximately within the range of 40,000 to 60,000 plants/ha. At a plant density higher than this, mutual shading induces barrenness, which in turn limits grain yield.

Reports on the response of maize to varying plant density have been inconsistent. Singh and Nair (1975), in India, observed that increase in plant population from 25,000 to 50,000 plants/ha resulted in 44 per cent increase in grain yield; a further increase of 8 per cent was observed when this was increased to 75,000 plants/ha. In England, Bunting (1973) observed increase in grain yield with increase in plant population. At plant population levels of 40,000, 80,000 and 120,000 plants/ha, he recorded yields of 4,020, 4,720 and 5,270 kg/ha, respectively.

In Nigeria, Chinwuba (1967), from an experiment involving five populations which ranged between 24,000 and 72,000 plants/ha found that grain yield increased with increase in plant population from 24,000 to 43,000 plants/ha, but decreased at 72,000 plants/ha. Baker (1975) obtained an increase of 11 per cent in grain yield at Samaru when the maize population waw increased from 35,000 to 61,000 plants/ha. Based on the results of field trials conducted at Mokwa, de Wolf (1966) concluded that a plant population of 36,000 plants/ha would be adequate for maximum grain yield. Similarly, Agboola and Keyode (1981) in field trials at Mokwa and Samaru with plant population levels ranging from 37,000 to 62,000 plants/ha

observed that there was no significant difference in the yield obtained from the various plant populations adopted. They noted that the yields from the lowest population (37,000 plants/ha) compared favourably with that from the highest population (62,000 plants/ha). On the other hand, Ologunde and Ogunlela (1984) obtained significantly higher grain yield from a higher plant population at Mokwa and Umu-Aran. Averaged over years and nitrogen rates, increases in grain yields obtained were 40 and 53 per cent when plant population was increased from 24,000 to 48,000 plants/ha at Mokwa and Umu-Aran, respectively. They noted that a further increase in plant population to 72,000 plants/ha resulted in 10 per cent and 18 per cent yield reductions at the respective locations. They suggested that a plant population of about 50,000 plants/ha may be regarded as being adequate for maximum maize yield in the southern Guinea savanna ecological zone of the country. This suggested plant density is higher than the current officially recommended plant population of 36,000 plants/ha for maize in the Nigerian savanna ecological zone (Anon., 1973).

The generally low yields of maize at low plant densities have been associated with low light interception resulting from poor ground cover (Haggar and Cooper, 1972) while the decline in yield occurring at levels above the optimum plant population has been attributed to inter-plant competition for moisture, nutrient, light and carbon dioxide.

A very important factor affecting the response of maize to varying plant population is the moisture condition of the soil. de Geus (1973), reported that for the maize growing areas of South Africa where the rainfall varies from 375 to 875mm, a low plant population of 11,750 plants/ha is adequate in the lower rainfall areas, in order to give each plant access to more moisture. With fewer plants per hectare each plant would have at its disposal a larger soil volume to satisfy not only its water requirements but also its nitrogen and other requirements. Based on the results of an experiment with three plant populations and three nitrogen levels, conducted over a period of nine years, under conditions of insufficient soil moisture, 11,750 plants/ha yielded significantly more than did 23,500 plants/ha which in turn outyielded 32,250 plants/ha.

Plant population has been known to affect plant height and ear height in maize. Osorio (1976) reported increase in ear height with increasing plant population. Norden (1965) found that increasing plant population from 12,000 to 62,000 plants/ha increased plant height by 17 per cent; while Abdullahi (1975) observed that plant height was not significantly affected by plant population. However, within the plant population (17,570 - 70,282) adopted, plant height tends to increase with increase in plant population.

Many workers have studied the effect of plant densities

on the yield components of maize. Bunting (1973) observed that the number of ears per plant producing ripe grain decreased with increasing plant density. He observed an average of more than one fertile ear per plant at densities below 70,000 plants/ha. At a higher plant density of 200,000 plants/ha, however, he observed an average of 0.8 fertile ear/plant. Similar observations were made by Filev and Pan'kin (1976) and Rathore et al. (1976).

Wilson and Allison (1978) observed that the size of grain, the number of grains/ear and the length of ear decreased with increasing plant population. Similarly, Ologunde (1974) observed that weight/ear, number of kernels/ ear, weight/1,000 kernels and length of ear decreased by 36.8, 23.4, 12.7 and 19.8 per cent, respectively, when the rate of planting was increased from 40,000 to 80,000 plants/ha.

Chinwuba (1967) in Nigeria found that percentage loss in stand at harvest and percentage barren plants increased linearly as plant population increased from 24,000 to 72,000 plants/ha.

Kohnke and Mike (1951) observed that silking date was delayed by one day for each increment of 8,750 to 10,000 plants/ha. These data are close to that obtained by Shubeck and Caldwell (1955), showing a 5-day delay in silking associated with increase in plant population from 8,900 to 45,500 plants/ ha. Contrary to this, Zuber and Grogan (1956) could not associate any variation in silking date with increase in

planting rate.

Horrocks and Zuber (1970) in Missouri reported increase in shelling percentage with increase in plant population over the range of 30,000 to 60,000 plants/ha. Singh et al. (1978) in India found that increasing plant population had negative effect on shelling percentage. However, Ologunde and Ogunlela (1984) in Nigeria noted that plant densities appeared to have no effect on shelling percentage. The variation in response by shelling percentage to increase in plant population could be attributed to the method of determination, location effect and the cultivar planted.

2.3 Nutrient Element Concentrations in the Ear Leaf

Generally, an increase of nitrogen in the growth medium normally leads to an increase in the concentration of nitrogen in the maize plant (Krantz and Chandler, 1951; Thompson, 1962; Ologunde, 1974; Kalia, 1975; Santos et al., 1975; Rabuffeti and Kramprath, 1977; Cornforth and Steele, 1981). Cornforth and Steele (1981) observed from a series of trials that nitrogen concentration in the ear leaves was increased significantly by increase in the levels of nitrogen application.

The addition of nitrogen fertilizers has been shown by many investigators to enhance considerably the utilization of fertilizer phosphorus by maize. These effects were most

marked on soils low in available nitrogen. Terman and Noggle (1973) and Terman et al. (1977) observed an increase in phosphorus concentration and uptake with applied nitrogen. Such increase in phosphorus uptake upon the addition of nitrogen was considered by Miller (1974) to result from one or more of the following mechanisms:-

a) An increase in root growth in the volume of soil fertilized.

b) An increased physiological capacity of the root to adsorb phosphorus, probably due to an involvement of nitrogen intermediates in the adsorption process.

c) Alteration of pH at the soil root interface due to excess of cation over anion adsorption and a consequent release of H^+.

However, Shukla (1972), in Guyana, observed a decrease in the concentration of phosphorus with increase in soil nitrogen. The influence of nitrogen fertilizers on the availability of phosphate differs with the form in which the nitrogen is applied as well as with soil physical and chemical conditions. Generally, NH_4^+-N increased phosphorus uptake more than NO_3^--N. This effect was noted to be more pronounced as soil temperature increased (Dormaar and Ketcheson, 1960).

Maize is one of the many crops which take up nitrogen and potassium in nearly equal amounts. Increased rates of

nitrogen were found to increase the levels of potassium in maize leaves when adequate amounts of the other two major nutrients were supplied (Murdock et al., 1962; Hume et al., 1979). Conflicting reports were given by Tyner and Webb (1946), who observed that increasing the levels of nitrogen in the soil decreased the percentage content of potassium in the leaves. Such decrease in potassium content with increase in applied nitrogen has been attributed to dilution effect (Ologunde, 1974).

Increasing nitrogen in the growth medium has also been reported to affect the levels of Ca, Mg, Mn, S, Zn, Al and Cu in the ear leaf of the maize plant. Steele et al. (1901) observed that added N significantly increased the levels of S, Mn and Zn in the ear leaf of maize; while the levels of Mg tended to be higher in the absence of added N (Hume et al., 1979). In field experiments on a dark brown clay (pH 5.0) in southern Rhodesia, increasing N supply in the soil depressed Al levels but increased Cu, Zn and Mn contents (Thompson 1962). Hume et al. (1979) observed increases in S levels in the leaf with added N. Such increaseswere thought to result from a mechanism similar to those involved in increase in P uptake by addition of N (Miller, 1974). Increases in Ca and Mg concentrations in the ear leaf of maize with increase in applied N have also been reported by Terman and Noggle (1973) and Cornforth and Steele (1901). Such increases may be due to the usual effect of NO_3^- ions in increasing the total inorganic cations in plants (Cunningham 1964).

It has been reported that increasing plant population can influence the per cent nitrogen content of the ear leaf. Gagro (1978) observed that the average content of nitrogen in the leaf decreased with increase in plant population. Abdullahi (1975) has earlier reported a significant decrease in the nitrogen content of leaves at silking when plant population was increased from 19,570 to 57,710 plants/ha. However, a further increase in plant population to 78,282 plants/ha resulted in a non-significant decrease in nitrogen content.

2.4 Relationship between Nutrient Element Concentrations and Grain Yield

Maize yields as a function of the concentration of plant nutrients in the ear leaf at tassel has been researched quite extensively. Tyner (1946) recommended the sampling of the ear leaf at full silk for leaf analysis. He gave four reasons for his selection:-

1. The stage is easily recognized and described.
2. All varieties mature in about the same number of days once silking and tasselling occur.
3. The weight of vegetative parts is at or near its peak at this stage and
4. This is a period when nutrient demands by the plant are very high.

Following Tyner's (1946) work, investigators have more or less standardized upon the selection of the ear leaf for assessing nutrient status of maize plants and for studying the relationship between nutrient concentration in the ear leaf and yield (Hanway, 1962). An additional advantage for the selection of the ear leaf for assessing the nutrient status of maize plant is that reliable relationships between leaf composition at this stage and yield response to fertilizers have been established (Hanway, 1962).

Dumenil (1961) found a statistically significant relationship between maize yield and nitrogen, phosphorus and potassium concentrations in the ear leaf. Hanway (1962) found that when other factors are fairly constant, yield increases from different levels of application of nitrogen fertilizers are usually directly proportional to the increase in the per cent nitrogen in the leaf resulting from the fertilizer application. Steele et al. (1982) in their studies established that there is a relationship between the relative grain yield of maize (the yield expressed as a percentage of the maximum) and the concentrations of nitrogen in leaves and grain. In this trial, maximum grain yield was estimated to occur with a nitrogen concentration of 3.21 per cent in ear leaves sampled at 50 per cent silking and 1.52 per cent in grain. In the United States, maximum grain yield was associated with about 1.5 per cent nitrogen in grain (Pierre et al., 1977).

Andhria et al. (1953) and Reichman et al. (1959) have

also reported high positive correlations between the level of the nutrient element in the leaf, the rate of nutrient application or its availability in the soil and the yield of the maize grain. Santos et al. (1975) observed that leaf nitrogen content and grain yield increased linearly with increased rates of nitrogen application, but could not establish a critical nitrogen level. Agboola (1972), in Nigeria, cautioned that high ear leaf nutrient content was not a guarantee of high grain yield since ear leaf nutrient value of low yielding varieties were similar to those of the high yielding varieties.

The high positive correlations found between leaf nitrogen and grain yield has led to calculation of regression equations in an attempt to establish some quantitative relationships. Tyner (1946), in West Virginia, found that for each change of 0.1 per cent nitrogen, phosphorus and potassium in the ear leaf at silking grain yields varied by 277.8, 158.6 and 128.5 kg/ha, respectively. Bennett et al. (1953) found that each change of 0.1 per cent nitrogen was related to a yield change of 200.0 kg of maize. Viets et al. (1954), however observed that each change of 0.1 per cent nitrogen corresponded to 353 to 430 kg of maize. These investigators however cautioned that the existence of many uncontrollable and variable factors which influence final yields could make the widespread use of such quantitative interpretation questionable.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Site

A field trial was conducted during the 1983 wet season at the Institute for Agricultural Research (IAR) farm, Samaru (11^{o} $11^{'}$N, 07^{o} 38^{o}E), Nigeria. Samaru is located within the northern Guinea savanna zone (Keay, 1959). The experimental field used had been left fallow in the preceeding three years. The soil type was a sandy loam. The rainfall data collected at Samaru for the 1983 wet season are shown in Appendix A.

3.2 Soil Sample

After disc ploughing and harrowing a composite soil sample was taken from 0-20cm depth prior to fertilizer application, and this was analysed for physico-chemical properties the results of which are presented in Table 3.1. The analysis was done at the National Cereal Research Institute, Moor Plantation, Ibadan.

3.3 Treatments

3.3.1 Nitrogen

Nitrogen (N) was applied as calcium ammonium nitrate (26% N) at the rate of 0, 50, 100, 150 and 200 kg N/ha. Each rate of nitrogen was applied in two split doses, half at planting and the other half was applied six weeks later. The

Table 3.1: The Physico-chemical properties of the soil collected up to a depth of 20cm from the experimental site at Samaru, 1983.

Soil Properties	
Physical properties	**Characteristics**
Sand (%)	71.1
Silt (%)	18.5
Clay (%)	10.4
Textural Class	Sandy Loam
Chemical properties	
pH in Water	5.9
pH in 0.01M KCl	5.2
Organic C (%)	0.33
Total N (%)	0.026
Available P (ppm)	16.2
Exchangeable Cations (meq/100g)	
K	0.26
Mg	0.61
Ca	2.02
Na	0.03
C.E.C. (meq/100g)	3.3

first dose of N fertilizer was banded on top of the ridge by making a groove about 8cm deep and 2cm wide. The second dose was applied six weeks after planting by side dressing in a hole about 10cm deep, 8-15cm on both sides of the maize plant and covered with soil.

Basal application of phosphorus (P) and potassium (K) was done at the rates of 60 kg P_2O_5/ha and 60 kg K_2O/ha, respectively. Phosphorus was applied as single superphosphate (18% P_2O_5), while potassium was applied as muriate of potash (60% K_2O).

3.3.2 Plant population

Three plant population levels were compared, namely, 25,000, 50,000 and 75,000 plants per hectare. Rows were spaced 75cm apart and interplant spacing was varied to maintain the desired plant population levels. The interplant spacings adopted were 50, 25 and 17cm for the 25,000, 50,000 and 75,000 plants/ha plant populations, respectively.

3.4 Plot Size

Each gross plot was 6.0 x 10m and the net plot from which grain and other yield variables were estimated, was 3.0 x 10m.

3.5 Planting

Planting was done on ridges on June 29. Three seeds of maize (cv.096) were sown per hill at a depth of 5cm and thinned

to one seedling per stand after two weeks.

3.6 Weed Control

Weeds were controlled by pre-emergence application of primagram at the rates of 2 kg a.i./ha. This was supplemented with hoe weeding as the need arose.

