EFFECTS OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF SWEET POTATO (*Ipomoea batatas* (L) Lam)

By

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

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DECEMBER, 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.

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CERTIFICATION

This thesis entitled 'EFFECTS OF NITROGEN AND PHOSPHORUS ON THE GROWTH AND YIELD OF SWEET POTATO (Ipomoea batatas (L) Lam)' by Ibrahim Habibu DUTSIN-MA 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.

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DEDICATION

This work is dedicated to my wife Baraka.

And my children Halima and Fatima.

ACKNOWLEDGEMENT

I sincerely wish to express my gratitude and immense appreciation to my major supervisor, Mr. S. K. Karikari, for his invaluable advice and encouragement throughout the period of this study. The same goes to Dr. M. K. Ahmed and Dr. I. U. E. Asenime for their guidance and immense contribution towards the success of this work. My heartfelt appreciation also goes to the members of staff of the Department of Agronomy, especially Prof. J. Y. Yayock, Dr. T. D. Sinha, Dr. Vijay Kumar, Dr. V. S. Ogunlela and to Dr. J. K. Adu of the Department of Soil Science, I.A.R., for the continuous advice and encouragement they gave me.

Thanks also go to Mrs. O.V. Dunmade of the Agricultural Economics Section, A.E.R.L.S. and Mr. Lawrence Okereke of the Food Science and Technology Department for the assistance they rendered during the execution of this project and to Mr. Cyril O. Egeolu for his clerical assistance.

Special thanks also go to my brothers and sister for the unflinching moral support they have rendered throughout the course of this study. Sincere appreciation is also expressed to my wife Baraka and my children Halima and Fatima for the love, patience, moral encouragement and understanding they have displayed throughout the period of my study. Finally, I wish to extend my gratitude to both Sokoto Rima and Kaduna Karaduwa River Basin and Rural Development Authorities for funding this course.

ABSTRACT

Investigation was carried out at Samsru during the 1984 wet season to observe the effect of nitrogen and phosphorus on the growth and yield of sweet potato. The treatments comprised three levels each of nitrogen and phosphorus (0, 6O and 120kg N/ha; 0, 30 and 60kg P_2O_5/ha) and two varieties (TIS 9265 and TIS 2498).

The investination revealed that application of nitrogen affected the growth, yield components and yield of sweet potato, while phosphorus application had no effect on the growth, yield components and yield, Application of 60kg N/ha significantly increased the total and marketable yields by 58.2 and 75.2 per cent, respectively over the control.

However increasing the level to 120kg N/ha significantly reduced these yields by 23.8 and 33.8 per cent, respectively when compared with the 60kg N/ha level. The number of tubers was significantly reduced by the application of 120kg N/ha, while the application of 60 and 120kg N/ha significantly increased the tuber weight. But the difference between the two levels was not significant.

It was also revealed that the two varieties respond similarly to nitrogen fertilization, although variety TIS 2498 was superior over TIS 9265 in terms of total and marketable yields, the number of tubers, marketable tubers as well as vegetative character of dry matter production.

TABLE OF CONTENTS

Chapter			Page
		Dedication	i
		Acknowledgements	ii
		Abstract	iii
		Table of Contents	iv
		List of Tables	vii
		List of Figures	ix
1	INTRODUCTION		1
	1.1	Importance of Sweet Potato	1
	1.2	Origin and Spread	2
	1.3	Botanical Features	2
	1.4	Ecological Adaptation	3
	1.5	Utilization	3
	1.6	Yield	4
2	LITERATURE REVIEW		5
	2.1	Effect of Nutrients on Root Crops	5
	2.2	Effect of Nitrogen on Sweet Potato	6
	2.2.1	Effect of nitrogen on sweet potato growth	6
	2.2.2	Effect of nitrogen on yield components	7
	2.2.3	Effect of nitrogen on yield	8
	2.2.4	Effect of nitrogen on tuber quality	11
	2.3	Effect of Phosphorus on Sweet Potato	12
	2.3.1	Effect of phosphorus on sweet potato growth	12
	2.3.2	Effect of phosphorus on yield and yield components	13
	2.4	Fertility Status of Savanna Soils	14

Chapter			Page
	2.4.1	Nitrogen status of savanna soils	14
	2.4.2	Phosphorus status of savanna soils	15
3	MATERIALS AND METHODS		17
	3.1	Experimental Site	17
	3.2	Treatments and Experimental Design	17
	3.3	Field Operations	19
	3.3.1	Land preparation	19
	3.3.2	Planting	19
	3.3.3	Weed control	20
	3.3.4	Harvesting	20
	3.4	Data Collection	20
	3.4.1	Meteorological data	20
	3.4.2	Growth characteristics	20
	3.4.3	Yield and yield components	22
	3.4.4	Tuber quality	23
	3.5	Analysis of Data	24
4	RESULTS		25
	4.1	Effect of Nitrogen, Phosphorus and Variety on Growth of Sweet Potato	25
	4.1.1	Leaf dry weight	25
	4.1.2	Stem dry weight	27
	4.1.3	Root dry weight	29
	4.1.4	Total dry matter	31
	4.1.5	Length of vine at harvest	33
	4.1.6	Number of branches at harvest	35

Chapter			Page
	4.1.7	Leaf area index	35
	4.1.8	Crop growth rate	37
	4.1.9	Tuber growth rate	39
	4.2	Effect of Nitrogen, Phosphorus and Variety on yield and Yield Components ..	41
	4.2.1	Total tuber, marketable and cull yield	41
	4.2.2	Mean total number of tubers, number of marketable and cull tubers per plant ...	46
	4.2.3	Mean tuber and mean marketable tuber weights	49
	4.3	Effect of Nitrogen, Phosphorus and Variety on Tuber Quality	51
	4.3.1	Tuber dry weight	51
	4.3.2	Crude protein content	51
	4.3.3	Starch content	54
	4.3.4	Tuber sweetness and texture	56
5	DISCUSSION		59
	5.1	Effect of Nitrogen	59
	5.2	Effect of Phosphorus	63
	5.3	Effect of Variety	64
	5.4	Interactions	65
6	SUMMARY AND CONCLUSION		66
	REFERENCES		69
	APPENDICES		76
	BIOGRAPHY		79

LIST OF TABLES

Table		Page
1	Physical and chemical properties of the soil of the experimental site	18
2	Leaf dry weight (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru in 1984	26
3	Stem dry weight (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru in 1984	28
4	Root dry weight (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru in 1984	30
5	Total dry matter (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru in 1984	32
6	Length of vine (m) and number of branches per plant at harvest of sweet potato as influenced by nitrogen phosphorus and variety at Samaru in 1984	34
7	Leaf area index (m^2/m^2) of sweet potato at 4, 6, 8, 12 and 16 WAP as influenced by nitrogen, phosphorus and variety at Samaru in 1984	36
8	Crop growth rate (g/m^2/day) of sweet potato at 4, 6, 8, 12 and 16 WAP as influenced by nitrogen, phosphorus and variety at Samaru in 1984	38
9	Tuber growth rate (g/m^2/day) of sweet potato at 8, 12 and 16 WAP as influenced by nitrogen, phosphorus and variety at Samaru in 1984	40
10	Mean total tuber, marketable and cull yield (t/ha) of sweet potato as influenced by nitrogen, phosphorus and variety at Samaru in 1984	42

Table		Page
11	Observed and estimated sweet potato yield as influenced by nitrogen and phosphorus at Samaru in 1984	44
12	Mean total number, marketable and cull tubers per plant of sweet potato as influenced by nitrogen, phosphorus and variety at Samaru in 1984	47
13	The interaction between nitrogen and variety on mean number of marketable tubers per plant	40
14	Mean weight of tuber and marketable tuber (g/tuber) of sweet potato as influenced by nitrogen, phosphorus and variety at Samaru in 1984	50
15	Tuber dry weight (per cent) of sweet potato as influenced by nitrogen, phosphorus and variety at Samaru in 1984	52
16	Crude protein content (per cent) of sweet potato tuber as influenced by nitrogen, phosphorus and variety at Samaru in 1984	53
17	Starch content (per cent)of sweet potato tuber as influenced by nitrogen, phosphorus and variety at Samaru in 1984	55
18	Quality of sweet potato (boiled) as influenced by nitrogen, phosphorus and variety at Samaru in 1984	57
19	Quality of sweet potato (fried) as influenced by nitrogen, phosphorus and variety at Samaru in 1984	58

LIST OF FIGURES

Figure		Page
1	Response of sweet potato tuber yield to nitrogen application at Samaru in 1984 ...	45

LIST OF APPENDICES

Appendix		Page
A	Rainfall distribution (mm) during the 1984 crop growing period at Samaru	76
B	Maximum and minimum temperatures (^{0}C) during the 1984 crop growing period at Samaru	77
C	Sunshine hours during the 1984 crop growing period at Samaru	78

Chapter 1

INTRODUCTION

1.1 Importance of Sweet Potato

Root and tubers are the next most important crops after the grain crops which form the staple food of human beings, especially in the humid tropics. In Africa, this group of food stuff has been estimated to provide nearly a third of the total nourishment to human being (Lucas, 1968). The world production of the major root and tuber crops namely sweet potato, potatoes, cassava, yams and cocoyam in 1980 was 407.11 million metric tonnes out of which sweet potato production was about 107.25 million metric tonnes (FAO, 1980). Sweet potato (Ipomoea batatas (L) Lam) is also one of the most important food crops throughout the tropical, subtropical and warmer parts of the temperate zone (Miller and Hanendez, 1970). It is the sixth most important food crop in the world and ranks after wheat, rice, maize, potato and cassava.