3.7 Observations

The observation taken at tasselling were plant height, ear height, number of green functional leaves per plant, days to 50 per cent tasselling and silking, leaf area and dry matter yield. At harvest, observations taken include stover weight, total dry matter yield (from five randomly selected plants from the discard rows), grain yield, and yield components. The various yield components were determined from a sample of 20 ears per plot. These include length of ear, kernel depth, ear diameter, weight per 1,000 kernels, number of kernels per ear and number of ears per plant.

3.7.1 Leaf samples

The ear leaves of five randomly selected plants were sampled from each plot at full silk as described by Tyner (1946). The samples were placed in a forced air oven at approximately 70^{o}C for 72 hours. Each oven dried sample was ground in a Wiley mill to pass through 2mm mesh screen. Analysis for N, P, K, Ca, Mg, Mn, Cu and fe was done at the National Cereals Research Institute, Moor Plantation, Ibadan.

Total N was determined by micro-Kjeldehl method (Bremner, 1965). Phosphorus was determined by vanodomolybdate [illegible] colorimetric method (Jackson, 1958). Potassium was determined by flame photometer and Ca, Mg, Mn, Zn, Cu and Fe were determined using an atomic absorption spectrophotometer as described by Jackson (1958). Results are reported on a dry weight basis.

3.8 Experimental Design and Statistical Analysis

The experiment was laid out in a randomized complete block design. The five levels of nitrogen and the three rates of plant population were combined to give fifteen treatments which were replicated four times.

The data were analysed as a randomized complete block design. Analysis of variance was done for each of the observed paremeters. Main and interaction effects were determined for the observed parameters. Singnificance of mean differences was determined using the test of least significance difference (L.S.D.). Simple correlation analyses were made for some selected variables.

Chapter 4

RESULTS

4.1 Grain Yield and Yield Components

Table 4.1 shows the effects of nitrogen rates and population levels on grain yield and yield components.

4.1.1 Grain yield

The effect of nitrogen on the grain yield was significant. There was a significant increase in grain yield with each 50 kg N/ha increment in the rates of N from 0 to 150 kg/ha. A further increase in the rate of N to 200 kg/ha resulted in a non-significant 8 per cent increase in grain yield. Grain yields of 403, 2235, 3459, 3853 and 4151 kg/ha were obtained for 0, 50, 100, 150 and 200 kg N/ha levels, respectively.

Plant population had a significant effect on grain yield. Although, an increase in plant density from 25,000 to 50,000 plants/ha did not affect grain yield significantly, a further increase in density by 25,000 plants/ha, however, decreased grain yield by 11 per cent. The nitrogen and population interaction effect on grain yield was not significant.

4.1.2 Number of kernels per ear

The effect of nitrogen on the number of kernels per ear was significant at the 0.01 level of probability. Increasing

the nitrogen rate from 0 to 100 kg/ha significantly increased the number of kernels per ear; thereafter, each 50 kg N/ha increment had no effect on this variable.

The number of kernels per ear decreased significantly by each increment in plant population. The levels of decrease due to plant population were 10 and 22 per cent when plant population was increased from 25,000 to 50,000 and 75,000 plants/ha, respectively. Interaction effect of nitrogen and population on the number of kernels per ear was not significant.

4.1.3 Length of ear

Ear length increased with each 50 kg N/ha increment in applied N up to the 150 kg/ha rate (Table 4.1). Increasing the rate of N above 150 kg/ha had no further influence on the length of ear. The length of ear decreased significantly for each increment in population up to the 75,000 plants/ha density. These decreases were 10 and 21 per cent for 50,000 and 75,000 plants/ha, respectively.

Nitrogen and population interaction effect was significant at the 0.05 level of probability (Figure 4.1). With no applied N, increase in population density from 25,000 to 75,000 plants/ha resulted in a non-significant decrease in the length of ear. As the rate of N was increased, the length of ear for each increment in plant population level also decreased. The longest ear length was obtained when 25,000 plants/ha was

Table 4.1: The effect of nitrogen and plant population on grain yield and yield components of maize at Samaru, 1983.

N - Applied (kg N/ha)	Grain yield kg/ha	No. of kernels per ear	Ear length (cm)	Ear diameter (mm)	Weight/1,000 kernels (g)	Kernel depth (mm)	No. of ears per plant
0	403	172.4	7.1	28.8	125.9	10.1	0.6
50	2235	299.8	10.8	31.2	174.7	13.4	1.2
100	3459	404.3	13.1	38.8	202.4	14.9	1.2
150	3053	413.1	13.9	38.6	201.8	14.9	1.3
200	4151	429.6	14.1	39.7	207.1	15.4	1.4
LSD (0.05)	300.1	29.1	0.7	1.2	16.0	0.8	0.1
Population (Plants/ha)							
25,000	3063	304.8	13.2	38.2	196.2	14.7	1.6
50,000	2050	345.6	11.0	36.1	103.6	13.7	0.9
75,000	2540	301.2	10.4	34.4	167.3	12.8	0.7
LSD (0.05)	230.7	22.5	10.5	1.0	12.9	0.6	0.00
Mean	2020	343.8	11.0	36.2	102.4	13.7	1.9
C.V. %	13.3	10.3	6.9	4.2	10.7	7.5	11.8
Interaction (N x P)	NS	NS	*	NS	NS	NS	**

NS = Not Significant
* = Significant (P = 0.05)
** = Significant (P = 0.01)

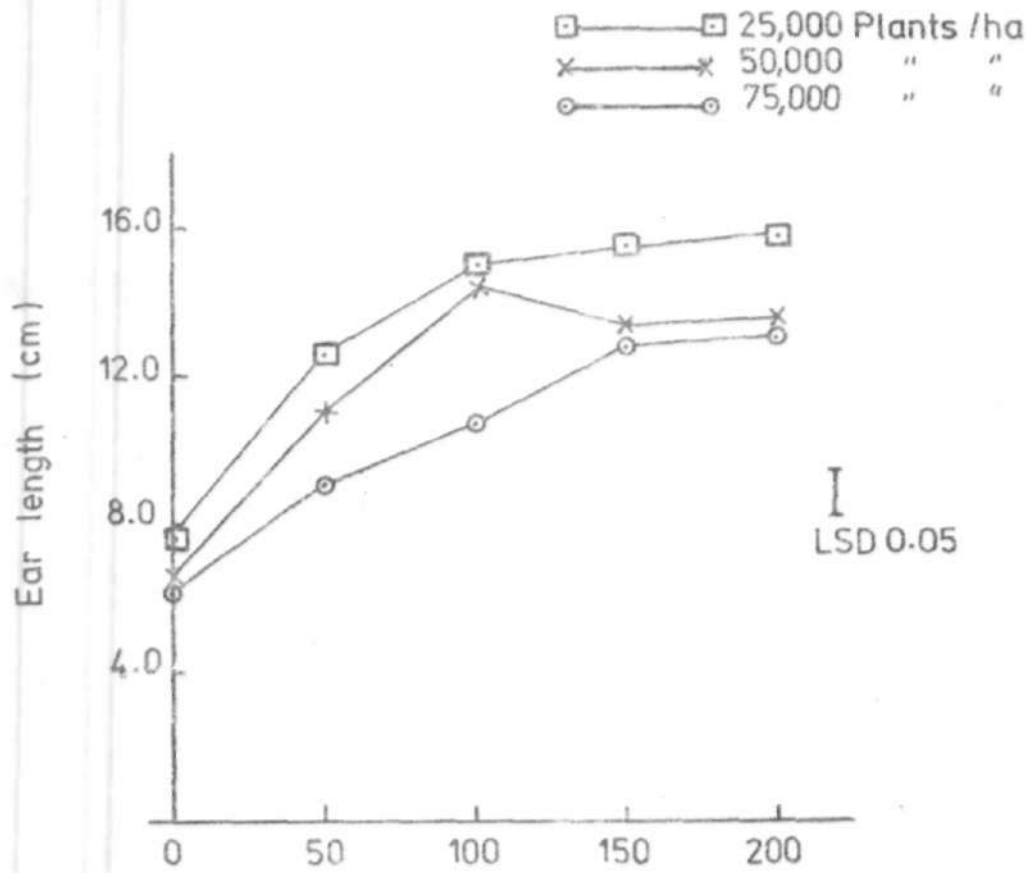


Fig. 4.1: Interaction between nitrogen and population on the ear lenth of maize in the northern Guinea Savanna, 1983.

supplied with 200 kg N/ha.

4.1.4 Ear diameter

Ear diameter was influenced by applied N (Table 4.1). There was a 37.8 per cent increase in ear diameter when the rate of nitrogen was raised from 0 to 200 kg/ha. The first two increments of 50 kg N/ha, however, influenced ear diameter more than did the subsequent increments in applied N.

Significant decrease in ear diameter was observed with each increment of 25,000 plant density. About 5 and 10 per cent decreases in ear diameter were observed when the plant density was increased from 25,000 to 50,000 and to 75,000 plants/ha, respectively.

The interaction between nitrogen and population on the ear diameter was not significant.

4.1.5 Weight per 1,000 kernel

Applied nitrogen rates significantly affected the weight per 1,000 kernels (Table 4.1). Increasing the nitrogen rate from 0 to 100 kg/ha increased the weight per 1,000 kernels. Rates above 100 kg N/ha had no effect on weight per 1,000 kernels. The weight per 1,000 kernels were 125.9, 174.7, 202.4, 201.8 and 207.1, for 0, 50, 100, 150 and 200 kg/ha N rates, respectively.

Increasing the population level from 25,000 to 75,000

plants/ha resulted in a 15 per cent decrease in weight per 1,000 kernels. The first 25,000 plants/ha increment in population level resulted in a slight decrease in weight per 1,000 kernels, while a further increase in the population to 75,000 plants/ha resulted in a significant decrease in this variable. The interaction effect of nitrogen and population was not significant.

4.1.6 Kernel depth

A significant increase in kernel depth was observed with each 50 kg N/ha increase in nitrogen level from 0 to 150 kg/ha. However, a slight but non-significant increase in kernel depth was observed when the applied nitrogen was further increased to 200 kg/ha. A 52.5 per cent increase in kernel depth occurred when nitrogen rate was raised from 0 to 200 kg/ha. Kernel depth decreased significantly for each 25,000 plants/ha increase in population by 6 and 12 per cent, respectively. The nitrogen and population interaction effect was not significant.

4.1.6 Number of ears per plant

A significant increase in the number of ears per plant due to nitrogen application was observed when N rate was increased from 0 to 50 kg/ha, with a non-significant increase resulting when the applied N was increased to 100 kg/ha. A further increase in the rate of applied N to 150 kg/ha resulted in a significant increase in the number of ears per plant, with

a slight but non-significant increase resulting with increase in N rates to 200 kg/ha.

The number of ears per plant decreased significantly for each 25,000 plants/ha increase in plant population. The magnitudes of decrease due to plant population were 42 and 57 per cent for increase in population from 25,000 to 50,000 and to 75,000 plants/ha, respectively.

The interaction between nitrogen and population for the number of ears per plant was significant (Figure 4.2). At each rate of applied N, increasing the plant population level decreased the number of ears per plant. Application of 200 kg N/ha to a plant population of 25,000 plants/ha gave the highest number of ears per plant.

4.2 Morphorlogical Characters

Table 4.2 shows the effects of nitrogen and plant population on plant height at tassel, ear height, number of functional leaves per plant and days to 50 per cent tasselling and silking.

4.2.1 Plant height at tassel

Nitrogen application positively influenced plant height at tassel. Plant height increased with each increase in applied N up to the 150 kg/ha rate. A non-significant 5 per cent increase in plant height was observed when the nitrogen rate was further increased to 200 kg/ha.

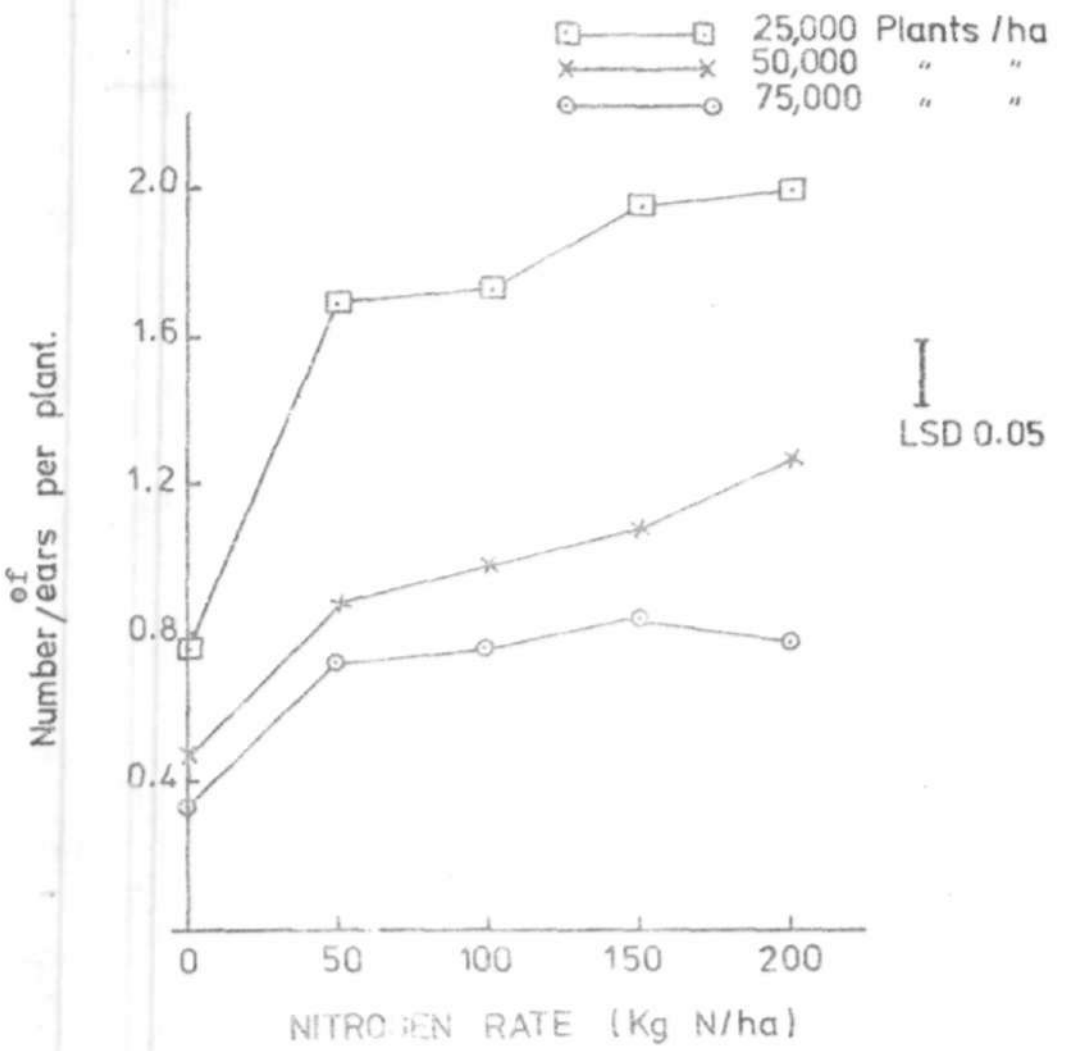


Fig. 4.2: Interaction between nitrogen and population on the number of ears per plant of maize in the northern Guinea Savanna, 1983.

Table 4.2: The effect of nitrogen and plant population on some morphorlogical characters of maize at Samaru, 1983.

N - Applied (Kg N/ha)	Plant height at tassel (cm)	Ear height (cm)	Number of leaves per plant	Days to 50 per cent tasselling	Days to 50 per cent silking
0	62.4	52.3	7.7	77.0	05.6
50	134.5	06.4	11.9	67.1	74.7
100	161.0	112.8	13.1	64.9	70.4
150	170.3	117.9	13.6	64.6	70.3
200	107.0	121.1	13.5	64.7	7[illegible].0
LSD (0.05)	10.6	7.9	0.6	1.2	1.5
Population (Plants/ha)					
25,000	139.6	93.3	12.4	66.5	72.3
50,000	143.1	97.3	11.0	67.7	74.3
75,000	152.4	103.7	11.7	68.6	75.9
LSD (0.05)	0.2	6.1	0.5	0.9	1.2
Mean	145.0	98.1	12.0	67.6	74.2
C.V. %	0.9	9.9	6.5	2.2	2.5
Interaction (N x P)	NS	NS	NS	NS	NS

NS = Not Significant

Increase in plant population had a significant positive effect on plant height. Each 25,000 plants/ha increment in population level from 25,000 to 75,000 plants/ha, progressively increased the plant height. However, the first 25,000 plants/ha increment resulted in only a 3 per cent increase in plant height, while a further increase in the population level to 75,000 plants/ha resulted in a 7 per cent increase in plant height. The interaction of nitrogen and plant population had no effect on plant height.

4.2.2 Ear height

Nitrogen application below 100 kg N/ha significantly affected ear height. A non-significant increase in ear height however resulted when nitrogen above 100 kg/ha was applied.

Increasing the plant population from 25,000 to 50,000 plants/ha have no effect on ear height. When plant population was further increased to 75,000 plants/ha, ear height was significantly increased by about 7 per cent. The interaction between nitrogen and plant population on ear height was not significant at the 5 per cent level of probability.

4.2.3 Number of leaves per plant

Applied nitrogen positively affected the number of functional leaves per plant. A significant increase in the number of functional leaves per plant due to nitrogen was observed with each increase in nitrogen rate from 0 to 100 kg/ha,

with a non-significant increase resulting when the applied nitrogen was increased to 200 kg/ha. The average number of leaves per plant were 7.7, 11.9, 13.1, 13.6 and 13.5 for nitrogen rates of 0, 50, 100, 150 and 200 kg/ha, respectively, (Table 4.2).

A significant effect of plant population on the number of functional leaves per plant was observed. The number of functional leaves per plant decreased significantly as the population rate was raised from 25,000 to 50,000 plants/ha and a non-significant decrease with a further increase in plant population to 75,000 plants/ha. The per cent decrease due to increase in plant population from 25,000 to 50,000 and 75,000 plants/ha were 5 and 6, respectively. The interaction between nitrogen and plant population was not significant.

4.2.4 Days to 50 per cent tasselling

Nitrogen application had a highly significant effect on the number of days to 50 per cent tasselling. Days to tasselling was 12.3 days earlier with 200 kg N/ha as compared to the no nitrogen treatment. Substantial decreases in days to tasselling were observed with each increase in applied N up to 100 kg N/ha. A further 50 kg N/ha increment in N, however, had no substantial effect on days to 50 per cent tasselling.

A positive effect of plant population was observed on the number of days to 50 per cent tasselling. Days to 50 per cent

tasselling was about 1 day later when plant population was increased from 25,000 to 50,000 plants/ha. However, a further increase in population to 75,000 plants/ha had no substantial effect on the number of days to 50 per cent tasselling. The interaction between nitrogen and plant population was not significant.

4.2.5 Days to 50 per cent silking

Days to 50 per cent silking was negatively affected by applied N. There was a significant decrease in the number of days to 50 per cent silking with each increase of 50 kg N/ha from 0 to 100 kg/ha. However, further increases in the rates of nitrogen to 200 kg/ha had no effect on this variable.

Number of days to 50 per cent silking was positively affected by changes in plant population. The attainment of silking was significantly delayed with each increase in plant population from 25,000 to 75,000 plants/ha. Some 2.0 and 3.6 days of delay in silking were observed when plant population was increased from 25,000 to 50,000 and to 75,000 plants/ha, respectively. The nitrogen by plant population interaction effect was not significant.

4.2.6 Ear leaf area, total leaf area per plant and leaf area index

Table 4.3 shows the effect of nitrogen and plant population on the ear leaf area, total leaf area per plant and

Table 4.3: The effect of nitrogen and plant population on the ear leaf area, leaf area per plant and leaf area index of maize at Samaru, 1983.

N - Applied (Kg N/ha)	Ear leaf area (cm^2)	Leaf area per plant (cm^2)	Leaf area index
0	214.5	1500	0.81
50	367.5	2707	1.21
100	480.1	3759	1.80
150	594.0	4724	2.32
200	607.5	4505	2.14
LSD (0.05)	57.6	654	0.36
Population			
(Plants/ha)			
25,000	514.0	3985	0.99
50,000	444.1	3467	1.74
75,000	400.4	2973	2.24
LSD (0.05)	44.6	506	0.28
Mean	452.9	3475	1.66
C.V. %	15.5	23	16.20
Interaction(N x P)	**	NS	*

* = Significant (P = 0.05)
** = Significant (P = 0.01)
NS = Not Significant.

leaf area index.

The effect of nitrogen on the ear leaf area, total leaf area per plant and leaf area index were significant at the 0.01 level of probability. Significant increases in ear leaf area, total leaf area per plant and leaf area index, due to nitrogen were observed with each increase in nitrogen rate from 0 to 150 kg/ha with non-significant decreases in leaf area per plant and leaf area index resulting when applied nitrogen rate was increased to 200 kg/ha. However, increasing rate of N from 150 to 200 kg/ha resulted in a non-significant increase in the ear leaf area.

The effects of plant population on the ear leaf area, total leaf area per plant and leaf area index were significant. Significant decreases in ear leaf area and total leaf area per plant were observed when the population level was increased from 25,000 to 50,000 plants/ha. A further increase in population to 75,000 plants/ha resulted in a non-significant decrease in ear leaf area and total leaf area per plant. A significant decrease in leaf area index was however observed for each 25,000 plants/ha increase in plant population from 25,000 to 75,000 plants/ha.

The interactions between nitrogen and plant population on the ear leaf area and leaf area index were significant. Figure 4.3 shows that at low nitrogen rates of 0 and 50 kg/ha, ear leaf area was not significantly affected by increases in plant

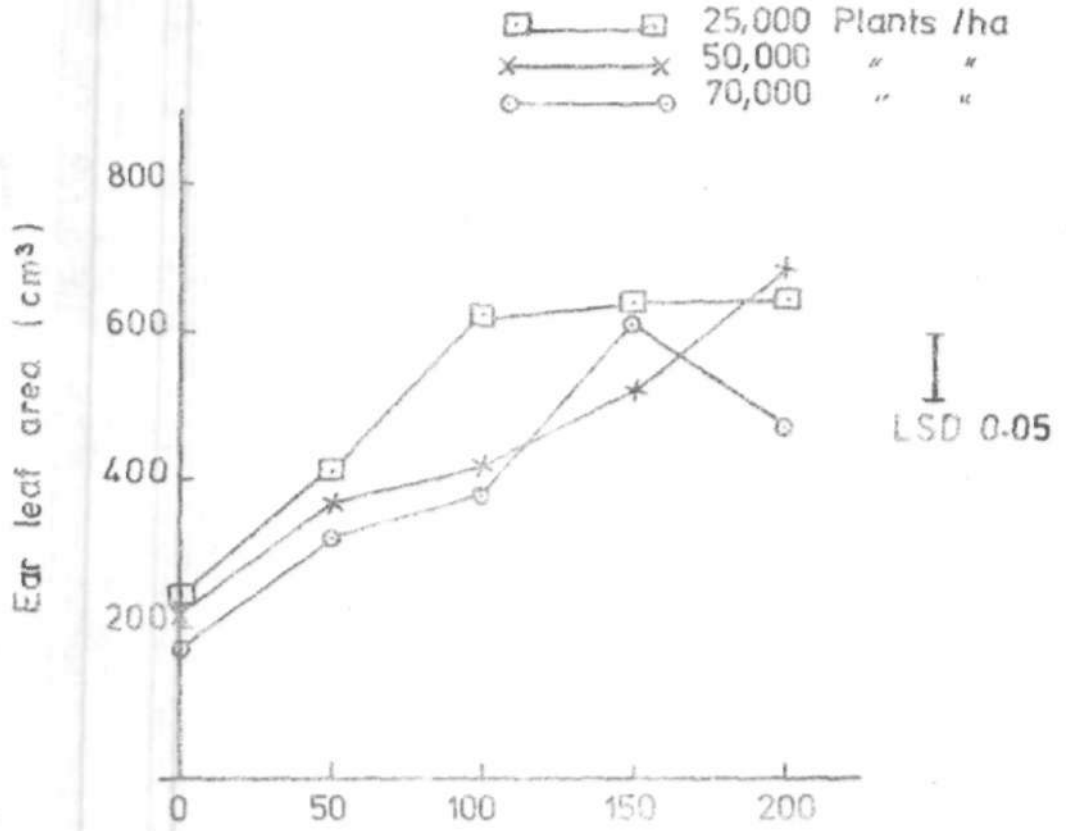


Fig. 4. 3: Interaction between nitrogen and population on the ear leaf area (cm^3) of maize in the northern Savanna, 1983.

population. However, at N rates higher than 100 kg N/ha, responses of ear leaf area to increase in population differs significantly. At 200 kg N/ha ear leaf area for the 75,000 plants/ha population reduced significantly, while those of the other two plant densities remained relatively high.

At each rate of applied N, increasing plant population increased the leaf area index (Figure 4.4). Application of 150 kg N/ha to a plant population of 75,000 plants gave the highest leaf area index. Increasing the N rate above 150 kg/ha resulted in the reduction in the leaf area index of plants at 75,000 plants/ha while those of the 25,000 and 50,000 plants/ha were not adversely affected.

4.2.7 Dry matter yield at tasselling

The data showing the effect of nitrogen on the dry matter yield at tassel are contained in Table 4.4. Dry matter yield at tasselling increased as the nitrogen rate was increased up to the 100 kg/ha rate. A further increase in the rate of nitrogen to 200 kg/ha resulted in only a slight increase in dry matter yield at tasselling. Dry matter yields were 1.0, 3.3, 6.7, 7.0 and 8.0 kg/plot for nitrogen rates of 0, 50, 100, 150 and 200 kg/ha, respectively. Plant population had a significant positive effect on the dry matter yield at tasselling. Increasing the population from 25,000 to 75,000 plants/ha significantly increased the dry matter yield. An increase of 35 and 76 per cent was observed by raising the population rate

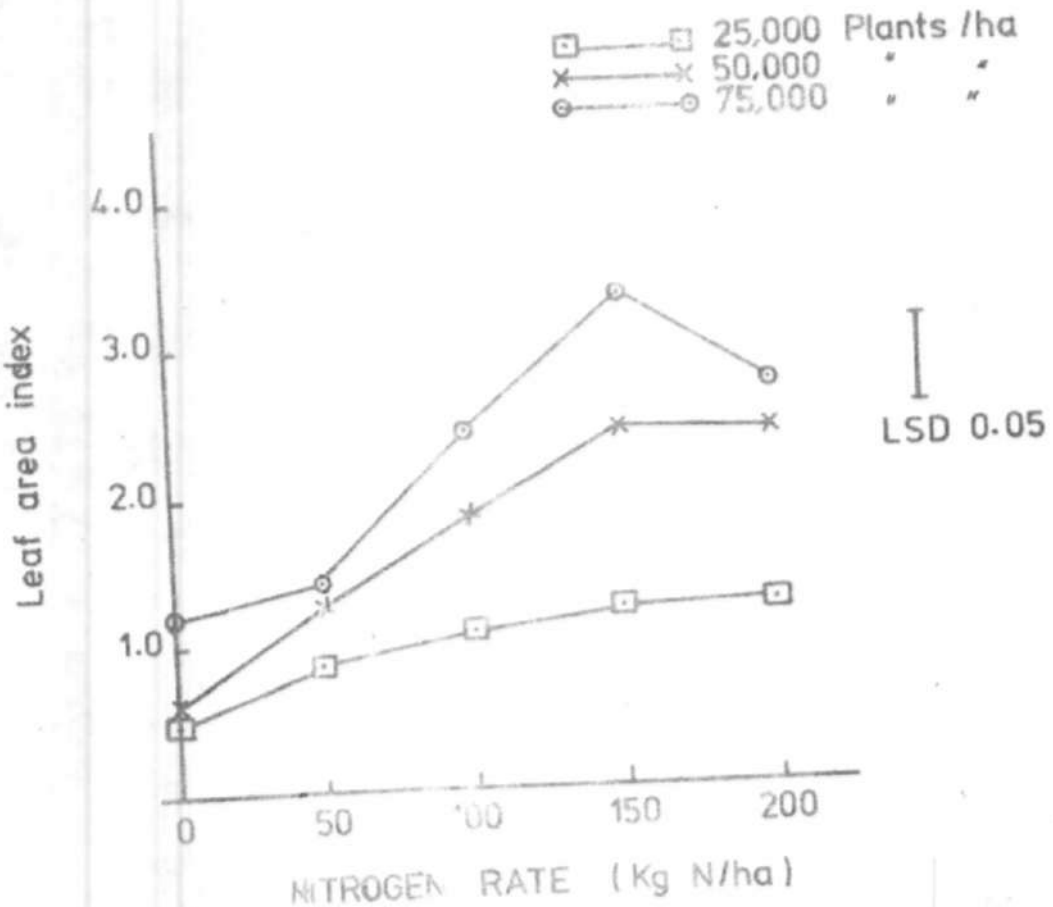


Fig. 4.4: Interaction between nitrogen and population on the leaf area index of maize in the northern Guinea Savanna, 1983.

Table 4.4: The effect of nitrogen and plant population on Stover weight, grain to stover ratio Dry matter yield at tasselling and at harvest of maize at Samaru, 1983.