It is a high yielding crop with production per unit area exceeding that of rice and with higher food value. While it has been considered mainly as a source of carbohydrate it is also an excellent source of vitamins particularly beta-carotene (pro-vitamin A) in orange-flesh varieties and l-ascorbic acid (vitamin C). It also supplies mineral salts which are not obtained in most of the diets

rich in carbohydrates. These mineral salts which are composed largely of potassium are valuable in offsetting the acid effect of meat and other common protein foods in the body. In Nigeria the production of sweet potato is low compared with cassava and yams. Its total production of 240,000 tonnes is less than one per cent of the total production of the root crops (FAO, 1980).

1.2 Origin and Spread

Sweet potato is indigenous to the tropical Americas from where it was disseminated first to the tropical island of the Pacific and New Zealand (Hahn, 1977). Colombus introduced it into Europe in the 15 century and it was subsequently introduced into Africa by Spanish and Portuguese explorers and traders after 1500 AD (Yen, 1970). There is no record of its introduction into Nigeria.

1.3 Botanical Features

Sweet potato is a dicotyledonous plant belonging to the family Convulvulaceae. This family includes about 45 genera and 1000 species, but only Ipomoea batatas is of economic importance as a food crop (Onwueme, 1978). It is a herbaceous perennial plant, but is normally cultivated as an annual. Under cultivation it is usually propagated from vine (stem) cuttings. It has stems which are usually long and prostrate, but there are some varieties with short and erect stems.

1.4 Ecological Adaptation

Sweet potato requires at least 500mm of well distributed rain during its growing season, it does best however, in regions with 750 to 1000mm of rainfall per annum. It has a good drought tolerance but drought conditions during tuber initiation reduce yield considerably (Kay, 1973). The crop is sun-loving and does best where light intensity is relatively high. Daylength affects both flowering and tuber formation processes. Short days promote both flowering and tuber formation, while long days tend to favour vine development. It is grown in a variety of soils, but the ideal soil for its cultivation is a well drained sandy loam or loamy soils. A soil pH of 5.6 to 6.6 is preferred though it can still produce considerable yield in soils with lower pH values. Maximum yield is attained under a temperature of not less than 20°C. Growth is best on temperatures above 24°C, when temperature falls below 10°C growth is severely retarded (Onwueme, 1978).

1.5 Utilization

The most important use of sweet potato is as food for human beings either in its original form or as manufactured into flour or starch. In most developing countries, it is consumed immediately after harvest without any intermediate storage or processing as in the case with grain crops. It may be consumed after boiling, frying or roasting. The leaves

and tender shoots are eaten as vegetables in many parts of the tropics. The vines and tubers are also used as animal feed. Beside food, tubers are also used in the industries for the manufacture of starch, alcohol, vinegar, lactic acid, yeast, etc.

1.6 Yield

The present yield in Nigeria is about 4 tonnes per hectare (Chinaka, 1983). Low yield of sweet potato in Nigeria and many other tropical countries has been attributed to the use of unimproved varieties, lack of fertilization as farmers seldom apply fertilizer to this crop and inadequate agronomic practices. Efforts towards sweet potato improvement in the country have been more on the breeding and selection of high yielding varieties, while little has been done on the nutritional aspect of the crop. It is against this background that the present study was carried out to study the effect of nitrogen and phosphorus fertilizers and their interactions on the growth, yield and quality of two improved sweet potato varieties.

Chapter 2

LITERATURE REVIEW

2.1 Effect of Nutrients on Root Crops

Even though it has been observed that such crops as cassava and sweet potato can still produce modest yield on soils with low nutrient content, it still holds good for this as for all other tuber crops that adequate supply of nutrients must be placed at their disposal if they are to produce high yields corresponding to their high productivity. Therefore, fertilization of these crops particularly with the three major nutrients, nitrogen, phosphorus and potassium is indispensable.

Nitrogen application create a bulk of foliage and consequently an extensive assimilation area, the prerequisite for good development of tuber (Jacoby, 1965). However, heavy application of nitrogen without simultaneous application of phosphate and potash leads to rank growth of the vegetative portion and depresses yield and keeping quality of the tuber. In potato, Van Burg (1967) observed that increasing the rate of applied nitrogen stimulates the growth of the haulm and delays the start of tuber initiation. Gunaseno and Harris (1969) also reported that increasing nitrogen increased the proportion of leaf and stem in the total dry matter and decreased the proportion of the tubers.

Phosphorus is indispensable for the sound development of the root system. It promotes the process of ripening and is a decisive participant in the formation of starch in the tuber.

Root crops have a high potassium requirement, a deficiency of potassium not only leads to depression of yields as well as reducing the starch content, but it can also have an unfavourable influence on the commercial value of the tubers. Duncan et al. (1958) observed heavy losses in weight as well as fungal attack during storage of sweet potato in the absence of adequate potassium fertilization.

2.2 Effect of Nitrogen on Sweet Potato

2.2.1 Effect of nitrogen on sweet potato growth

Nitrogen is a major constituent of chlorophyll, plant protein and amino acids. Increasing its supply in the soil promotes vegetative growth by enhancing cell division and elongation. Excessive nitrogen promotes excessive vegetative growth at the expense of roots. While in plants deficient in nitrogen, the growth of the plant is gradually checked and remains stunted, the number of leaves decreases, leaves become smaller in size and are tinged with yellow and the length of the internodes is shortened (Spence and Ahmad, 1967). Lin and Wen (1956) in a fertilizer experiment in Taiwan, observed that nitrogen dressings primarily promoted the growth of tops and had less effect on

the production of tubers. According to Tsuno and Fujise (1964), nitrogen increases dry matter production by increasing leaf expansion of leaf area index and increases the distribution ratio of above-ground parts to under-ground parts. A linear relationship between nitrogen content and leaf area index and a linear decline in the net assimilation rate with increase in leaf area index was observed by Watson (1958); Fujise and Tsuno (1962) and Tsuno and Fujise (1965).

2.2.2 *Effect of nitrogen on yield component*

The main components of yield in tuberous crops are the number and mean weight of tubers which are directly related to the process of tuberization, that is tuber initiation and tuber growth (Togari, 1950; Wilson, 1970; Wilson and Lowe, 1973). According to Togari (1950) the initiation of the tuber first determines the number of tuberous roots, next cell division determines the size of the tubers. He further reported that large amount of soil nitrogen during the tuber initiation favours the production of non-tuberous roots.

Nambiar *et al.* (1976) observed that increasing applied nitrogen rate from 50 to 100 kg/ha significantly increased the number of tubers per plant. Bartolini (1982) reported that increasing the level of nitrogen from zero to 90kg N/ha reduced the number of marketable roots, which he attributed to the vigorous growth of the plant which produced more

vegetative part and lower yield.

2.2.3 Effect of nitrogen on yield

Evidence regarding the effect of nitrogenous fertilizer on sweet potato yield is conflicting, some researchers are of the view that soil rich in nitrogen or the use of nitrogenous fertilizer increased the production of vine but tuber yield declined (Togari, 1948; Van Den Abeele and Van Denput, 1958; Jacoby, 1965; Tsuno and Fujise, 1965 and Bartolini, 1982). Aldrich (1962) observed that application of 506kg of ammonium sulphate per hectare resulted in a highly significant reduction in yield and that though smaller application had less effect, it tended to give yield reduction.

On the other hand, various other researchers have observed a yield response to nitrogen application. Ware and Johnson (1949) in their studies with three soil types in USA to determine the effect of increasing application of available nitrogen, observed that with two of the soil types (Norfolk and Decatur soils), the marketable yield increased from zero to 135kg N/ha and with the Hartsell soils the marketable yield increased from zero to 101kg N/ha application. They concluded that sweet potato plant under favourable supplies of water responds to and requires relatively high application of available nitrogen for the production of high yields. Patterson and Speights (1962), reported from Texas, (USA) a response up to 107.6kg N/ha. Li (1970) in a study on the effect

of N, P and K on sweet potato observed that sweet potato tuber yields were increased from 21.70 t/ha with no fertilizer to 44.58 t/ha with 80kg N + 200kg K/ha in irrigated condition and from 19.02 t/ha no fertilizer to 38.31 t/ha with 80kg N + 200kg K in rainfed plots. Nandipuri et al. (1973) found that increasing nitrogen from 28 to 56kg/ha had resulted in a corresponding increase in total vine weight, root size and yield of sweet potato in India.