N - Applied (Kg N/ha)	Stover weight kg/plot	Grain to Stover ratio	Dry matter yield tasselling (kg/plot)	Dry matter yield at harvest (kg/plot)
0	3.1	0.258	1.0	3.9
50	6.4	0.609	3.3	10.3
100	9.9	0.464	6.7	14.5
150	11.5	0.443	7.9	16.6
200	11.0	0.449	8.0	17.1
LSD (0.05)	1.3	0.054	1.0	1.3
Population (Plants/ha)				
25,000	7.1	0.563	4.0	11.1
50,000	9.1	0.428	5.5	13.2
75,000	9.5	0.400	7.1	13.3
LSD (0.05)	0.9	0.042	1.0	0.9
Mean	8.5	0.452	5.5	12.5
C.V.	16.0	13.0	14.3	12.5
Interaction (N x P)	NS	*	**	NS

NS = Not Significant
* = Significant (P = 0.05)
** = Significant (P = 0.01)

from 25,000 to 50,000 and 75,000 plants/ha, respectively.

A significant nitrogen x population interaction for dry matter yield at tasael was observed (Figure 4.5). For each level of plant population, a near linear response to applied N was observed. With low applied N (0 - 50 kg/ha) the three plant densities used gave essentially similar dry matter yield. However, at high N rates (100 - 200 kg/ha) dry matter yield of each of the population densities was markedly different with 75,000 plants/ha density having the highest dry matter yield at each of the applied N rate.

4.2.8 Dry matter yield at harvest

Data on dry matter yield at harvest are shown in Table 4.4. A significant increase in dry matter yield at harvest was observed with each increase in N rate from 0 to 150 kg/ha. A further increase in N rate to 200 kg/ha resulted in a non-significant 3 per cent increase in dry matter yield.

Plant population had a marked effect on dry matter yield at harvest (Table 4.4). Increasing the population level from 25,000 to 50,000 plants/ha significantly increased the dry matter yield by 18 per cent. However, a non-significant increase was observed when plant density was further raised to 75,000 plants/ha. The interaction between nitrogen and population on the dry matter yield at harvest was not significant.

4.2.9 Stover weight

The effect of applied nitrogen on the stover weight was

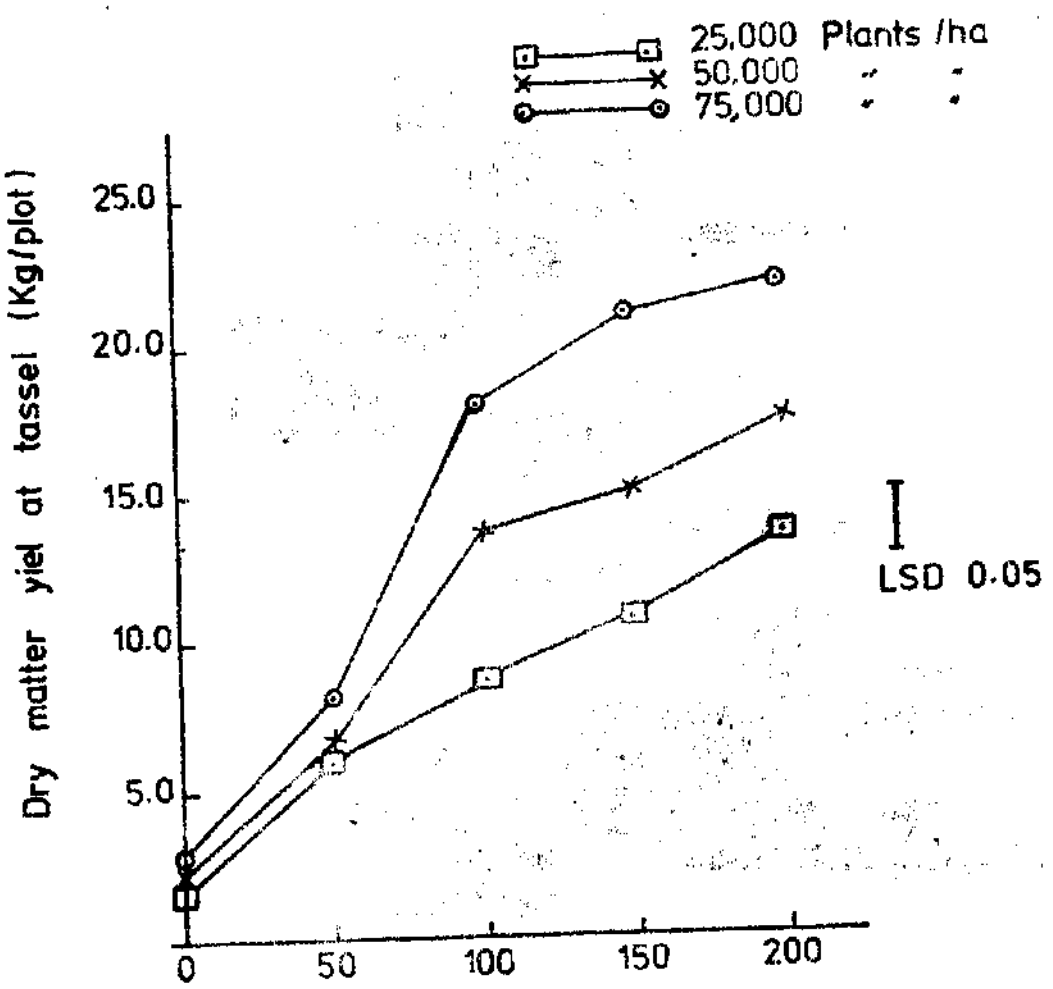


Fig. 4.5: Interactions between introgen and population on the dry matter yield of maize at tassel in the northern Guinea Savanna, 1983.

significant (Table 4.4). Stover weight increased with increase in applied nitrogen up to 150 kg N/ha. A non-significant increase was observed when the nitrogen rate was subsequently raised to 200 kg/ha. Stover weight was 3.1, 6.4, 9.9, 11.4 and 11.9 kg/plot for nitrogen rates of 0, 50, 100, 150 and 200 kg/ha, respectively.

Plant population had a significant influence on stover weight. There was a significant increase in stover weight as the population rate was raised from 25,000 to 50,000 plants/ha. A further increase in population to 75,000 plants/ha resulted in a non-significant increase in stover weight. Increases in stover weight due to increase in plant population were 29 and 34 per cent, when plant population was increased from 25,000 to 50,000 and 75,000 plants/ha, respectively. The interaction between nitrogen and plant population for stover weight was not significant.

4.3 Grain : Stover Ratio

The data on the grain : stover ratio as influenced by nitrogen and plant population are contained in Table 4.4. An increase in grain : stover ratio due to nitrogen application was observed with increase in nitrogen rate from 0 to 50 kg/ha, with a significant decrease resulting from further increase in the rates of applied nitrogen to 100 kg/ha. Thereafter, each 50 kg N/ha increment had no effect on this variable.

A significant decrease in the grain : stover ratio was

observed for each 25,000 plants/ha increase in population rate from 25,000 to 75,000 plants/ha. Decreases in grain : stover ratio resulting from increases in population to 50,000 and 75,000 plants/ha were 24 and 29 per cent, respectively.

The interaction between nitrogen and population for grain : stover ratio was significant (Figure 4.6). Increments in N rate above 50 kg N/kg did not have effect on grain : stover ratio when plants were planted at populations greater than 25,000 plants/ha. The maximum grain : stover ratio of 0.74 was obtained with a plant population of 25,000 plants/ha. This grain : stover ratio value, however, was not significantly different from those obtained with 150 and 200 kg N/ha at the same plant population.

4.4 Shelling Percentage

The data on shelling percentage are presented in Table 4.5. Increasing the nitrogen rate from 0 to 50 kg/ha increased the shelling percentage by 7 per cent. Applied N, however, had no effect on shelling percentage when increased above a level of 50 kg/ha.

The maximum shelling percentage of 00.8 per cent was obtained with a population of 50,000 plants/ha. The population density of 25,000 plants/ha produced essentially the same shelling percentage while the shelling percentage observed with the 75,000 plants/ha was slightly lower than that for either the 25,000 or 50,000 plants/ha.

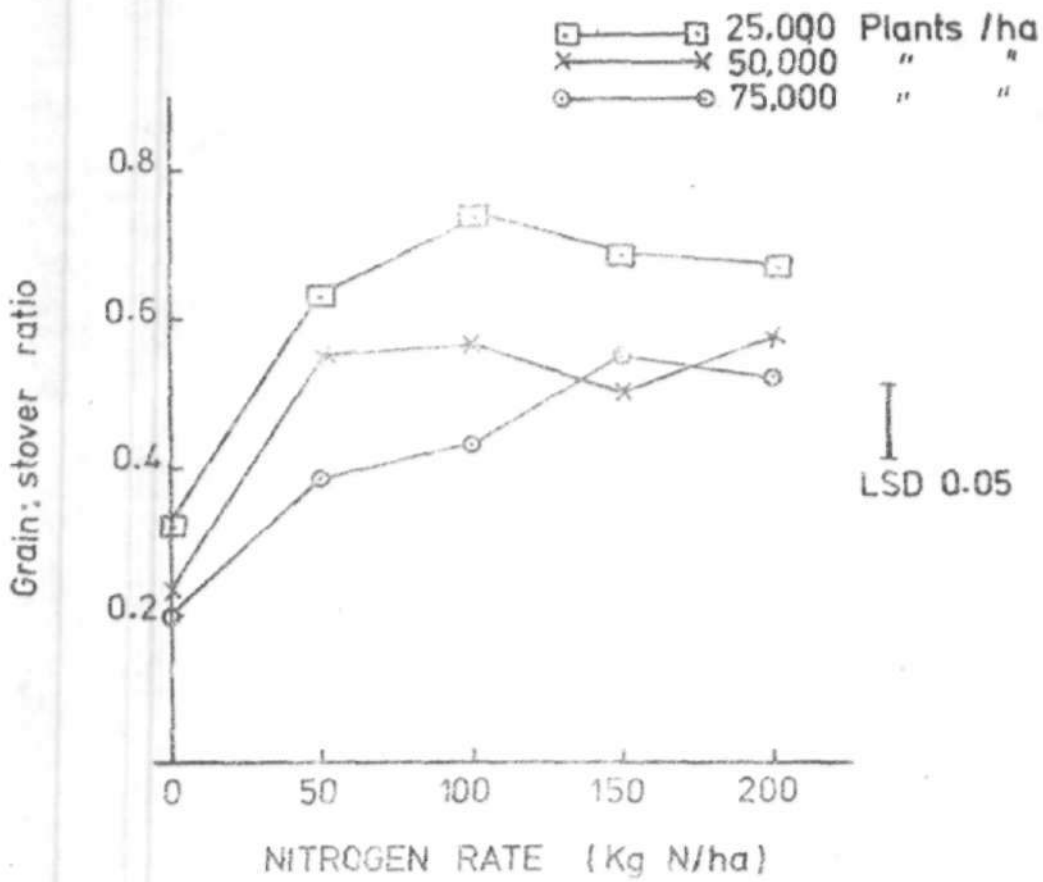


Fig. 4.6: Interaction between nitrogen and population on grain to stover ratio of maize in the northern Guinea Savanna, 1983.

Table 4.5: The effect of nitrogen and plant population on shelling percentage and number of barren stalks per plot of maize at Samaru, 1983.

N - Applied (kg N/ha)	Shelling percentage	[1]No. of barren stalk per plot
0	75.5	7.1
50	80.7	3.8
100	81.5	3.1
150	81.4	2.8
200	81.6	2.7
LSD (0.05)	1.2	0.7
Population (Plants/ha)		
25,000	79.9	1.5
50,000	80.8	3.2
75,000	79.7	7.0
LSD (0.05)	0.9	0.5
Mean	80.1	3.9
C.V. %	1.8	20.7
Interaction (N x P)	*	**

* = Significant (P=0.05)

** = Significant (P = 0.01)

1 = Square root transformed data.

The nitrogen x population interaction effect on shelling percentage was significant (Table 4.6). The highest shelling percentage of 81.9 was observed with a plant population of 50,000 plants/ha and a nitrogen rate of 100 kg N/ha. The data in table 4.6, however, suggest the tendency for maize planted at a low population (25,000 plants/ha) to have a relatively high shelling percentage with low applied N. When the plant population was increased to 75,000 plants/ha, a relatively high N rate (100 kg N/ha) was required to bring the shelling percentage to a high value of about 81 per cent.

4.4.1 Number of barren stalks per plot

There was a progressive decrease in the number of barren stalks with increase in applied nitrogen from 0 to 200 kg/ha (Table 4.5). However, only the first increment of nitrogen from 0 to 50 kg/ha resulted in a significant decrease in number of barren stalk.

Barrenness was significantly aided by increase in plant density. The number of barren stalks increased significantly for each 25,000 plants/ha increase in population level. The number of barren stalks per plot were 1.5, 3.2, and 7.0 for the 25,000, 50,000 and 75,000 plants/ha, respectively.

The interaction between nitrogen and plant population for number of barren stalks per plot was significant at the 0.01 level of probability (Figure 4.7). It shows that at the

Table 4.6: The effect of interaction between nitrogen and plant population on the shelling percentage of maize at Samaru, 1983.

N - Applied	Population (plants/ha)			
(kg N/ha)	25,000	50,000	75,000	Mean
0	73.9	70.2	74.5	75.5
50	81.4	81.2	79.5	80.7
100	81.6	81.9	80.9	81.5
150	81.3	81.3	81.7	81.4
200	81.4	81.4	81.9	81.6
Mean	79.9	80.8	79.7	
LSD (0.05)	= 2.0			

0 rate of applied N, increased plant population significantly increased the number of barren plants/plot. Application of N reduced barrenness in maize planted at all population densities, however, the magnitude of reduction was greater for the 50,000 plants/ha than for the 75,000 plants/ha density. Nitrogen rates higher than 50 kg N, however, had no effect on barrenness in maize planted at 25,000 plants/ha.

4.5. Nutrient Element Concentrations in the Ear Leaf

Table 4.7 shows the effect of nitrogen and plant population on the nutrient element concentrations in the ear leaf.

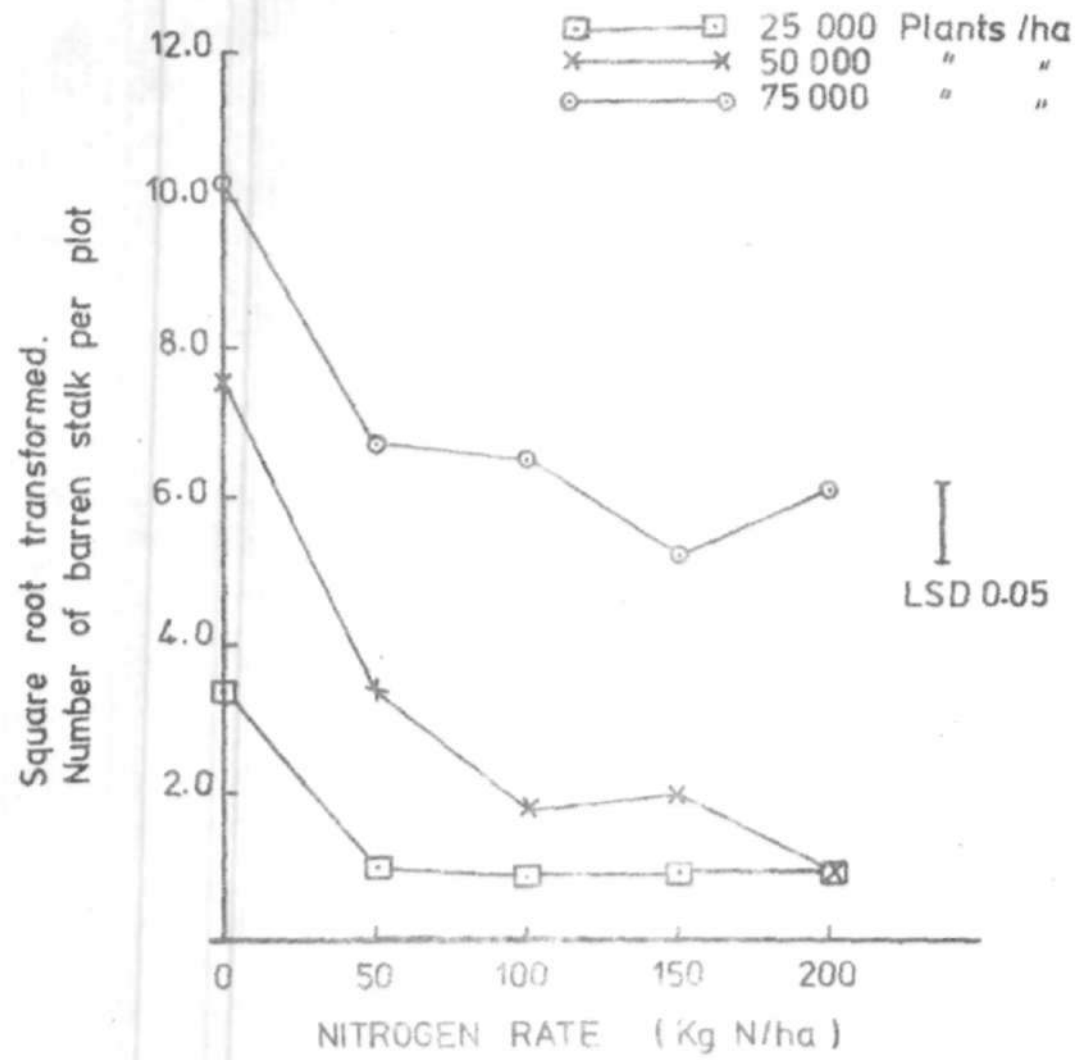


Fig. 4.7: Interaction between nitrogen and population on the number of barren stalk per plot of maize in the northern Guinea Savanna, 1983.

Table 4.7: The effect of nitrogen and plant population on nutrient element concentrations in the ear leaf of maize at silking at Samaru, 1983.

N - Applied (kg N/ha)	N	P	K	Ca	Mg	Mn	Zn	Cu	Fe
	%					ppm			
0	1.53	0.236	1.11	0.264	0.131	153.2	26.2	21.2	120.3
50	1.80	0.247	1.10	0.205	0.145	168.4	24.2	21.9	122.2
100	2.07	0.256	1.13	0.208	0.165	171.7	26.1	21.7	122.8
150	2.12	0.264	1.19	0.242	0.192	183.8	26.8	21.2	119.0
200	2.16	0.264	1.34	0.236	0.202	181.4	27.0	21.9	119.0
LSD (0.05)	0.26	NS	0.13	NS	0.015	10.7	NS	NS	NS
Population (Plants/ha)									
25,000	2.03	0.248	1.14	0.205	0.171	175.1	26.2	21.7	125.3
50,000	1.91	0.257	1.17	0.269	0.156	164.5	26.0	21.5	119.9
75,000	1.88	0.255	1.21	0.219	0.164	174.4	26.0	21.5	116.7
LSD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS
Mean	1.94	0.253	1.12	0.213	0.167	171.7	26.1	21.6	120.7
C.V. %	12.9	11.9	13.4	19.0	11.0	13.3	11.7	12.3	10.7
Interaction (N x P)	NS	NS	NS	NS	NS	NS	*	NS	**

NS = Not Significant

* = Significant (P = 0.05)

** = Significant (P = 0.01)

4.5.1 Nitrogen

Applied N significantly affected ear leaf nitrogen concentration (Table 4.7). Nitrogen in the ear leaf increased as the rate of applied N was increased from 0 to 100 kg/ha. A non-significant increase resulted as the N rate was further increased to 200 kg/ha. A 41.2 per cent increase in the N concentration in the ear leaf was observed by raising the rate of applied N from 0 to 200 kg/ha.

Plant population had no significant effect on ear leaf N concentration, but the concentration of N in the ear leaf decreased with increase in plant population from 25,000 to 75,000 plants/ha. The interaction of nitrogen and plant population on ear leaf N concentration was not significant.

4.5.2 Phosphorus

Although applied N increased P concentration in the ear leaf the differences were not statistically significant (Table 4.7).

Plant population had no significant effect on the ear leaf P concentration. Interaction effect of nitrogen and plant population for phosphorus concentration in the ear leaf was not significant.

4.5.3 Potassium

Nitrogen application of 0 to 150 kg/ha had no effect on

ear leaf K concentration (Table 4.7). A substantial increase in K concentration was, however, observed when applied N was increased to 200 kg/ha. Increasing the rates of applied N from 0 to 200 kg/ha resulted in a 20.7 per cent increase in the K concentration in the ear leaf.

Plant population had no effect on the potassium concentration in the ear leaf. A tendency for the concentration of potassium in the ear leaf to increase with each increase in population was, however, observed. The nitrogen and plant population interaction for potassium concentration in the ear leaf was not significant.

4.5.4 Calcium

Response of ear leaf calcium concentration to applied N was not consistent. Calcium concentration in the ear leaf was however higher at low than at high nitrogen rates.

Plant population had no significant effect on the calcium concentration in the ear leaf. Nevertheless, the highest concentration of 0.269 per cent of calcium in the ear leaf was observed in plants sown at 50,000 plants/ha. The interaction of nitrogen and plant population for calcium concentration in the ear leaf was not significant.

4.5.5 Magnesium

The concentration of magnesium in the ear leaf was significantly affected by applied N. A progressive increase

in magnesium concentration of the ear leaf was observed with each increase in applied N up to 150 kg N/ha. A further increase in applied N to 200 kg/ha resulted in a non-significant increase in magnesium concentration in the ear leaf.

Population rate had no effect on the magnesium concentration in the ear leaf. However, the magnesium concentration in the ear leaf was higher at low population density than at higher population densities. The nitrogen and plant population interaction for magnesium concentration in the ear leaf was not significant.

4.5.6 Manganese

The response of manganese concentration to applied N was similar to that of magnesium. A significant increase in the manganese concentration due to nitrogen was observed with increase in N rate from 0 to 50 kg/ha, with a non-significant increase resulting when the applied N was increased to 100 kg/ha. A further increase in the rate of applied N to 150 kg/ha.resulted in a significant increase in the manganese concentration in the ear leaf, with a slight decrease resulting with increase in N rates to 200 kg/ha. Population level had no significant effect on the manganese concentration in the ear leaf. The nitrogen and plant population interaction effect was not significant.

4.5.7 Zinc, copper and iron

The effect of nitrogen on zinc (Zn), copper (Cu) and

iron (Fe) concentrations in the ear leaf was not significant. Population rate had no significant effect on the Zn, Cu and Fe concentrations in the ear leaf.

The nitrogen and plant population interaction was significant only for Zn (Table 4.8) and Fe (Table 4.9). Table 4.8 shows that a nitrogen rate of 100 kg/ha and a plant population of 25,000 plants/ha resulted in the highest Zn concentration in the ear leaf. Generally, there was no consistent trend in the response of ear leaf Zn concentration to applied nitrogen and population. The application of 200 kg N/ha to a population of 50,000 plants/ha resulted in the highest ear leaf Fe concentration of 131.3 ppm (Table 4.9). Generally, high N rate on low plant population tends to decrease ear leaf Fe concentration. At high plant population, this trend appeared to have disappeared.

4.6 Simple Correlation Studies

Simple correlation studies were made between grain yield and some selected variables (Table 4.10). The selected variables are days to 50 per cent tasselling, ear height, shelling percentage, ear length, weight per 1,000 kernels, number of leaves per plant, ear leaf area, total leaf area per plant, dry matter yield at tassel and grain to stover ratio.

Only days to 50 per cent tasselling was negatively correlated with grain yield ($r = -0.901$). All the other variables; ear height, shelling percentage, ear length, weight

Table 4.8: The effect of interactions between nitrogen and plant population on Zn (ppm) concentrations in the ear leaf of maize at Samaru, 1983.

N - Applied	Population (plants/ha)			
(kg N/ha)	25,000	50,000	75,000	Mean
0	26.0	26.7	26.0	26.2
50	25.0	24.2	23.5	24.2
100	30.0	23.5	24.7	26.1
150	24.0	26.7	29.7	26.8
200	26.0	29.0	26.0	27.0
Mean	26.2	26.0	26.0	

LSD (0.05) (N x P) = 4.3

Table 4.9: The effect of interactions between nitrogen and plant population on Fe (ppm) concentrations in the ear leaf of maize at Samaru, 1983.

N - Applied	Population (plants/ha)			
(kg N/ha)	25,000	50,000	75,000	Mean
0	143.3	113.5	104.3	120.3
50	125.0	120.5	121.0	122.2
100	120.5	118.5	129.3	122.8
150	120.5	115.0	120.8	119.0
200	117.5	131.3	108.3	119.0
Mean	125.3	119.9	116.7	

LSD (0.05) (N x P) = 18.4

Table 4.10: Simple correlation coefficients for the relationships between selected variables and grain yield of maize grown at different plant population and nitrogen rates.

Variables	Days to 50% tasselling	Ear height	Shelling percentage	Ear length	Wt/1,000 kernel	No. of leaves/ plant	Ear leaf area	Total leaf area/ plant	Dry matter yield at tassel	Grain/ stover ratio
Ear height	** -0.0549									
Shelling percentage	** -0.7015	** 0.7264								
Ear length	** -0.8715	** 0.9030	** 0.7129							
Wt/1,000 kernels	** -0.0403	** 0.0309	** 0.7478	** 0.9108						
No of leaves per plant	** -0.9223	** 0.0800	** 0.7693	** 0.8670	** 0.0194					
Ear leaf area	** -0.7667	** 0.0621	** 0.6037	** 0.8406	** 0.7443	** 0.7004				
Total leaf area/plant	** -0.7226	** 0.0226	** 0.5472	** 0.7771	** 0.6676	** 0.7502	** 0.8415			
Dry matter yield at tassel	** -0.6000	** 0.7405	** 0.6094	** 0.5960	** 0.5586	** 0.7375	** 0.6080	** 0.6050		
Grain/stover ratio	** -0.0301	** 0.7505	** 0.6904	** 0.8724	** 0.0272	** 0.7712	** 0.7266	** 0.6003	** 0.3943	
Grain yield	** -0.9009	** 0.9306	** 0.7041	** 0.9229	** 0.8618	** 0.8095	** 0.8358	** 0.7556	** 0.7600	** 0.8226

*, ** indicates a significant difference at the 0.01 and 0.001 levels of probability, respectively.

per 1,000 kernels, number of leaves per plant, ear leaf area, total leaf area per plant, dry matter yield at tassel and grain to stover ratio were positively correlated with grain yield (Table 4.10).

Comparison of the selected variables with each other indicates that only days to 50 per cent tasselling was negatively correlated with all the other variables, while the remaining variables positively correlated with each other at the 0.001 level of probability. The only exception being the correlation of dry matter yield at tassel with grain to stover ratio that was positively correlated at the 0.01 level of probability.

4.7 Relationship between Ear Leaf Nutrient Content and Grain Yield

Table 4.11 presents the simple correlation for the relationship between grain yield and the ear leaf nutrient content. Grain yield was positively correlated with ear leaf N ($r = 0.52$) and Mg ($r = 0.75$) concentrations. While the correlation between P, K and grain yield were positively significant at the 0.05 level of probability. The Mn, Zn and Cu concentrations in the ear leaf was, however, not correlated with grain yield.

The concentration of N in the ear leaf positively affected the concentration of both Mg and Mn in the ear leaf, while that of P affected only K and Mg. The concentration of K in the ear

Table 4.11: Simple correlation coefficients for the relationships between grain yield and ear leaf nutrient content of maize at tassel.

Variables	N	P	K	Ca	Mg	Mn	Zn	Cu	Fe
N									
P	0.1692								
K	0.0226	0.2509*							
Ca	-0.0308	0.0352	0.0693						
Mg	0.5491**	0.2981**	0.4327**	-0.0549					
Mn	0.4350**	-0.0031	-0.1128	-0.1155	0.2231				
Zn	0.1629	0.0033	-0.1118	-0.0644	0.2354	0.2564*			
Cu	0.2101	0.0751	-0.0172	-0.0221	0.0348	0.5120**	0.1046		
Fe	0.0937	0.0204	-0.0659	0.1035	-0.0907	0.0979	-0.1604	0.040	
Grain yield	0.5170**	0.3223*	0.3132*	-0.0775	0.7516**	0.2330	0.0597	0.0001	-0.0125

*, ** Significant at the 0.05 and 0.001 levels of probability, respectively.

leaf affected the concentration of only Mg while Ca and Mg had no significant effect on the concentrations of Mn, Zn, Cu and Fe in the ear leaf. Of all the micronutrients, only Mn appeared to have any appreciable effect on Zn and Cu concentrations in the ear leaf.

4.8 Relation of Grain Yield to Nitrogen Concentration in the Ear Leaf

Figure 4.8 presents the relation of yield to nitrogen concentration in the ear leaf. Grain yield increased linearly with increase in nitrogen concentration in the ear leaf. However, when the nitrogen percentage approximates 2 per cent, there is a tendency for changes in ear leaf nitrogen to be associated with smaller increases in yield than those at lower nitrogen contents. The regression equation $Y = -600.6 + 1765.9N$ indicates that for each 0.1 per cent change in the ear leaf, there would be a corresponding change of 176.6 kg/ha in yield.

Figure 4.9 shows that increases in yield and increases in leaf nitrogen over control was positively correlated $r = 0.58$. The relation was best described by a linear equation $Y = 1760.4 + 2647.4N$. This equation shows that for each 0.1 per cent change in ear leaf nitrogen corresponded to 264.8 kg/ha increase in yield.