Other researchers however, have reported a significant response up to a certain level after which yields were either not significantly increased or were significantly reduced by the higher levels. A response of nitrogen rate from 50 to 100kg N/ha by 'Centennial' was reported by Miller and Covington (1982). They noted that increasing the nitrogen rate to 200 kg/ha did not produce further significant increase in yield. Similarly, Navarro and Padda (1983) recorded a yield increase with an application of 280kg N/ha but which decreased with application of 560kg N/ha which encouraged vine growth in sweet potato grown on Fedesborg clay loam. Hammet et al. (1984) also observed that root yields were higher with 101kg N/ha than with 202kg N/ha. Nwinyi and Emezie (1984), in their factorial experiment consisting of three levels of nitrogen, phosphorus and potash, observed that 45kg N, 0kg P_2O_5 and 140kg K/ha gave the highest fresh and saleable tuber yield and 90kg N/ha gave the highest vine yield.

Landrau and Samuels (1951) on the other hand experimented with rates of N as high as 177.5 kg/ha and found no consistent difference in yield of 'Porto Rico' potato.

So far as response to nutrients, mainly to nitrogen is concerned, varieties play an important role. Some varieties respond to high levels of nitrogen whereas other varieties do not respond very much and others give a negative response. Togari (1948) and Tsuno and Fujise (1965) have observed that the response of heavy application of nitrogen differs according to variety; in some varieties a high yield is obtained with high nitrogen application without causing over-growth of the aerial part, while in others the yield of tubers decreased drastically with increase in nitrogen application due to too much top growth. Togari (1948) in his experiment reported that in 'Okinawa No. 100' with which runner weight does not greatly increase with heavy N application, there was a slight increase in yield even when 90kg N/ha was applied compared with 30kg N/ha control. On the other hand, in 'Tsuranashi Genji' with which increased N caused over-growth of aerial parts, the yield did not change by N application treatment between 15 to 60kg N/ha and decreased in the 90kg N/ha treatment. Bourke (1992) also observed an inconsistent response to nitrogen fertilizer

treatments which according to him was caused by nitrogen cultivar interaction, with nitrogen giving increased tuber yield in some cultivars and a decrease in others.

Haynes (1971) has grouped sweet potato varieties into three according to their nitrogen responses into those that have a positive response to nitrogen application, those with negative response and those that have no response.

2.2.4 Effect of nitrogen on tuber quality

The protein and starch content of tubers have been shown to be associated with applied nitrogen fertilizer by some researchers. Constantin et al. (1974) found that increasing increment of N from zero to 101 kg/ha resulted in increased firmness and protein content of 'Centennial' roots, but found no effect on dry matter. Li (1982) has also observed an increase in protein content from 4.3 to 5.3 per cent by application of 50 and 150 kg/ha of nitrogen, respectively. Walter et al. (1984) have also reported that for 'Jewel' and 'Centennial' an increase in nitrogen application from zero to 112 kg/ha increased protein content without adversely affecting yield. Similarly, Constantin et al. (1984) reported that contents of dry matter, carotenoids and protein increased linearly with nitrogen application when three sweet potato cultivars were grown under five different N regimes.

The protein content of sweet potato vary from cultivar to cultivar and from field to field. Purcell et al. (1976) observed variation of crude protein content of 4.1 to 8.8 per cent from one location to the other. Li (1982) also found a highly significant difference in protein content of roots varying with varieties and nitrogen levels.

The level of nitrogen fertilization affects the starch content of the roots (Bartolini, 1982). He observed that increasing the level of nitrogen fertilizer seemed to result in an increase in the percentage starch content of the roots.

2.3 Effect of Phosphorus on Sweet Potato

2.3.1 Effect of phosphorus on sweet potato growth

Phosphorus is one of the three major nutrients required by the sweet potato crop. It is required as a small but vital ingredient in nucleo-protein. It is a constituent of cell nuclei and is essential for cell division and growth. The effect of phosphorus on crops is manifested in earliness in plant maturity and improvement in crop quality. It is indispensable for the sound development of the root system. It promotes the process of ripening and is a decisive participant in the formation of starch in the tubers. Its deficiency results in reduced leaf size, the leaf turn dark green and become less glossy

and elongation of stem is checked. Spence and Ahmad (1967) induced P deficiency in sweet potato in their water culture experiment. The deficiency symptoms appeared when the P content was lowered to 0.12 per cent in the dry matter of plant tissue and serious deficiency symptoms were observed when P content was below 0.11 per cent.

2.3.1 Effect of phosphorus on yield and yield components

In experiments conducted in various parts of Japan, Togari (1940) found that yield of sweet potato was not affected by phosphorus application. Patterson and Speight, (1962); Li (1970); Anon (1975); Anon (1977) and Navarro and Padda (1983) have the same view as that of Togari (1940).

Hammet et al. (1982) also reported that sweet potato cultivar 'Centennial' did not respond to 15, 30, 45 or 60kg P/ha over an 8 year period when grown in a silt loam, which they attributed to low soil pH and relatively high native P. levels.

On the other hand, Stino and Lashin (1953) in the Nile delta, Egypt, found an increase in yield of tuber due to P treatment and further, the runner weight (vine) increased with P application. Similarly, Uriyo and Kesseba (1973) obtained a yield increase with increase in rate of P from 0 to 50kg applied alone or in combination with 50 or 100kg K/ha on red oxisol soil in Tanzania.

Phosphorus application has also been reported to reduce the protein content of the tuber, but has no effect on tuber dry matter, (Constantin et al. 1977). Hammet et al. (1982) have also observed a reduction in tuber protein as percentage of dry weight with an increase in P rate.

According to Tsuno (1973) the effect of P fertilization must be judged from the view point of tuber quality. When P fertilizer is applied, sweet potatoes become longer in shape, increase in sweetness and have a mealier texture.

2.4 Fertility Status of Savanna Soils

2.4.1 Nitrogen status of savanna soils

Soils in the savanna region of Nigeria are usually low in fertility (Watson, 1963; Jones, 1974). Over half of the soils are ferruginous tropical soils which are generally low in nitrogen. According to Jones and Wild (1975) the total nitrogen content of savanna soils ranges from 0.008 to 0.29 per cent. Consequently savanna soils often respond to nitrogen fertilizer application. This has also been confirmed by Goldsworthy (1967); Jones (1973a) and Olagunde and Egharevba (1981).

The low level of nitrogen in savanna soils has been closely linked with the generally low organic matter content of the soils. Jones (1973b) found the carbon mean value of the soil to be 0.68 per cent. Soil mineral nitrogen is obtained as

a result of decomposition of soil organic matter which is low as a result of the long severe dry season aggravated by the annual grass burning which causes a general decrease in the vegetation (Ahn. 1970). Rainfall is another important factor which affects the organic matter content of the soil (Jones, 1973b). The small and short duration rainfall of the savanna sustains little vegetation and for a very short time and organic matter content of the soil decrease with decreasing rainfall. Thus savanna soils which are low in organic matter content (Ahn. 1970; Jones 1973b), are equally poor in mineral nitrogen.

2.4.2 Phosphorus status of savanna soils

Phosphorus is one of the two major nutrients limiting crop production in the savanna zone (Mokwunye, 1979; Ologunde and Egharevba, 1981). The savanna soils total phosphate content are generally low. Goldsworthy and Heathcote (1963) reported a mean value of 107ppm in a total of 54 samples from unfertilized farmers plots, while Enwezor and Moore (1966) observed a slightly higher value of 110 as determined from a total of 14 samples. Jones and Wilds (1975) reported that the total phosphorus content of these soils ranged from 13ppm to 630ppm. While Mokwunye (1979) found that the total phosphorus content in savanna soils ranged from 100ppm to about 400ppm. He estimated that less than 10 per cent of the total phosphorus is in the active Al-P, Fe-P and Ca-P forms.

The available phosphorus status of the savanna soils is influenced by the low content of total phosphorus and its parent material. Uyovbisere (1979) has attributed the low phosphorus content of the savanna soils to its parent material which consists mainly of schists, granite, gneiss and sandstone all of which have **low appetite content.** Other factors which influence the available phosphorus status are loss of top soil through erosion, deposition of wind blown sand which may give a surface deposit low in phosphate and vegetation and climate. Soil phosphate content are higher in the forest zone than in the tall-grass savanna and are lowest in the semi arid soils of the north (Jones and Wild, 1975). These differences follow the same pattern as those of the organic carbon and nitrogen.

Chapter 3

MATERIALS AND METHODS

3.1 Experimental Site

The experiment was conducted during the wet season (June to November) of 1984 at the University Farm, Samaru (Lat. 11° 11' N, Long. 07 38' E and 686m above sea level). The soil of the experimental field was a well drained sandy loam; derived from a crystalline basement complex (Tomlison, 1965). Analysis of the soil showed that it was low in native nitrogen and medium in available phosphorus. Data on the physico-chemical properties of the soil are given in Table 1.

3.2 Treatments and Experimental Design

The experiment was laid out in a randomised complete block design with factorial arrangement and having the following treatments:

Three nitrogen levels (0, 60 and 120kg N/ha) each was tried at three different levels of phosphorus (0, 30 and 60kg P_2O_5/ha) and for two varieties (TIS 9265 which is a white skinned variety that matures in 130 days and TIS 2498 which is a red skinned variety that matures in 160 days). Thus the total treatment combination of 3 x 3 x 2 = 18. Each treatment was replicated three times. The gross and net plot sizes were 4.5 x 3.75 and 4.5 x 1.5m, respectively.