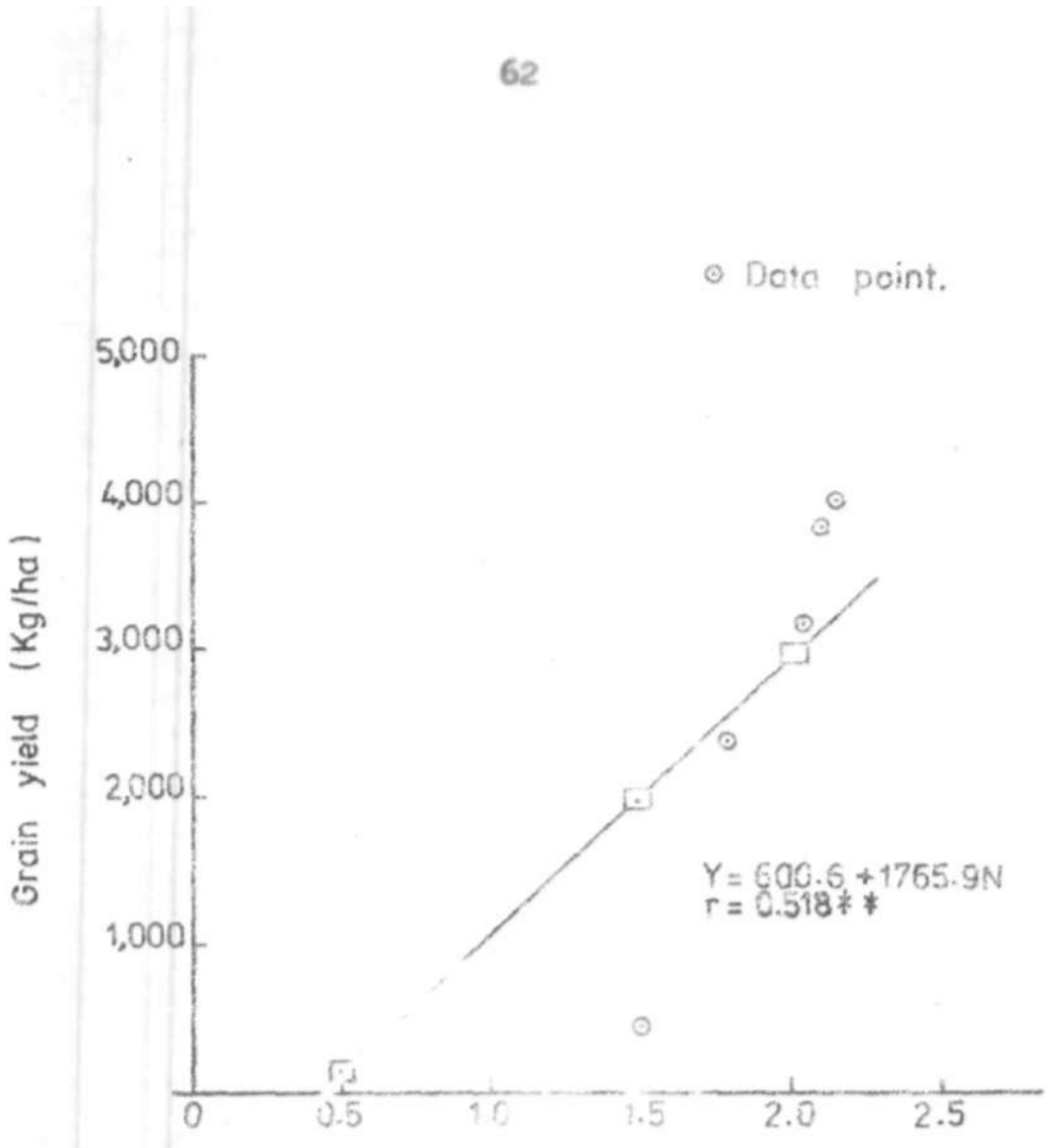


Fig. 4.8 Relationship between grain yield and nitrogen concentration in the ear leaf of maize in the northern Guinea Savanna, 1983.

of days to 50 per cent taselling and silking when N rates were increased from 0 to 240 kg N/ha. Shurma (1973) also observed that increase in nitrogen rate from 0 to 150 kg N/ha decreased the number of days to 50 per cent silking.

A significant increase in stover weight, dry matter yield at tassel and harvest was observed when the rates of N was raised from 0 to 150 kg/ha, and a non-significant increase resulted from further increase in the rate of applied N to 200 kg/ha. These results are in agreement with those of Jones (1973) and Hamissa et al., (1979) who observed independently an increase in dry matter yield in response to increase nitrogen fertilization. Olson et al., (1964) found significant increase in stover yield with increased N application.

An increase in grain : stover ratio was observed with increase in the rates of applied nitrogen. This result suggests that as more N was supplied to maize more of the N was used for grain formation rather than for stover yield. Jordan et al., (1950) has earlier reported increase in grain to stover ratio as a result of increased N application.

Shelling percentage increased with increased nitrogen application. However, only the first 50 kg N/ha significantly increased the shelling percentage. Horrocks and Zuber (1970) observed that shelling percentage increased with increased rates of nitrogen especially at high levels of nitrogen

application of 135 to 269 kg/ha. On the other hand, Ologunde and Ogunlela (1984) found that shelling percentage was increased by low rate of nitrogen and decreased by high nitrogen rate. Agboola and Kayode (1981) however observed that nitrogen application had no effect on shelling percentage. The different response observed by the various researchers can be attributed to the method of determination, location, date of planting, cultivar planted and cultural practices (Horrocks and Zuber 1970).

As expected, number of barren stalks per plot decreased with increase in applied N. Only the first 50 kg N/ha increase in N rate significantly decreased the number of barren stalks per plot. Results obtained by Singh et al., (1970) indicated a significant decrease in barrenness with increased application of nitrogen.

Differences among levels of nitrogen were significant at the 0.01 level of probability for ear leaf area, leaf area per plant and leaf area index. Nitrogen application was observed to have substantially increased the ear leaf area, leaf area per plant and leaf area index up to the 150 kg N/ha rate and the last 50 kg N/ha increment was not significant. These observations are consistent with the findings of El-Hattab et al., (1980) which indicated that leaf area and leaf area index increased with increased N rate.

ha resulted in a slight and non-significant decrease in grain yield. A further increase in plant density to 75,000 plants/ha significantly decreased the grain yield. The decrease in grain yield when the population was raised from 25,000 to 50,000 plants/ha was contrary to expectation, since it has been known that grain yield increased with increase in population up to a maximum after which a further population increase would result in a lower yield. The decrease in grain yield with increase in plant population to 50,000 plants/ha, could be attributed in part to the low total rainfall (466mm) received and poor rainfall distribution observed during the growing period. This possibly resulted in excessive inter plant competition for moisture and nutrient, resulting in decrease in the various yield components and final grain yield. Another factor may be the variety (cv 096) planted in this trial. This is a late maturing variety, which takes between 120 to 130 days to mature. Since the rainfall ended earlier than expected (September 25) the maize planted on the 29 June had only 90 days of rainfall. This probably increased the stress at higher plant density leading to decrease in yield. In a similar low rainfall condition of South Africa, de Geus (1973) reported that a low plant population of 11,500 plants/ha is recommended in order to give each plant access to more moisture and nutrient. It was observed that a plant population of 11,750 plants/ha yielded significantly more than 23,500 plants/ha which in turn outyielded 32,250 plants/ha. However, in Nigeria, Baker (1975) reported an increase of 11 per cent in

grain yield at Samaru when the maize population was increased from 35,000 to 61,000 plants/ha. While Agboola and Kayode (1981) at Samaru found no response in the yield obtained from the various plant population (37,000 to 62,000 plants/ha) adopted.

The increases in plant height and ear height with increase in plant population in this study confirmed the findings of Osorio (1976) who observed an increase in ear height with increase in plant population and Norden (1965), who found that increasing plant population from 12,000 to 62,000 plants/ha increased plant height by 17 per cent. Increase in plant height with increase in plant population has been attributed to interplant competition for light resulting in rapidly growing weaker plant.

Days to 50 per cent tasselling was delayed by 2 days when the plant population was raised from 25,000 to 75,000 plants/ha, while it was 3.6 days later in days to 50 per cent silking. An increase in population would result in an increase stress to the crop and thus the plant would mature latter than the less crowded plant. Kohnke and Mike (1951) observed a day's delay in silking date for each increase of 0,750 to 10,000 plants/ha. Shubeck and Caldwell (1955) reported a 5 day delay in silking associated with an increase in plant population from 8,900 to 45,000 plants/ha.

The number of leaves per plant decreased significantly

by 5.6 per cent with increase in population from 25,000 to 75,000 plants/ha. Stover weight, total dry matter yield at tassel and harvest increased by 3.4, 77.5 and 20.0 per cent, respectively, when the population level was increased from 25,000 to 75,000 plants/ha. A substantial reduction in grain to stover ratio was also observed with each 25,000 plants/ha increase in plant population rate. These findings were in agreement with that of Abdullahi (1975) at Samaru, who observed increased in the total dry matter at tassel and harvest with increase in population level from 19,570 to 70,202 plants/ha.

The number of barren stalks as expected increased significantly for each 25,000 plants/ha increase in population level. This may partially explain the reduced yield at high population. The high number of barren plants at high plant density can be attributed to inadequate rainfall experienced during the experimental petiod. Chinwuba (1967) in Nigeria observed that per cent barren stalks increased linearly as plant population increased from 24,000 to 72,000 plants/ha. Kalia (1975) reported significant increase in barrenness at higher rate of planting beyond 50,000 plants/ha.

A non-significant increase in shelling percentage was observed up to the 50,000 plants/ha population level. A significant decrease resulted when the population level was further increased to 75,000 plants/ha. Results obtained by

Rathore et al., (1976) in India, indicated a decrease in shelling percentage with increase in plant population. In contrast, however, Horrocks and Zuber (1970) in Missouri found an increase in shelling percentage with increase in population over the range of 30,000 to 60,000 plants/ha. While Clogunde and Ogunlela (1984) in Nigeria reported that population densities appeared to have no effect on shelling percentage. The considerable variation in shelling percentage to increase in plant population has been attributed to the method of determination, location, and the cultivar planted.

A significant decrease in ear leaf area and leaf area per plant was observed with increase in plant population from 25,000 to 50,000 plants/ha. A non-significant decrease resulted from further increase in population to 75,000 plants/ha. The leaf area index increased significantly for each 25,000 plants/ha increase in plant population from 25,000 to 75,000 plants/ha. These findings agreed with those reported by other researchers. Adelana and Milbourn (1972) and Lucas (1981) observed increased leaf area index with increase in plant population. Nunez and Kamprath (1969), found a linear reduction in leaf area per plant as plant population increased from 34,000 to 94,000 plants/ha. Competition for light and/or carbon dioxide probably brought about the decrease in leaf area with increase in plant population.

5.3 Nitrogen and Population Interaction

The interaction between nitrogen and population was

significant for ear length, number of ears for plant, grain to stover ratio, shelling percentage, ear leaf area, leaf area index, number of barren stalks per plot, and dry matter yield at tassel and harvest. However, nitrogen and population interaction affect was not significant for grain yield. The presence of interaction under the condition of this experiment is an indication of differential response to the different levels of population and nitrogen applied. The lack of interaction effect on grain yield was however contrary to the findings of Lang et al., (1956), Earley (1967), Sharma and Gupta (1968) and Ologunde and Ogunlela (1984). Inadequate soil moisture due to poor rainfall and its distribution probably accounted for the lack of interaction effect on grain yield.

5.4 Nutrient Element Concentration in the Ear Leaf

5.4.1 Nitrogen

The increase in the N concentration in the ear leaf with increased rates of nitrogen was expected. Several workers have reported an increase in the concentration of nitrogen in the ear leaf with increased rates of N application (Ologunde, 1974; Kalia 1975; Santos et al., 1975; Rabuffetti and Kamprath 1977; and Cornforth and Steele 1981).

Increase in plant density decreased the concentration of nitrogen in the ear leaf, although the decrease was not significant. Similar observations were made by Abdullahi (1975) at Samaru, who found a decrease in the nitrogen content

of the ear leaf with increase in plant population.

5.4.2 Phosphorus

Although the effects of increased N rates on the concentration of phosphorus (P) in the ear leaf was not significant the result show that phosphorus in the ear leaf tended to increase with increase in applied N. This result is in line with the findings of Terman et al., (1977) who reported an increase in P concentration with increased levels of nitrogen. Such increase in P uptake on addition of N has been attributed to:

a) Increase in root growth in the volume of fertilized soil (Duncan and Ohlrogge, 1958).

b) Increased physiological capacity of the root to adsorb P due to an involvement of N intermediates in the adsorption process (Miller 1965) and

c) Alteration of pH at the soil root interface due to excess of cation over anion adsorption and a consequent release of H^* (Miller et al., 1970).

The effect of plant population on the ear leaf P concentration was not significant in this trial.

5.4.3 Potassium

The increase in potassium (K) concentrations in the ear leaf with increasing nitroger rate is consistent with the

findings of Shukla (1972) and Hume et al., (1979). This might be due to the essential role which K^+ plays in the nitrate nutrition of plant, particularly in the regulation of nitrate-uptake.

Plant population had no significant effect on the per cent K content of the ear leaf. However, the per cent K content tended to increase with increase in population.

5.4.4 Other nutrient elements

Increased rate of applied N was found to significantly increase the levels of Magnesium (Mg) and Mangenese (Mn) in the ear leaf. Although not significant, applied N also tended to increase the Zinc (Zn) concentration. The effects of N on the ear leaf Calcium (ca), Copper (Cu) and Iron (Fe) concentration were not significant. While the response of ear leaf Ca and Fe concentrations to increasing N application, was not consistent, the concentration of Fe tended to be higher at low than at high N levels. Several workers, have reported increase in the ear leaf nutrient element with increased N rate. Terman and Noggle (1973) and Cornforth and Steele (1981) reported increase in the Ca and Mg concentration in the ear leaf with increase in applied N. Thompson (1982) observed an increase in the Cu, Zn and Mn content with increased level of N. While Steele et al., (1981) found that added N significantly increased the levels of Mn and Zn in the ear leaf. The increase in the Mg, Mn and Zn content of the ear leaf associated with

increase nitrogen fertilization can possibly be interpreted as indicating partial fulfilment of the plant's need for the elements. On the other hand, increase in the Mg, Mn and Zn concentration in the ear leaf with added N might be due to the effect of NO_3^- in increasing the total inorganic cation in plants (Cunningham, 1964).

Population effects on the concentration of the ear leaf Ca, Mg, Mn, Zn, Cu and Fe were not significant. The interactive effect of nitrogen and population was only significant for the concentration of Zn and Fe in the ear leaf.

5.5 Relationship between Ear Leaf Nitrogen Concentration and Grain Yield

The nitrogen content of the ear leaf was significantly correlated with the grain yield. Several workers have found highly significant correlation between maize yield and percentage of N in the ear leaf. (Reichman et al., 1959; Dumenil, 1961; Peck et al., 1969; Walker and Peck, 1974; Steele et al., 1982).