Table 1. The Physico-chemical properties of the soil of the experimental site.

Soil Characteristics	0 - 15cm	15 - 30cm
pH		
in water	5.90	5.40
in $CaCl_2$	5.30	5.00
Exchangeable Cations (Meq/100g)		
Ca	2.495	2.495
Mg	0.757	0.757
K	0.486	0.512
Na	0.113	0.096
C.E.C. (Meq/100g)	7.50	6.80
Organic carbon (%)	0.65	0.64
Total N	0.060	0.050
Available P (ppm)	7.00	4.55
Physical Classification		
% Clay	6	10
% Silt	42	38
% Sand	52	52
Textural class .. Sandy loam		

3.3 Field Operations

3.3.1 Land preparation

The experimental field was ploughed and harrowed and a composite soil sample taken from two depths (0 to 15cm and 15 to 30cm) prior to fertilizer application and analysed for its physical and chemical properties. A basal application of 100kg K_2O/ha was broadcasted as muriate of potash prior to ridging. Ridges were made 75cm apart.

Phosphatic fertilizer was applied at planting and the nitrogenous fertilizer was applied in two equal split doses, half at planting and the other half six weeks after planting (WAP). The fertilizers were applied in a shallow groove along the rows about 10cm from the plant and 5cm deep and covered well with soil. Calcium ammonium nitrate (CAN 26% N) and Single Superphosphate (SSP 18% P_2O_5) were used as sources of nitrogen and phosphorus, respectively.

3.3.2 Planting

Vine cuttings of about 30cm in length having four to five nodes were planted at 30cm apart on ridges in a slanting form at an angle of approximately 45^{o} with about one-half to two thirds of its length beneath the soil. The vine cuttings were brought from International Institute of Tropical Agriculture (IITA), Ibadan, on 17 June and planting was done on 18 June, 1984.

3.3.3 Weed control

Two hoe-weedings were done at two and six WAP. Thereafter complete canopy covered the interspaces which suppressed further weed growth.

2.3.4 Harvesting

Harvesting was done after 22 weeks by digging out the tubers from under ground before the soil became too hard.

3.4 Data Collection

3.4.1 Meteorological data

Data on rainfall distribution, temperatures figures and sunshine hours for Samaru during the expxrimentation period were collected and are presented in Appendices A, B and C, respectively.

3.4.2 Growth characteristics

Assessment for growth study was started at four WAP. Samplings for dry matter production were taken at 4, 6, 8, 12 and 16 WAP. Two plants were sampled from each plot and their stem, leaf (lamina and petiole) and root dry weight were determined by oven-drying to a constant weight at $70^{o}C$. Total dry weight of the whole sample was determined by addition of all parts mentioned above. At harvest five plants were sampled from each plot and the length of vine and number of branches per plant were determined.

Leaf area index (LAI) was determined at each sampling using the following formular suggested by Watson (1958):

$$LA_t = \frac{a + b}{c} \times d \ (m^2)$$

where a = weight of discs

b = weight of remaining laminae

c = number of discs

d = sample disc area in m^2.

Twenty fresh leaves were randomly taken and their laminae detached. The laminae were placed on top of each other and a cork borer with an area of $2.5cm^2$ was pressed through these leaves so that complete leaf discs were formed. The discs and the remaining leaves were then dried. The weight of the discs was determined. The area per unit weight of lamina was calculated from the number of discs, the known area per disc and the weight of the discs. It was then multiplied by the weight of the dry laminae in the sample to give total area per sample. LAI was calculated using the equation:

$$LAI = \frac{LA_t \times P}{n}$$

where P = number of plants per square meter

n = number of plants sampled.

Crop growth rate (CGR) and tuber growth rate (TGR) were calculated using the following formulae:

$$CGR = \frac{W_2 - W_1}{t_2 - t_1} \ g/m^2/day$$

$$TGR = \frac{R_2 - R_1}{t_2 - t_1} \ g/m^2/day$$

where W_1 - total dry weight at time t_1

W_2 - total dry weight at time t_2

R_1 - root dry weight at time t_1

R_2 - root dry weight at time t_2

3.4.3 Yield and yield components

Total tuber yield, marketable and cull yields were determined per plot and were converted to per hectare therefrom. The mean total number of tubers, number of marketable tubers (i.e. tubers weighing more than 140g) and number of cull tubers (i.e. tubers weighing less than 140g) per plant were also counted. Tuber dry weight percentage was determined by drying samples in the oven at $70^{o}C$ for 72 hours. Mean tuber weight and mean marketable tuber weight per plant were determined by dividing the number of tubers and number of marketable tubers per plant by total yield and marketable yield per plant, respectively. An analysis of the yield response to nitrogen and phosphorus was conducted to determine the effect of both linear and quadratic responses and their contribution to yield variability.

3.4.4 Tuber quality

Protein content: Protein content was determined on dry weight basis using the Kjeldahl method, where total N per cent was determined and was multiplied by a factor of 6.25 to get the crude protein percentage.

Starch content: Starch content (on dry weight basis) was determined using the calorimetric determination method as described by Allen et al. (1974).

Cooking quality: Tubers from the same entry in the field experiment were combined and sampled for the purpose of determining the cooking and frying qualities of sweetness and texture. Tubers were boiled and fried and were served to 12 tasters who assessed each treatment on its sweetness and texture on a scale as follows:

Sweetness	1	- not sweet
	2	- slightly sweet
	3	- moderately sweet
	4	- very sweet
Texture	1	- very moist
	2	- moist
	3	- intermediate
	4	- dry (firm)

3.5 Analysis of Data

An analysis of variance was done to test the treatment effects for significance using the 'F' test as described by Snedecor and Cochran (1967). The effects of nitrogen and phosphorus and their interactions in all parameters measured were of primary interest. Where 'F' test showed significance, means of such main effects and interaction effects were compared using the least significant difference (LSD) and Duncan's multiple range tests (DMRT), respectively.

Chapter 4

RESULTS

4.1 Effect of Nitrogen, Phosphorus and Variety on Growth of Sweet Potato

As the sweet potato tuber itself is a vegetative part, therefore, various growth indices such as dry weights of leaf, stem and total dry matter, number of branches and length of vine at harvest, leaf area index, crop growth rate and tuber growth rate all contributed to tuber weight, hence they were recorded and analysed statistically.

4.1.1 Leaf dry weight

Data recorded on leaf dry weight as influenced by nitrogen, phosphorus and variety at 4, 6, 8, 12 and 16 WAP are presented in Table 2. Statistical analysis of the data revealed that differences due to nitrogen levels at the initial stage of growth (4 WAP)were not statistically significant. However, the differences in the mean nitrogen levels were highly significant at all the other stages of growth. At 6 WAP the differences between control and 60kgN/ha on one hand and 60 and 120kg N/ha on the other were not significant statistically but the highest level of 120kg N/ha resulted in significantly higher leaf dry weight when compared with the control. At 8 WAP the difference between 60 and 120kg N/ha was not significant statistically. The mean

Table 2. Leaf dry weight (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru, in 1904.

Treatment	Weeks After Planting				
	4	6	8	12	16
N (kg/ha)					
0	23.3	100.5a[1]	173.0b	261.2c	183.6c
60	24.6	137.9ab	242.0a	361.1b	241.0b
120	30.1	169.0a	265.5a	420.6a	317.6a
SE(±)	3.30	11.69	16.13	20.40	17.11
P_2O_5 (kg/ha)					
0	25.0	125.2	212.5	337.3	249.4
30	25.4	139.0	225.6	349.3	239.5
60	27.7	150.5	243.7	356.4	253.4
SE(±)	3.30	11.69	16.13	20.40	17.11
Variety					
TIS 9265	22.5	130.4	223.1	319.0b	212.9b
TIS 2498	29.6	146.4	231.6	375.5a	282.0a
SE (±)	2.70	9.54	13.17	16.66	13.97

[1]Means followed by the same letter with a treatment are not significantly different at 5% level of significance.

differences due to nitrogen level both at 12 and 16 WAP were similar. Each increment in nitrogen level significantly increased the leaf dry weight. The differences in means due to application of phosphorus did not reach the levels of significance in all stages of sampling. Similarly the differences between the two varieties under study were not significant up to 8 WAP and these were significant (P = 0.05) at 12 and 16 WAP. Variety TIS 2490 yielded significantly higher leaf dry weight then TIS 9265. All the first order of interaction between nitrogen x phosphorus, nitrogen x variety and phosphorus x variety and the second order of interaction among nitrogen x phosphorus x variety were not significant statistically.

4.1.2 Stem dry weight

Data in Table 3 show the effect of nitrogen, phosphorus and variety on the stem dry weight at 4, 6, 8, 12 and 16 WAP. Statistical analysis of the data indicated that differences due to nitrogen levels were not significant statistically at 4 and 6 WAP. These were highly significant at 8 and 12 WAP and significant at 16 WAP. The differences on the stem dry weight were also more or less similar to leaf dry weight wherein these differences were not significant statistically in the initial stages of 4 and 6 WAP, but differences in nitrogen means were highly significant at 8 and 12 WAP and significant at 16 WAP. At 8 WAP the highest level of

Table 3. Stem dry weight (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru, in 1984.