Maximum grain yield in this study was associated with 2.16 per cent N in the ear leaf. In their trial, Steele et al. (1982) reported that maximum grain yield was obtained with a N concentration of 3.21 per cent in the ear leaf. The lower value recorded in this trial may be related to the level of N (0.026%) in the soil and the cultivar planted.

The relationship of yield to per cent N in the ear leaf

was significant, (r = 0.518). The regression equation shows that each 0.1 per cent change in the ear leaf N resulted in a change of 176.6kg/ha in grain yield. However, the R^2 value 26.8 for the relationship was low. Tyner (1946) in West Virginia found that for each change of 0.1 per cent N in the ear leaf at silking grain yield varied by 277.8kg/ha, while Bennett et al. (1953) found that for each change of 0.1 per cent N there was a yield change of 200kg/ha. A linear relationship was also found to exist between increase in yield over control resulting from nitrogen fertilization and associated increase in the N content of the leaf. The regression equation indicated that for each 0.1 per cent change in N, corresponded to 264.8kg/ha increase in yield. Employing a similar approach, Bennett et al., (1953) observed a change in yield of 200kg/ha for each 0.1 per cent change in nitrogen in the ear leaf. The existence of many uncontrollable and variable factors which influenced final yields makes the widespread use of such quantitative interpretation questionable.

5.5.1 Critical N per cent of the ear leaf

The establishment of a critical nutrient level have been made for maize in various places (Tyner, 1946; Bennett et al., 1953; Jones, 1967; Santos et al., 1975). The critical level of a nutrient is generally assumed to be that which borders on adequacy. When the critical level of nutrient per cent is reached, little or no yield increase is to be expected from

applying additional increment of the nutrient in question. However, because of the nature of response to N and the weather constraints observed in the study, it was difficult to establish a critical value for N in the ear leaf. In their studies, Santos et al. (1975) observed that N content and grain yield increased linearly with increase rate of N application but could not establish a critical N level. While Tyner (1946) published critical values of 2.9 per cent N for maize.

5.6 Correlation Studies

The high positive correlation observed between ear height, shelling percentage, ear length, weight per 1,000 kernel, number of leaves per plant, ear leaf area, total leaf area per plant, dry matter yield at tassel, grain to stover ratio and grain yield shows that an increase in each of the above variables will lead to increase in grain yield. The negative correlation between days to 50 per cent tasselling and grain yield was due to drought effect.

The significant correlation between N, P, K, Mg in the ear leaf and grain yield observed in this study confirm the findings of Dumenil (1961), Peck et al., (1969) and Walker and Peck (1974) who observed highly significant correlation coefficients between maize yield and the percentage of N, P and K in the ear leaf.

Nitrogen concentration in the ear leaf correlated positively

with the Mg and Mn content in the ear leaf. While P concentration affected K and Mg. The concentration of K in the ear leaf only affected the concentration of Mg. Of all the micro-nutrients only Mn in the ear leaf positively affected Cu and Zn concentration in the ear leaf. Results reported by Agboola and Corey (1973) indicated a negative correlation between K and Ca in maize leaf and a positive correlation between plant N and tissue P and Cu. Such correlation between elements in the ear leaf shows that the accumulation of an element can accentuate high accumulation of other elements, which under the condition of this experiment tends to suggest that such an element plays a vital role in maize production.

Chapter 6

SUMMARY AND CONCLUSIONS

An experiment was conducted during the 1983 wet season at the Institute for Agricultural Research (IAR) farm, Samaru, to investigate the effects of five rates of N (0, 50, 100, 150 and 200 kg/ha) and three plant densities (25,000, 50,000 and 75,000 plants/ha) on the growth, yield and yield components of maize. It was also to study the effect of these variables on the nutrient element concentrations in the ear leaf, and to evaluate the relationship between the nitrogen content of the ear leaf and grain yield.

Grain yield increased significantly with increase in nitrogen application up to the 150 kg N/ha rate and a non-significant increase resulted from further increase in the level of nitrogen to 200 kg/ha. Length of ear, ear diameter, number of kernels per ear, kernel depth, weight per 1,000 kernels and number of ears per plant increase by 98.6, 37.0, 149.2, 52.5, 64.5 and 145.4 per cent, respectively, with increase in N from 0 to 200 kg/ha. Ear height, number of leaves per plant and shelling percentage increased significantly with increase in N rates from 0 to 50 kg/ha, and a non-significant increase resulted from further increase in the levels of N to 200 kg/ha. Increase in N rates from 0 to 200 kg/ha delayed days to 50 per cent tasselling and silking by 12.3 and 15.6 days, respectively. Significant increase in plant height, stover weight, ear leaf area, dry matter

yield at tassel and at harvest who observed for each 50 kg N/ha increase in N up to the 150 kg/ha rate. Further increase in the rates of applied N to 200 kg/ha did not result in any significant increase. Grain to stover ratio increased significantly with increase in N rate from 0 to 50 kg/ha, with a significant decrease resulting from further increase in applied N to 100 kg/ha. Thereafter, each 50 kg N/ha increment had no effect on this variable. Number of barren stalks per plot decreased with increase in applied N. However, only the first 50 kg N/ha increment in N level resulted in a significant decrease in the number of barren stalks.

Increased in the rate of applied N from 0 to 150 kg/ha significantly increased the leaf area per plant and leaf area index. A non-significant decrease resulted when the levels of N was raised to 200 kg/ha.

A slight and non-significant decrease in grain yield was observed with increase in plant population from 25,000 to 50,000 plants/ha. A significant decrease in grain yield resulted from further increase in plant population from 50,000 to 75,000 plants/ha. This result tends to indicate that under low rainfall condition as recorded for this trial, it would be adequate to use a planting density that is on the low side in order to maintain reliable production. Such stand may not attain quite as high a production as thicker stands in good years, but will be more reliable in adverse years. Number of

kernels per ear, length of ear, ear diameter, kernel depth, number of ears per plant, grain to stover ratio, number of barren stalks per plot, and leaf area index decreased significantly with each 25,000 plants/ha increase in plant population. Plant height, ear height, stover weight, total dry matter yield at tassel and at harvest increased by 9.2, 11.1, 3.4, 77.5 and 20.0 per cent, respectively, with increase in plant population from 25,000 to 75,000 plants/ha. Days to 50 per cent tasselling and silking was 2.0 and 3.6 days earlier when the plant population was raised from 25,000 to 75,000 plants/ha, respectively. Number of leaves per plant decreased significantly by 5.6 per cent when the rate of planting was raised from 25,000 to 75,000 plants/ha. A non-significant increase in shelling percentage with increase in population from 25,000 to 50,000 plants/ha was observed. A significant decrease resulted when the plant population level was raised to 75,000 plants/ha. Ear leaf area and leaf area per plant decreased significantly with increase in population from 25,000 to 50,000 plants/ha. A non-significant decrease was observed from further increase in population to 75,000 plants/ha.

The interaction between nitrogen and plant population was significant only for ear length, shelling percentage, ear leaf area, leaf area index, number of barren stalks per plot and dry matter yield at tassel. Increase in N application significantly increased the concentration of N, K, Mg and Mn

in the ear leaf. While not significant, increased N rate tended to increase the ear leaf concentration of P, Ca and Zn. Plant population had no significant effect on the ear leaf content of N, P, K, Ca, Mg, Mn, Zn Cu and Fe. However, the concentration of N, Zn, Cu and Fe in the ear leaf tended to be higher at low than at high population level. Nitrogen x population interaction effect was only significant for Zn and Fe concentration in the ear leaf.

The N content of the ear leaf was positively correlated with the grain yield. A linear relationship was found to exist between increases in yield resulting from increase N fertilization and associated increases in N content of the leaf.

LITERATURE CITED

Abdullahi, A. (1975). 'Studies of the post flowering development of maize (Zea mays L.)'. Unpublished Ph.D. Thesis, Ahmadu Bello University, Zaria, Nigeria, 110 pp.

Adelana, B.O. and Milbourn, G.M. (1972). 'Effect of plant population density on maize'. Journal of Agricultural Science (Cambridge), 78: 65-71.

Agboola, A.A. (1972). 'The relationship between the yields of eight varieties of Nigerian maize and content of N, P and K in the leaf at flowering stage'. Journal of Agricultural Science (Cambridge), 79: 391-396.

Agboola, A.A. and Corey, R.B. (1973). 'The relationship between soil pH, organic matter, available phosphorus, exchangeable potassium calcium, magnesium and nine elements in maize, tissue'. Soil Science, 115: 367-375.

Agboola, A.A. and Kayode, G.O. (1981). 'Effect of different nitrogen levels, plant population and soil nutrient status on yield and yield components of maize (Zea mays L.) in different ecological zones of Nigeria'. Fertilizer Research, 2: 177-191.

Andharia, R.M., Standford, G. and Scholler, F.W. (1953). 'Nitrogen status of Marshall silt loam as influenced by different crop rotation'. Soil Science Society of American Proceedings, 17: 247-251.

Anonymous (1973). 'Maize production in the northern states of Nigeria'. Extension Bulletin II. Agricultural Extension and Research Liaison Services, IAR, Zaria, Nigeria, 24 pp.

Arnon, I. (1975). 'Mineral nutrition of maize'. International Potash Institute, Berne, Switzerland, 452 pp.

Bache, B.W. and Rogers, N.E. (1970). Soil phosphate values in relation to phosphate supply to plants from some Nigerian soils'. Journal of Agricultural Science (Cambridge) 74: 282-290.

Baker, E.F.I. (1975). 'Effects and interactions of "package deal" inputs on yield and labour demand of maize'. Experimental Agriculture, II: 295-304.

Balasubramanian, V., Nnadi, L.A. and Mokwunye, A.U. (1978). 'Fertilizing sole crop maize for high yields'. Samaru Miscellaneous Paper 76, Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Barber, S.A. and Olsen, R.A. (1968). 'Fertilizer use on corn'. In: Changing Patterns in Fertilizer Use. Madison, Wisconsin, Soil Science Society of America: 163-188.

Bennett, W.A., Stanford, G., and L. Dumenil (1953). 'Nitrogen, phosphorus and potassium content of corn leaf and grain as related to nitrogen fertilization and yield'. Soil Science Society of American Proceedings, 17: 252-258.

Bishop, R.F., Smeltzer, G.G. and MacEachern, C.R. (1972). 'Response of corn to N, P and K'. Canadian Journal of Soil Science, 44: 56-65.

Bolton, A. (1971). 'Response of maize varieties in Tanzania to different plant population and fertilizer levels'. Experimental Agriculture, 7: 193-203.

Bremner, J.M. (1965). 'Total nitrogen' pp 1149-1178. In C.A. Black (ed). Methods of Soil Analysis, Part 2. Chemical and Microbiological Properties. American Society of Agronomy, Madison, Wisconsin.

Brown, P. (1966). 'Maize growing in Nyansaland (Malawi). II. Fertilizer requirements'. Experimental Agriculture, 2: 49-60.

Bunting, E.S. (1973). 'Plant density and yield of grain maize in England'. Journal of Agricultural Science (Cambridge), 81: 455-463.

Chinwuba, P.M. (1967). 'Effect of plant population on development and yield of maize in Western Nigeria'. African Soils, 12: 101-106.

Cornforth, I.S., and Steele, K.W. (1981). 'Interpretation of maize leaf analysis in New Zealand'. New Zealand Journal of Experimental Agriculture, 9: 91-96.

Cunningham, R.K. (1964). 'Cation-anion relationship between the ratio of sum of the cations/sum of the anions and nitrogen concentrations in several plant species'. Journal of Agricultural Science (Cambridge), 63: 109-111.

de Geus, J.G. (1973). 'Fertilizer guide for the tropics and sub-tropics'. Centre D' Etude de I'Azote. Bleichermey 33 CH-8002, Zurich, 774 pp.

de Wolf, F. (1966). 'Maize programme' Nokwa, Nigeria. In Third Annual Report of the AID-ARS projects on major cereals in Africa.

Dickson, J. (1968). 'Plant density and nitrogen studies with irrigated hybrid maize in the Lockyer Valley, Queensland'. Queensland Journal of Agriculture and Animal Science, 25: 119-210.

Dormear, J.F. and Kitcheson, J.W. (1960). 'The effect of nitrogen and soil temperature on the growth and phosphorus uptake of corn plants grown in the green house'. Canadian Journal of Soil Science, 40: 177-184.

Douglas, J.A., Cottier, K., Kain, W.M., O'Connor, M.B. and Douthorn, T. (1972). 'Advance in maize production'. Proceedings of Ruakura Farmers Conference, 1972, pp. 121-128.

Drowney, L.A. (1971). 'Relationship between plant density and yield of maize'. Journal of Australian Institute of Agricultural Science, 37: 138-141.

Dumenil, L. (1961). 'Nitrogen and phosphorus composition of corn leaves and corn yields in relation to critical levels and nutrient balance'. Soil Science Society of American Proceedings, 25: 295-301.

Duncan, W.G. and Ohlrogge, A.A. (1958). 'Principles of nutrient uptake from fertilizer bands. II. Agronomy Journal, 50: 605-608.

Earley, E.B. (1967). 'Boost corn yield potential'. Better Crops, 51(1): 6-8.

El-Hattab, H.S., Hussein, M.A., El-Hattab, A.H.D., Raoug, M.S.A. and El-Normany, A.A. (1980). 'Growth analysis of maize plant in relation to grain yield as affected by nitrogen levels'. Zeitschrift fur Acker und Pflanzenbau 149(1): 46-57.

F.A.O. (1980). 'Production year book', 34. United Nations Food and Agricultural Organization, Rome.

Filev, D. and Pan'Kin, V. (1976). 'Effect of plant density and fertilizers on productivity of maize hybrid'. Referativnyi Zhurnal, 7, 1977, 170 pp. In Field Crop Abstracts, 31(3) Abstr. 1717, 1978.

Gagro, M. (1978). 'Effect of nitrogen fertilization and plant density on stem height of hybrids'. Soils and Fertilizers, 44(1), Abstr. 571, 1981.

Goldsworthy, P.R. (1967). 'Response of cereals to fertilizers in northern Nigeria. II. Maize'. Experimental Agriculture, 3: 263-273.

Hagger, R.J. and D.C. Cooper (1972). 'Effects of plant population and fertilizer nitrogen on maize grown for silage in Nigeria'. Experimental Agriculture, 8: 251-263.

Hamissa, M.R., Mawardi, A., Aziz, I.A. and Hakin, M.A.A. (1979). 'Sources of nitrogen for maize'. Agricultural Research Review, 59(4): 103-112.

Hanway, J.J. (1962). 'Plant Analysis'. Guide for corn needs'. Better Crops, 46(3): 50-55.

Horrocks, P.R. and Zuber, S. (1970). 'Corn shelling percentage studies'. Missouri Agricultural Experimental Station Research Bulletin, 976.

Hume, L.J., Widdowson, J.P., Hosking, W.J., and Tama, K. (1979). 'Responses to fertilizer N, P, K and S by maize on three soils of Rarotonga Cook Islands'. New Zealand Journal of Experimental Agriculture, 7: 235-243.