Treatment	Weeks After Planting				
	4	6	8	12	16
N (kg/ha)					
0	11.9	59.4	113.7b	294.1b	252.2c
60	12.4	60.9	135.1b	396.5a	372.3b
120	13.3	76.5	160.8a	445.4a	495.3a
SE(±)	1.00	6.46	7.57	23.08	36.01
P_2O_5 (kg/ha)					
0	12.1	62.3	125.1	371.3	379.3
30	12.4	60.0	142.0	304.7	359.1
60	12.9	74.4	147.5	390.1	381.4
SE(±)	1.00	6.46	7.57	23.08	36.01
Variety					
TIS 9265	12.6	77.0a[1]	141.6	339.7b	351.4
TIS 2498	12.4	59.5b	134.8	424.3a	395.1
SE(±)	0.82	5.28	6.18	19.50	29.40

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

120kg N/ha produced significantly higher stem dry weight over the control and 60kg N/ha rate. The difference between 0 and 60kg N/ha was not significant. At 12 WAP application of both 60 and 120kg N/ha increased the stem dry weight over the control. The difference between the two levels was not significant statistically. At 16 WAP each increment in nitrogen level significantly increased the stem dry weight. Differences due to application of phosphorus on stem dry weight were not significant at all the sampling stages.

Differences between the two varieties were significant at 6 WAP and highly significant at 12 WAP. Variety TIS 9265 produced significantly higher stem dry weight at 6 WAP. It also produced a higher stem dry weight at 4 and 8 WAP, but the differences were not significant. At 12 and 16 WAP variety TIS 2498 produced higher stem dry weight, but was significant only at 12 WAP. The interaction effects between nitrogen x phosphorus, nitrogen x variety and phosphorus x variety and among nitrogen x phosphorus x variety were not significant statistically.

4.1.3 Root dry weight

Result of the effect of nitrogen, phosphorus and variety on root dry weight at 4, 6, 8, 12 and 16 WAP are shown in Table 4. Root dry weight at 4 WAP was very small but it progressively increased with the stage of growth. The differences due to nitrogen were not significant

Table 4. Root dry weight (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru in 1904.

Treatment	Weeks After Planting				
	4	6	8	12	16
N (kg/ha)					
0	1.9	12.3	52.1	195.7b[1]	475.4b
60	2.0	11.9	65.3	204.4a	645.7a
120	2.0	10.5	61.5	250.9a	540.0b
SE(±)	0.24	1.17	5.39	12.54	35.59
P_2O_5 (kg/ha)					
0	1.9	11.7	54.9	246.3	530.7
30	1.9	11.4	58.6	254.4	596.9
60	2.0	11.6	65.6	238.3	525.4
SE(±)	0.24	1.17	5.39	12.54	35.59
Variety					
TIS 9265	1.6	11.1	62.1	231.8	407.3b
TIS 2498	2.2	12.0	57.3	260.8	620.1a
SE(±)	0.20	1.39	4.40	10.24	29.06

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

statistically up to 8 WAP, but thereafter, these differences were highly significant at both 12 and 16 WAP. The significance of the root dry weight was similar at both sampling stages that is application of nitrogen recorded significantly higher root dry weight than control and the difference between 60 and 120kg N/ha application was not significant statistically.

Phosphorus application had no significant influence on root dry weight at all the sampling stages. The varietal differences were not significant at all stages except at 16 WAP, where variety TIS 2498 recorded higher root dry weight than TIS 9265. None of the treatment interactions between the first order of interaction and among the second order of interaction was significant statistically.

4.1.4 Total dry matter

Data on the effect of nitrogen, phosphorus and variety on total dry matter production (stem, leaf and root) at 4, 6, 8, 12 and 16 WAP are shown in Table 5.
Close examination of the data revealed that differences due to nitrogen application at 4 WAP were not significant, these were significant at 6 and 8 WAP and highly significant at 12 and 16 WAP. At 6 WAP the nitrogen treatments fall into two non-significant groups of 0 - 60 and 60 - 120kg N/ha, the highest level of 120kg N/ha resulted in a significantly higher total dry matter when compared with the control. At

Table 5. Total dry matter (g/m^2) of sweet potato at different sampling stages as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Weeks After Planting				
	4	6	8	12	16
N (kg/ha)					
0	36.7	180.2b[1]	340.7b	756.7b	911.2b
60	39.0	218.0ab	433.1a	1042.0a	1270.7a
120	48.3	256.0a	492.9a	1135.5a	1352.9a
SE(±)	4.41	18.63	22.31	32.92	72.73
P_2O_5 (kg/ha)					
0	38.2	198.9	392.5	954.9	1167.4
30	40.7	218.4	426.1	988.3	1215.2
60	45.1	236.5	440.1	991.0	1160.2
SE(±)	4.41	18.63	22.31	32.92	72.73
Variety					
TIS 9265	38.3	218.5	420.7	891.7b	1051.5b
TIS 2498	44.4	217.6	423.7	1064.4a	1310.3a
SE(±)	3.60	15.21	18.21	26.88	59.30

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

8 WAP nitrogen increment progressively increased the total dry matter. At 12 and 16 WAP, the response of nitrogen was similar in respect to total dry matter, control resulted in a significantly lower total dry matter when compared with the two level of nitrogen application and the differences between 60 and 120kg N/ha were not significant statistically.

Differences due to phosphorus levels under trial were not significant statistically at all the sampling stages. Similarly the differences between the two varieties were not significant at the initial stages, but these differences were highly significant at 12 and 16 WAP. Variety TIS 2490 yielded significantly more total dry matter than the other variety. The interaction effects between the first order of interaction and among the second order of interection were not significant statistically.

4.1.5 Length of vine at harvest

Result of the effect of nitrogen, phosphorus and variety on the length of vine and number of branches at harvest are shown in Table 6. An analysis of the result indicated that differences due to nitrogen on length of vine were highly significant. Each increment in nitrogen level significantly increased the length of vine.

Differences due to phosphorus levels were not significant statistically. Similarly there was no significant

Table 6. Length of vine and number of branches per plant at harvest of sweet potato as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Length of Vine (m)	Number of Branches per plant
N (kg/ha)		
0	3.4c[1]	12.2b
60	4.1b	15.6b
120	5.1a	19.0a
SE(±)	0.15	1.74
P_2O_5 (kg/ha)		
0	4.2	15.7
30	4.1	15.7
60	4.4	15.4
SE(±)	0.15	1.74
Variety		
TIS 9265	4.2	13.9
TIS 2498	4.2	17.3
SE(±)	0.12	1.42

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

difference between the two varieties on the length of vine at harvest. None of the interaction effects between the first order of interaction and among the second order of interaction was significant statistically.

4.1.6 Number of branches at harvest

Result of the effect of nitrogen, phosphorus and variety on number of branches revealed that differences due to nitrogen application were significant at (P = 0.05). Application of 120kg N/ha rate produced a significantly higher number of branches compared with the 60kg N/ha and the control. Application of 60kg N/ha, however, did not result in a significantly higher number of branches when compared with the control.

Increasing the phosphorus level had no significant effect on the number of branches. The varietal difference was also not significant statistically. Also none of the interactions between the first order and among the second order of interactions was significant statistically.

4.1.7 Leaf area index

Data on LAI as influenced by nitrogen, phosphorus and variety are presented in Table 7. An examination of the data indicated that LAI increased from 4 WAP to a maximum at 12 WAP, after that there was a drop at 16 WAP. Differences due to nitrogen levels were not significant at

Table 7. Leaf area index of sweet potato at 4, 6, 8, 12 and 16 WAP as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Weeks After Planting				
	4	6	8	12	16
N (kg/ha)					
0	0.6	2.0b[1]	3.2b	4.5c	3.1c
60	0.7	2.6b	4.0ab	6.0b	3.9b
120	0.8	3.2a	5.1a	7.1a	4.9a
SE(±)	0.10	0.20	0.29	0.34	0.20
P_2O_5 (kg/ha)					
0	0.6	2.4	3.8	5.5	3.8
30	0.7	2.7	4.2	6.0	4.0
60	0.7	2.8	4.3	6.2	4.1
SE(±)	0.10	0.20	0.29	0.34	0.20
Variety					
TIS 9265	0.6	2.3b	3.9	5.4b	3.6b
TIS 2490	0.8	2.6a	4.3	6.4a	4.4a
SE(±)	0.00	0.16	0.24	0.28	0.23

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

4 WAP, but were highly significant at all the other sampling stages. At 6 WAP the difference between the control and 60kg N/ha was not significant, but application of 120kg N/ha resulted in a significantly higher LAI than the two levels. At 8 WAP the difference between control and 60 and 60 and 120kg N/ha was not significant statistically but the highest level of 120kg N/ha resulted in a significantly higher LAI when compared with control. The mean differences due to nitrogen levels both at 12 and 16 WAP were similar, each increment in nitrogen level significantly increased the LAI.

Differences in mean due to phosphorus application on the LAI were not significant at all the sampling stages. Differences between the two varieties were not significant at 4 and 8 WAP, significant at 12 and 16 WAP and highly significant at 6 WAP. Variety'TIS 2498'produced a significantly higher LAI than 'TIS 9265'. The interaction effects between the first order of interaction and among the second order of interaction were not significant statistically.

4.1.8 Crop growth rate

Table 8 shows the effect of nitrogen, phosphorus and variety on crop growth rate at different sampling stages. In all the treatments, CGR increase from 4 WAP to 12 WAP after which it dropped at 16 WAP showing a pattern similar to LAI. Differences in means due to nitrogen application

Table 8. Crop growth rate ($g/m^2/day$) of sweet potato at 4, 6, 8, 12 and 16 WAP as influenced by nitrogen, phosphorus and variety at Samaru, in 1984.

Treatment	Weeks After Planting				
	4	6	8	12	16
N (kg/ha)					
0	1.3	10.4	11.5	14.9b[1]	5.5
60	1.3	12.9	15.4	21.8a	8.5
120	1.7	14.9	16.9	23.0a	7.8
SE(±)	0.16	1.29	1.96	1.03	2.19
P_2O_5 (kg/ha)					
0	1.3	11.6	13.0	20.1	7.6
30	1.4	12.8	14.8	20.1	8.1
60	1.6	13.8	15.1	19.4	6.1
SE(±)	0.16	1.29	1.96	1.03	2.19
Variety					
TIS 9265	1.3	13.1	14.5	16.8b	5.7
TIS 2498	1.6	12.7	14.7	22.9a	8.8
SE(±)	0.13	1.05	1.60	0.84	1.79

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

did not reach the level of significance at all the stages sampled except at 12 WAP. At 12 WAP application of 60kg N/ha significantly increased the CGR; a further increase in nitrogen level to 120kg N/ha did not increase the CGR significantly when compared with the 60kg N/ha level.

Application of phosphorus levels did not significantly increase the CGR at all the sampling stages. The differences between the two varieties were not significant at 4, 6, 8 and 16 WAP, but were highly significant at 12 WAP. Variety TIS 2498 produced a higher CGR than TIS 9265. None of the interaction effects was significant statistically.

4.1.9 Tuber growth rate

Data on tuber growth rate at 8, 12 and 16 WAP as influenced by nitrogen, phosphorus and variety are presented on Table 9. A close look at the data showed that differences due to nitrogen levels were not significant at 8 and 16 WAP and were highly significant at 12 WAP. At 12 WAP application of 60kg N/ha significantly increased the tuber growth rate over the control, while application of higher rate (120kg N/ha) did not increase the tuber growth rate over the 60kg N/ha level.

Differences due to phosphorus levels were not significant statistically. The differences between the two varieties were not significant at 8 and 16 WAP, but at 12 WAP the difference was significant at (P = 0.05). Variety TIS 2498

Table 9. Tuber growth rate ($g/m^2/day$) of sweet potato at 8, 12 and 16 WAP as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Weeks After Planting		
	8	12	16
N (kg/ha)			
0	2.9	5.1b[1]	10.0
60	3.8	7.0a	12.9
120	3.7	7.1a	10.0
SE(±)	0.38	0.46	1.34
P_2O_5 (kg/ha)			
0	3.1	6.8	10.4
30	3.4	7.0	12.2
60	3.4	6.2	10.3
SE(±)	0.30	0.46	1.34
Variety			
TIS 9265	3.7	6.1b	9.1
TIS 2498	3.3	7.3a	12.8
SE(±)	0.31	0.37	1.09

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

produced a higher TGR than TIS 9265. The interaction effects between the first order of interaction and among the second order of interaction were not significant statistically.

4.2 Effect of Nitrogen, Phosphorus and Variety on Yield and Yield Components

4.2.1 Total tuber, marketable and cull yields

Total tuber yield (t/ha) increased from 19.4 in the control to 30.7 and 23.4 t/ha in plots fertilized with 60 and 120kg N/ha, respectively, (Table 10). The highest total yield of 30.7 t/ha was recorded by the application 60kg N/ha, this was followed by the 120kg N/ha which was at par with the control. The percentage increase in yield due to increase in nitrogen from 0 - 60kg N/ha was 58.2 per cent but increasing it to 120kg N/ha yielded only 20.6 per cent higher than the control. Similarly the marketable yield was significantly increased by raising the nitrogen level from 0 to 60kg N/ha. A further increase in the nitrogen level to 120kg N/ha reduced the yield significantly but was at par with the control. The result of the effect of nitrogen on cull yield revealed that inceasing the nitrogen level had no significant influence on cull yield.

Increasing the phosphorus level had no significant effect on total, marketable and cull yields. A significantly higher total yield was obtained by variety TIS 2498 as compared

Table 10. Mean total tuber, marketable and cull yield (t/ha)of sweet potato as influenced by nitrogen, phosphorus and variety, at Samaru in 1984.

Treatment	Yields (t/ha)		
	Total	Marketable	Cull
N (kg/ha)			
0	19.4b[1]	12.5b	6.9
60	30.7a	21.9a	8.8
120	23.4b	14.5b	9.0
SE(±)	1.53	1.40	0.94
P_2O_5 (kg/ha)			
0	24.5	16.1	8.4
30	25.8	16.6	9.1
60	23.3	16.1	7.2
SE(±)	1.53	1.40	0.74
Variety			
TIS 9265	21.7b	14.2b	7.5
TIS 2498	27.4a	18.4a	9.0
SE(±)	1.25	1.18	0.61

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

with TIS 9265. The overall mean yield of TIS 2498 (27.4 t/ha) was 26.3 per cent higher than the yield of TIS 9265 (21.7 t/ha). Similarly variety TIS 2498 produced a significantly higher marketable yield (18.4 t/ha) compared with TIS 9265 (14.2 t/ha). The varietal difference on cull yield was not significant statistically. The interaction effects between all the first order of interactions and among the second order of interaction on total, marketable and cull yields were not significant statistically.

An analysis of the sweet potato response to nitrogen and phosphorus on total tuber yield was conducted. The observed and estimated tuber yields at different levels of fertilizers and for both linear and quadratic responses are shown on Table 11. Response of sweet potato to nitrogen revealed that quadratic response was highly significant. The coefficient of determination (R^2) indicated that only 12.9 per cent of the variation was accounted by linear response out of a total of 99.9 per cent of variability which was accounted by both linear and quadratic; quadratic response contributed 87.0 per cent of the variability. Similar analysis on phosphorus indicated no significant response due to phosphorus levels although linear response contributed 23.3 per cent out of total of 98.7 per cent of the total variation. From a regression analysis of the nitrogen response, the optimum nitrogen rate for maximum tuber yield lies between 60 and 70kg N/ha (Fig. 1).

Table 11. Observed and estimated sweet potato yield as influenced by nitrogen and phosphorus at Samaru in 1984.

Treatment	Tuber yield (t/ha)		
		Estimated	
	Observed	Linear	Quadratic
N (kg/ha)			
0	19.4	22.4	19.3
60	30.7	24.5	30.6
120	23.5	26.6	23.4
*R^2	-	0.129	0.870
P_2O_5 (kg/ha)			
0	24.5	25.1	
30	25.8	24.5	24.5
60	23.3	23.9	25.0
R^2		0.233	0.754

*Multiple coefficient of determination.

Analysis of variance of linear and quadratic response to nitrogen and phosphorus application in sweet potato at Samaru in 1984.

Source of variation	DF	SS	MS	F
Block	2			
Nitrogen - Linear	1	152.03	152.03	3.59
Quadratic	1	1024.53	1024.53	24.19**
Phosphorus - Linear	1	12.32	12.32	0.29
Quadratic	1	40.19	40.19	0.95
Error (npv-1) (b-1)	34	1440.29	42.36	