Jackson, M.L. (1958). 'Soil Chemical Analysis'. Prentice-Hall Inc. Englewood Cliffs, New Jersey.

Jenny, H. (1930). 'A study of the influence of climate upon the nitrogen and organic matter content of the soil'. Missouri Agricultural Experimental Station Bulletin, 152: 61-62.

Jones, J.B. Jr. (1967). 'Interpretation of plant analysis for several agronomic crops'. In soil testing and plant analysis, Part III. Soil Science Society of American Special Publication, 2. Madison, WI. 49-75.

Jones, M.J. (1973). 'Time of application of nitrogen fertilizer to maize at Samaru, Nigeria'. Experimental Agriculture, 9(2): 113-120.

Jordan, H.V., Laird, I.C.C. and Ferguson, D.D. (1950). 'Growth rates and nutrient uptake by corn in a fertilizer spacing experiment'. Agronomy Journal, 42: 261-268.

Kalia, B.D. (1975). 'Studies on plant population, nitrogen levels and weed control methods in rainfed maize'. Thesis Abstracts, IV(1). March, 1978, 13-14.

Kassam, A.H., J. Kowal, M. Dagg and Harrison, M.N. (1975). 'Maize in West Africa and its potential in savanna areas'. World Crops, March-April, 1975.

Keay, R.W.J. (1959). 'An Outline of Nigerian Vegetation'. 3rd Edition, Lagos. Government Printer.

Kohnke, H. and Mike, S.R. (1951). 'Rates and patterns of seeding corn on high fertility land'. Agronomy Journal, 43: 488-493.

Krantz, B.A. and Chandler, W.V. (1951). 'Lodging, leaf composition and yield of corn as influenced by heavy application of nitrogen and potash'. Agronomy Journal, 43: 547-552.

Lang, A.J. Pendleton, J.W. and Dungan, G.H. (1956). 'Influence of population and nitrogen levels on yield, protein and oil contents of nine corn hybrids'. Agronomy Journal, 48: 284-289.

Litvinenko, L.G. and Lebedyer, S.I. (1978). 'Effect of nitrogen nutrition on the activity of maize photosynthetic apparatus'. Soils and Fertilizers, 41(12), Abstr. 7171.

Lucas, E.O. (1981). 'The growth of two maize varieties in farmers plots located at two continguous ecological zones in Nigeria'. Journal of Agricultural Science (Cambridge), 97(1): 125-134.

Mikhail, S.M. and Shalaby, Y.Y. (1979). 'Effect of plant density and nitrogen on maize dry matter production'. Research Bulletin, Faculty of Agriculture, Am, Shams University, 1979, No. 1024: 7pp. In Field Crop Abstracts, 33(7). Abstr. 5399, 1980.

Miller, H.M. (1965). 'Influence of $(NH4)_2SO_4$ on root growth and phosphorus absorption by corn from a fertilizer band'. Soil Science Society of American Proceedings 57: 393-396.

Miller, H.M. (1974). 'Effect of nitrogen on phosphorus absorption by plants, pp 643-668. In Carson E.W. (ed). The plant root and its environment. Part II. Soil Physical and Chemical Aspects of the Root Environment'. Charlottesville, United States of America, University Press of Virginia.

Miller, M.H., Mamaril, C.P. and Blaira, J. (1970). 'Ammonium effects on phosphorus absorption through pH changes and phosphorus precipitation at the soil root interface'. Agronomy Journal, 62: 524-529.

Mohammed, M.I., Noor, M.A. and Alio, A.N. (1978). 'The Ifluence of the level of the nitrogen fertilizer and spacing on maize in Somalia'. Studi e Ricerche. 2(2), 1978, 109-115). In Field Crop Abstracts, 33(2): Abstr. 1151, 1980.

Mokwunye, U. (1974). 'Some reflections on the problem of "available" phosphorus in soils of tropical Africa'. Samaru Conference Paper 3. Institute of Agricultural Research, Samaru, Zaria.

Murdock, J.T., Stenzel, P.J. and Doersch, R.E. (1962). 'How fertility level and balance can affect corn production'. Better Crops, 46: 16-21.

Norden, A.J. (1965). 'Response of corn (Zea mays L.) to population, bed height and genotype on poorly drained sandy soil. II. Top growth and root relationships'. Agronomy Journal, 58: 299-302.

Norman, D.A., P. Peeder, W.J. Kroeker, D.H. Pryor, H.M. Hays and B. Huizinga, (1976). 'The feasibility of improved sole crop maize production technology for the small scale farmer in the northern Guinea savanna zone of Nigeria'. Samaru Miscellaneous Paper, 59. Institute for Agricultural Research, Samaru, Zaria.

Nunez, R. and Kamprath, E. (1969). 'Relationship between nitrogen responses, plant population and row width on growth and yield of corn'. Agronomy Journal, 61: 279-283.

Ologunde, O.O. (1974). 'Effect of nitrogen and population on yield and yield components of Zea mays L'. Unpublished M.Sc. Thesis. University of Missouri, Columbia, 164 pp.

Ologunde, O.O. and Ogunlela, V.B. (1983). 'Response to rate, timing and method of nitrogen fertilization by maize in the Nigerian southern Guinea savanna'. Nigerian Agricultural Journal, 19. In Press.

Ologunde, O.O. and Ogunlela, V.B. (1984). 'Relationship of plant density and nitrogen fertilization to maize performance in the Nigerian southern Guinea savanna'. Samaru Journal of Agricultural Research, 2: 99-109.

Olson, R.A., Thompson, C.A., Grabouski, P.H., Stukenholtz, D.D., Frank, K.K. and Dreier, A.F. (1964). 'Water requirement of grain crops as modified by fertilizer use'. Agronomy Journal, 56: 427-432.

Osorio, F.E. (1976). 'Population effects on yield and other characteristics of maize (Zea mays L.) in the EL-Zamorano Valley, Honduras, Ceiba, 1976, 20(2): 69-79. In Field Crop Abstracts, 33(2) Abstr. 1139, 1980.

Peck, T.R., Walker, W.M. and Boone, L.V. (1969). 'Relationship between corn (Zea mays L.) yield and leaf levels of ten elements'. Agronomy Journal, 61: 299-301.

Pierre, W.H., Dumerill, L., Jolley, V.D., Webb, J.R. and Shrader, W.D. (1977). 'Relationship between corn yield expressed as a percentage of maximum and the N percentage in the grain. I. Various N-rate experiments'. Agronomy Journal, 69: 215-226.

Powell, R.D. and Webb, J.R. (1972). 'Effects of high rates of nitrogen, phosphorus and potassium fertilizer on maize (Zea mays L.) grain yields'. Agronomy Journal, 64: 653-656.

Rabuffeti, A. and Kramprath, E.J. (1977). 'Yield, nitrogen and sulfur content of corn as affected by nitrogen and sulfur fertilization on coastal plain soils'. Agronomy Journal, 69: 785-788.

Rathore, D.N., Kirpal, S. and Singh, B.P. (1976). 'Effect of nitrogen and plant population on the yield attributes of maize'. Indian Journal of Agricultural Research, 10(2): 79-82.

Reichman, G.A., Grunes, D.L., Carlson, C.W. and Aleasi, J. (1959). 'Nitrogen and phosphorus composition and yield of corn as affected by fertilization'. Agronomy Journal, 51: 575-578.

Reyes, C.P., Javier, G.E. and Morales, D. (1972). 'Effect of rate of nitrogen on the grain yield and agronomic characters of four maize cultivars'. In XIII informe de in investigacion, 1971-1972, Division de Ciencias Agropecaurias y Maritimas, Instituto Technologico de Monterrey, Mexico, 20-29 pp. In Field Crop Abstracts, 28(2), Abstr. 745, 1975.

Salem, S.A. and Aly, A.E. (1979). 'Effects of nitrogen fertilizer levels and varieties on grain yield and some plant characters of maize (Zea mays L.). Alexandria Journal of Agricultural Research, 27(2): 337-345. In Field Crop Abstracts, 33(12). Abstr. 9881, 1980.

Santos, H.L.D., Bahia, F.A.F.C., Bahia, F., Magnavaca, R., Silva, J., Murad, A.M. and Pacheco, E.B. (1975). 'Trials on nitrogen, phosphorus and potassium application to maize crop in Minas Gerais. 2. Evaluation of maize nutrition by foliar diagnosis'. Persquise Agropecuaria Brasileira, Agronomia, 10(11): 47-51. In Field Crop Abstracts, 31(3). Abstr. 1728, 1970.

Sharma, R.K. (1973). 'Response of maizx to N-fertilization'. Madras Agricultural Journal, 60(6): 599-400. In Field Crop Abstracts, 28(9). Abstr. 5422, 1975.

Sharma, K.C. and Gupta, P.C. (1968). 'Effect of plant population and rates of nitrogen on the performance of hybrid maize'. Indian Journal of Agronomy, 13: 76-82.

Shubeck, F.E. and Caldwell, A.C. (1955). 'Effects of fertilizers and stand on corn and stand on soil moisture'. Minnesota Agricultural Experimental Station Technical Bulletin, 213.

Shukla, G.C. (1972). 'Effect of different levels of nitrogen and phosphorus on yield, soil properties and nutrients of corn. Agronomy Journal, 64(2): 136-139.

Shukla, S.P. and Bhardwaj, R.B.L. (1976). 'Effect of levels and source of nitrogen and phosphorus on growth, yield and nutrient uptake of maize grown under rainfed conditions'. Indian Journal of Agronomy, 21: 436-440.

Singh, R.P. and Nair, K.P.P. (1975). 'Plant density studies in maize in India'. Journal of Agricultural Science (Cambridge), 86: 617-621.

Singh, C.M., Sood, B.R. and Modgal, S.C. (1978). 'Response of rainfed pop corn (Zea mays Everta.) to nitrogen and plant population'. Experimental Agriculture, 14: 395-398.

Singh, R.B.D., Singh, N and Singh Y. (1979). 'Effect of N-fertilization on yield and moisture extraction by rainfed maize as affected by soil type and rainfall in Punjab, India'. Field Crops Research, 2: 109-115, 1979.

Steele, K.W., Mc Cormick, S.J., Percival, N., and Brown, N.S. (1981). 'N, P, K, Mg and S. requirements for maize grain production'. New Zealand Journal of Experimental Agriculture, 9: 243-249.

Steele, K.W., Cooper, D.M. and Dyson, C.B. (1982). 'Estimating nitrogen fertilizer requirements in maize grain production, 2. Estimates based on ear leaf and grain nitrogen concentration'. New Zealand Journal of Agricultural Research, 25: 207-210.

Stockinger, K.R. (1966). 'Fertility studies on maize'. In 3rd Annual Report of the AID-ARS project on major cereals of Africa.

Terman, G.L. and Noggle, J.C. (1973). Nutrient changes in corn as affected by dry matter accumulation with age and response to applied nutrients'. Agronomy Journal, 65: 941-945.

Terman, G.L., Noggle, J.C. and Hunt, C.M. (1977). 'Growth rate-nutrient concentration relationships during early growth of corn as affected by applied nitrogen, phosphorus and potassium'. Soil Science Society of American proceedings, 41: 363-368.

Thompson, J.W. (1962). 'Effect of fertilizers and soil amendments on the mineral constituents of maize'. Soil Science, 94: 323-330.

Tyner, E.H. (1946). 'The relation of corn yields to leaf nitrogen, phosphorus and potassium content'. Soil Science Society of American Proceedings, 11: 317-323.

Tyner, E.H. and Webb, J.R. (1946). 'The relation of corn yields to nutrient balance as revealed by leaf analysis'. American Society of Agronomy Journal, 38: 175-185.

Verma, B.S. and Singh, R.R. (1976). 'Effect of nitrogen, moisture regime and plant density on grain yield and quality of hybrid maize'. Indian Journal of Agronomy, 21(4): 441-445.

Viets, F.G. Jr., Crowford, C.L., Nelson, C.E. (1954). 'The relationships among corn yields, leaf composition anf fertilizer applied'. Soil Science Society of American Proceedings, 18: 297-301.

Walker, W.M. and Peck, T.R. (1974). 'Relationship between corn and plant nutrient content'. Agronomy Journal, 66: 253-256.

Wilson, J.H. and Allison, J.C.S. (1978). 'Effect of plant population on ear differentiation and growth on maize'. Annals of Applied Biology, 90(1): 127-132.

Zuber, M.S. and Grogan, C.O. (1956). 'Rates of planting studies with corn'. Missouri Agricultural Experimental Station Research Bulletin, 60.

Appendix A: Daily rainfall (mm) during the crop season at Samaru, 1983.

Days of the month	May	June	July	August	September
1	-	-	-	~2.1	2.0
2	-	9.8	11.0	35.0	-
3	-	4.0	Tr	14.5	-
4	-	-	9.7	1.1	1.1
5	-	-	6.6	0.8	21.0
6	-	-	-	-	11.3
7	-	-	0.9	27.0	-
8	-	0.2	0.3	0.5	16.3
9	Tr	Tr	-	-	-
10	-	7.4	18.2	17.8	-
11	3.5	-	0.8	-	2.6
12	16.4	-	-	-	-
13	-	-	0.3	-	7.4
14	16.9	-	-	-	-
15	-	6/6	-	-	12.0
16	-	-	6/0	-	10.0
17	0.1	-	-	-	-
18	-	Tr	-	40.4	4.6
19	Tr	-	-	21.0	1.6
20	17.2	-	1.2	14.6	-
21	-	Tr	-	-	-
22	-	-	18/4	0.5	-
23	2.0	-	-	6.2	Tr
24	3.0	24.5	-	-	Tr
25	-	1.0	0.5	26.3	3.5
26	1.3	-	Tr	24.7	-
27	-	-	0.3	-	-
28	8.9	17.1	27.0	19.2	-
29	-	3.7	6.3	-	-
30	-	-	-	-	-
31	4.0	-	-	-	-
Total	73.3	74.3	107.5	259.7	95.2

Source - Department of Soil Science, I.A.R., Samaru.

Tr - Trace

BIOGRAPHY: Godfrey Monibcritse AMORUWA

Name	:	G. M. Amoruwa
Date of Birth	:	July 15, 1951
Business Address	:	The Nigerian Sugar Company, Bacita.
Home Address	:	19A Commercial Avenue, Sapele.

Previous Qualifications

Institution Attended		From	To	Certificate/Degree
St. Malachy's Sec. Gram. School, Sapele	:	1964	1968	W.A.S.C.
Imade College, Owo	:	1971	1972	H.S.C.
University of Ibadan, Ibadan	:	1973	1976	B.Sc. (Agric.)

Post(s) held since the Award of First Degree

Organization		From	To	Position
Nigerian Sugar Company, Bacita	:	1977	1985	Agronomist

Year of Admission for Postgraduate Studies	:	1903
Admission Number	:	M.Sc/Agric./0610/82-83.