** Significant at 1% level

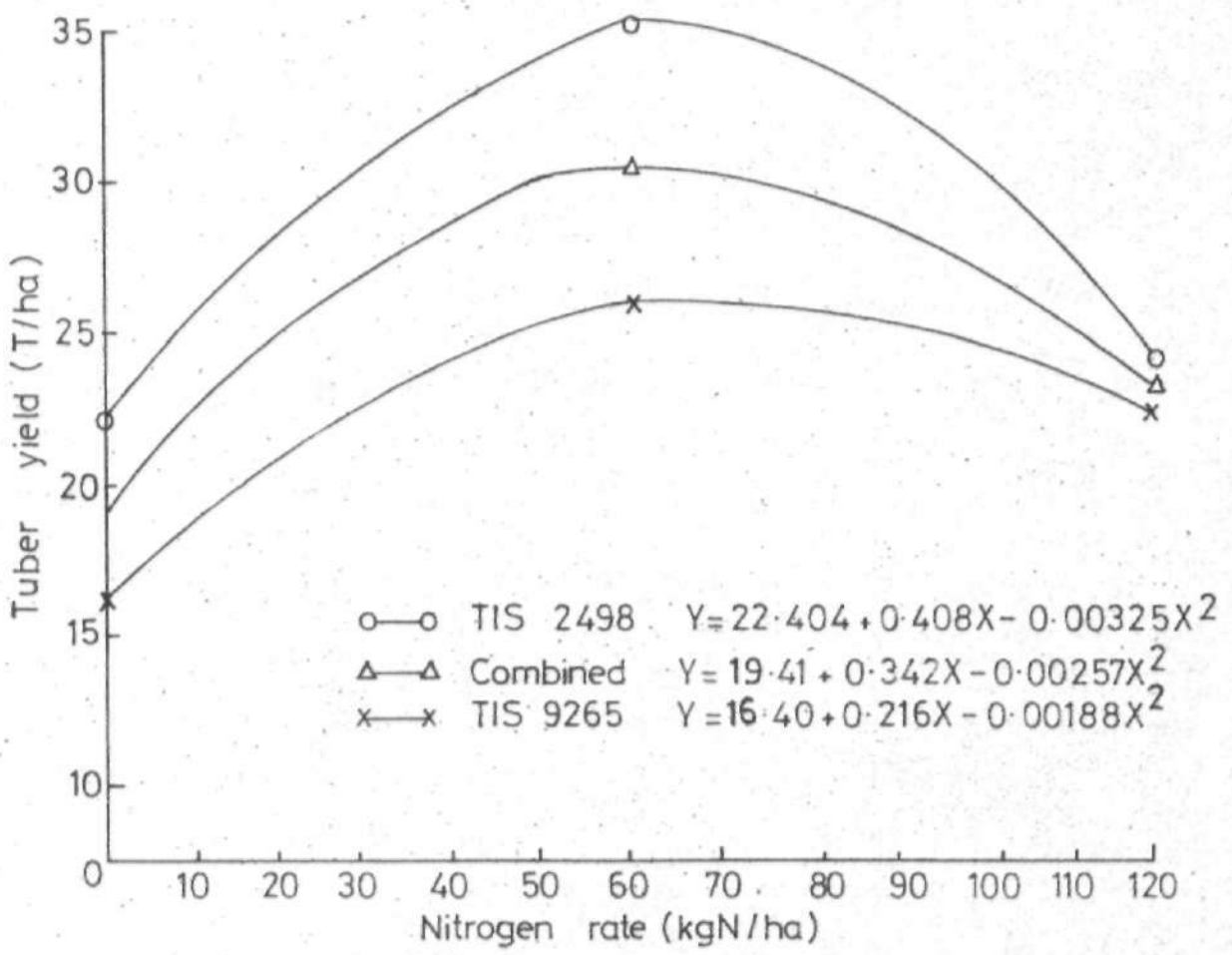


Fig. 1. Response of sweet potato to nitrogen application at Samaru in 1984.

4.2.2 Mean total number of tubers, number of marketable and cull tubers per plant.

The influence of nitrogen, phosphorus and variety on mean number of tubers, marketable and cull tubers per plant is shown in Table 12. Application of 60kg N/ha resulted in a slight increase in total number of tubers per plant which was not significantly different compared with the control. However, application of 120kg N/ha significantly reduced the number of tubers per plant compared with the control and the 60kg N/ha level. The effect of nitrogen on number of marketable tubers per plant was similar to that of total number of tubers per plant. Application of 60kg N/ha level produced statistically the same number of marketable tubers as the control, while increasing the nitrogen level to 120kg N/ha significantly reduced the number of marketable tubers per plant. However, the number of cull tubers per plant was not influenced by the application of nitrogen.

Raising the phosphorus level had no significant effect on total number of tubers, number of marketable and cull tubers per plant, respectively. Variety TIS 2498 produced a significantly higher number of tubers over TIS 9265. Similarly a significantly higher number of marketable tubers were obtained in variety TIS 2498 as compared with TIS 9265, while the varietal difference on number of cull tubers was not significant statistically.

Table 12. Mean total number, marketable and cull tubers per plant of sweet potato as influenced by nitrogen, phosphorus and variety, at Bamaru in 1984.

Treatment	Number of tubers per plant		
	Total	Marketable	Cull
N (kg/ha)			
0	5.8a[1]	2.3a	3.5
60	6.7a	2.5a	4.1
120	4.7b	1.3b	3.3
SE(±)	0.32	0.13	0.32
P_2O_5 (kg/ha)			
0	5.7	2.1	3.6
30	5.6	2.1	3.5
60	5.8	2.0	3.8
SE(±)	0.32	0.13	0.32
Variety			
TIS 9265	5.2b	1.9b	3.4
TIS 2498	6.2a	2.3a	3.9
SE(±)	0.26	0.11	0.26

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

The interaction effects between the first order of interaction and among the second order of interaction on total number of tuber and number of cull tubers were not significant statistically. There was however a significant nitrogen x variety interaction on mean number of marketable tubers (Table 13).

Table 13. The interaction between nitrogen and variety on mean number of marketable tubers per plant.

Variety	Nitrogen (kg/ha)		
	0	60	120
TIS 9265	1.0b[1]	2.4a	1.5b
TIS 2498	2.9a	2.7a	1.2c

SE (±) 0.13

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

When each variety was studied at varying levels of nitrogen it was observed that variety TIS 9265 yielded higher number of marketable tubers at 60kg N/ha when compared with the control and 120kg N/ha, the latter two were at par with each other. In variety TIS 2498 the control and 60kg N/ha yielded higher number of marketable tubers than

the 120kg N/ha level. When the two varieties were compared under the same level of nitrogen, TIS 2498 yielded significantly higher number of marketable tubers at 0kg N/ha level. They were at par at 60kg N/ha level and TIS 2498 was significantly lower at 120kg N/ha level.

4.2.3 Mean tuber and mean marketable tuber weights

Result of the effect of nitrogen, phosphorus and variety on mean tuber and mean marketable tuber weight (tuber size and marketable tuber size) are shown in Table 14. The mean tuber weight was significantly increased with application of nitrogen. Application of 60kg N/ha resulted in a significantly higher mean tuber weight when compared with the control. A further increase in the nitrogen level to 120kg N/ha did not significantly increase the mean weight above the 60kg N/ha level. The mean marketable tuber weight was increased with an increase in nitrogen level. Application of 60kg N/ha, however, produced significantly the same marketable tuber weight compared with the control, while application of 120kg N/ha resulted in a significant increase in mean marketable tuber weight than the other two treatments.

Increasing the phosphorus level did not significantly influence both the mean tuber and mean marketable tuber weights. The differences between the two varieties in both

Table 14. Mean weight of tuber and marketable tuber (g/tuber) of sweet potato as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Mean Tuber Weight (g)	
	Total tubers	Marketable tubers
N (kg/ha)		
0	119.4b[1]	104.6b
60	157.4a	293.1b
120	176.2a	495.2a
SE(±)	10.99	57.72
P_2O_5 (kg/ha)		
0	148.8	318.6
30	157.4	209.1
60	146.5	365.3
SE(±)	10.99	57.72
Variety		
TIS 9265	146.7	287.1
TIS 2490	155.3	361.5
SE(±)	8.97	47.12

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

mean tuber and mean marketable tuber weights were also not significant statistically. Similarly, none of the interaction effect was significant statistically.

4.3 Effect of Nitrogen, Phosphorus and Variety on Tuber Quality

4.3.1 Tuber dry weight (per cent)

Data on the effect of nitrogen, phosphorus and variety on tuber dry weight are shown on Table 15. Differences in means due to nitrogen levels were not significant statistically. Also differences due to phosphorus levels were not significant statistically.

A significantly higher tuber dry weight percentage was obtained in variety TIS2498 (30.3 per cent) compared with TIS 9265 (25.3 per cent). None of the interactions on tuber dry weight was significant statistically.

4.3.2 Crude protein content (per cent)

The effect of nitrogen, phosphorus and variety on the crude protein content of tubers are shown in Table 16. Increasing the nitrogen level resulted in a significant increase in percentage crude protein content over the control. Application of 60kg N/ha increased the percentage protein content above the control, but the difference was not significant statistically. The difference between the 60 and

Table 15. Tuber dry weight (per cent) of sweet potato as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Tuber dry weight (per cent)
N(kg/ha)	
0	27.5
60	27.8
120	20.0
SE(±)	0.50
P_2O_5 (kg/ha)	
0	27.5
30	28.8
60	27.9
SE(±)	0.50
Variety	
TIS 9265	25.3b[1]
TIS 2498	30.3a
SE(±)	0.41

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

Table 16. Crude protein content (per cent) of sweet potato tuber as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Crude protein per cent (dry weight basis)
N (kg/ha)	
0	3.8b[1]
60	4.3ab
120	5.3a
SE(±)	0.41
P_2O_5 (kg/ha)	
0	4.2
30	4.9
60	4.3
SE(±)	0.41
Variety	
TIS 9265	4.1
TIS 2498	4.0
SE (±)	0.34

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

120kg N/ha levels was also not significant. However, application of 120kg N/ha resulted in a significantly higher percentage crude protein content when compared with the control.

Phosphorus application did not have any significant influence on the crude protein content of the tuber. The difference in the crude protein content of the two varieties was also not significant statistically. Similarly the treatment interaction effects between first order of interaction and among the second order of interaction were not significant statistically.

4.3.3 Starch content (per cent)

Raising the nitrogen level had no significant effect on the starch content of the tubers (Table 17). Application of phosphorus however resulted in a significant increase in the starch content of the tuber. Application of 60kg P_2O_5 significantly increased the starch content when compared with the 30kg P_2O_5/ha and the control. The difference between 30kg P_2O_5/ha and the control was not significant statistically.

There was no significant difference in the mean percentage starch content between the two varieties. None of the treatment interactions between the first order of interaction and among the higher order of interaction was significant statistically.

Table 17. Starch content (per cent) of sweet potato tuber as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Starch per cent (dry wt.)
N (kg/ha)	
0	79.7
60	78.1
120	76.8
SE(±)	1.41
P_2O_5 (kg/ha)	
0	74.2b[1]
30	77.9b
60	82.5a
SE(±)	1.41
Variety	
TIS 9265	77.6
TIS 2490	78.0
SE (±)	1.15

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

4.3.4 Tuber sweetness and texture

Tables 18 and 19 show the effect of nitrogen, phosphorus and variety on the sweetness and texture of boiled and fried sweet potato tubers, respectively. Nitrogen levels had no significant influence on the sweetness and texture of both boiled and fried sweet potato tubers. Phosphorus application on the other hand increased the sweetness of both boiled and fried tubers. Phosphorus at 60kg P_2O_5/ha significantly influenced the sweetness of the tubers when compared with the control. However, there was no significant difference in sweetness between 30 and 60kg P_2O_5/ha and between 0 and 30kg P_2O_5/ha. The textural quality of the tuber was not significantly influenced by phosphorus, though increasing the level of phosphorus tended to increase the textural quality.

There was no significant varietal difference on the sweetness and texture in both boiled and fried tubers. Also, no significant treatment interaction effect between the first order of interaction and among the second order of interaction was observed on any of the parameters (i.e. sweetness and texture) of either boiled or fried sweet potato tubers.

Table 18. Quality of sweet tuber (boiled) as influenced by nitrogen, phosphorus and variety at Samaru in 1984.

Treatment	Boiled Tubers	
	Sweetness	Texture
N (kg/ha)		
0	2.6	3.0
60	2.6	3.1
120	2.6	3.0
SE(±)	0.00	0.10
P_2O_5 (kg/ha)		
0	2.5b[1]	2.9
30	2.6ab	3.0
60	2.8a	3.2
SE(±)	0.00	0.10
Variety		
TIS 9265	2.6	3.0
TIS 2490	2.6	3.1
SE(±)	0.06	0.00

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

Table 19. Quality of sweet potato tuber (fried) as influenced by nitrogen, phosphorus and variety at Samaru, 1984.

Treatment	Fried Tubers	
	Sweetness	Texture
N (kg/ha)		
0	2.9	2.9
60	3.0	2.0
120	2.8	2.8
SE(±)	0.09	0.10
P_2O_5 (kg/ha)		
0	2.7a[1]	2.7
30	2.9ab	2.0
60	3.1a	2.9
SE(±)	0.09	0.10
Variety		
TIS 9265	2.9	2.0
TIS 2490	2.9	2.8
SE (±)	0.06	0.00

[1]Means followed by the same letter within a treatment are not significantly different at 5% level of significance.

Chapter 5

DISCUSSION

5.1 Effect of Nitrogen

Vegetative growth, tuber yield, yield components and quality of the tuber were all influenced by the application of nitrogen. Application of nitrogen up to 60kg/ha increased the tuber yield significantly over the control. Higher level (i.e. 120kg N/ha) however, reduced the yield significantly when compared with the 60kg/ha. The mean total yield obtained with 60kg N/ha (30.7 t/ha) was 58.2 and 23.5 per cent more than the yields obtained with 0 and 120kg N/ha, respectively. This finding conforms with that of Patterson and Speights (1962); Li (1970); Nandipuri et al. (1973); Miller and Covington (1982); Navarro and Padda (1983) and Hammet et al. (1984) who reported increased yield with medium level of nitrogen and decreased yield with higher levels.

The increase in yield at 60kg N/ha level was as a result of 15.5 per cent increase in the number of tubers and 31.8 per cent increase in tuber weight over the control. A further increase in nitrogen decreased the tuber yield by 23.5 per cent. This decrease was associated with a 29.9 per cent decrease in tuber number, although the tuber weight was 11.9 per cent higher than the 60kg N/ha level. Similarly a significantly higher marketable yield was obtained with

60kg N/ha compared with the control as a result of an 8.7 per cent increase in number of marketable tubers and 58.8 per cent increase in marketable tuber weight. While 120kg N/ha level reduced the marketable yield by 33.8 per cent compared with the 60kg N/ha level as a result of 48.0 per cent reduction in number of marketable tubers, although tuber weight was 69.0 per cent higher than the 60kg N/ha level. This finding agrees with the report of Bartolini (1982) who observed a decrease in yield due to a reduction in number of marketable tubers with an increase in nitrogen fertilizer level. It however contrasts with the findings of Nambiar et al. (1976), who reported that increasing nitrogen rate from 50 to 100kg/ha significantly increased the number of marketable tubers per plant.

The decrease in the number of tubers and yield as a result of high nitrogen application could be due to higher and more vigorous vegetative growth of the plant at high nitrogen level which produced more vegetative part at the expense of the tubers. Also according to Togari (1950) large amount of soil nitrogen during tuber initiation retards the production of tuberous roots and favours the production of non-tuberous roots. The increase in tuber weight as a result of high nitrogen application is understandable as with lower number of tubers at 120kg N/ha level, the sink capacity of the plant is reduced and any photosynthate materiel passed down for storage is shared by

fewer tubers. The result seemed to indicate the presence of a compensatory relationship between tuber number and tuber size.

The leaf, stem, root and total dry weights were all increased with nitrogen application. A look at the effect of nitrogen at different sampling stages indicated that differences were not significant at the initial stages of growth but became significant at the late stages. The non-significant result due to nitrogen at the initial stages (4 to 6 WAP) might be explained on the basis of growth curve which is sigmoid in nature. At an early stage growth is generally slow. However, the differences became distinct at advance stages. A critical look at the data for the leaf, stem and root dry weights revealed that leaf and stem dry weights tended to decrease after 12 WAP, while it progressively increased in the case of root dry weight.

The length of vine and number of branches were also significantly increased by the application of nitrogen. The application of 120kg N/ha produced 33.3 and 35.7 per cent longer vine and higher number of branches, respectively when compared with the control. These results were in agreement with that of stem dry weight. This was as expected since the stem dry weight is a product of both length of stem and number of branches per stem.

LAI increased linearly with increase in nitrogen level at

all steges of sampling. The meximum LAI of 7.1 was recorded at 12 WAP with an application of 120kg N/ha. The result conforms with the report of Tsuno and Fujise (1962) who reported a linear relationship between nitrogen content and leaf area index. The meximum LAI also corresponds to the maximum CGR of 23.0g/m^2/day (161g/m^2/week) when nitrogen was applied at 120kg N/ha. Similar results were obtained by Kodoma et al. (1970) and Enyi (1977) who reported a maximum CGR of 150 and 163g/m^2/week when the LAI was 5.5 and 8.0, respectively.

There is a negative correlationship in sweet potato between the vegetative growth and tuber yield. Under high nitrogen fertilization or when the nitrogen concentration in the plant is high, more of the dry matter produced is distributed in the aerial parts and little is translocated to the roots for storage. High nitrogen concentration in the plant is a favourable condition for protein synthesis which is essential to the building of new organs (Tsuno, 1973).

The crude protein content of the tuber was increased from 3.8 per cent in the control to 4.3 and 5.3 per cent by the application of 60 and 120kg N/ha, respectively. This result is in conformity with those reported by Constantin et al. (1974); Li (1982); Miller and Covington (1982) and Purcell et al. (1984). Tuber starch content and dry matter percentage were not influenced by nitrogen fertilization.

This finding also agrees with that of Constantin et al. (1974) who found no effect on tuber dry matter content by increasing nitrogen from 0 - 101 kg/ha.

5.2 Effect of Phosphorus

Vegetative growth, yield and yield components were not significantly influenced by the application of phosphorus, although there was a tendency for the dry weights of the plant parts, LAI, CGR and TGR to increase with increase in phosphorus levels. This result is in conformity with the results of Rondle and Kang (1976), but contrasts with the report of Uriyo and Kassebe (1973) who obtained a response with an increase in P rate from 0 to 50kg P/ha on a red oxisol soil in Tanzania.

The inability of phosphorus to significantly influence both growth and yield in this study could be attributed to first, the low phosphorus requirement of sweet potato (Togari, 1940; Anon, 1975; Rendle and Kang, 1976; Navarro and Padda, 1983; Hammet et al, 1984) and the moderate amount of available phosphorus (7.00ppm) present in the 0 - 15cm depth of the soil of the experimental site which was able to provide the critical phosphorus level required by the crop.

Phosphorus fertilization on the other hand was found to have a significant influence on the starch content, sweetness and texture of the tubers. There was a linear

increase in starch content, sweetness and texture with an increase in the level of phosphorus. This finding agrees with the report of Tsuno (1973) that when phosphorus fertilizer is applied to sweet potato, the tubers become sweeter and mealier in texture. The higher starch percentage could be because phosphorus is an important constituent in starch synthesis and accumulation.

5.3 Effect of Variety

Sweet potato variety TIS 2498 excelled variety TIS 9265 in yield, yield components, tuber dry weight percentage and vegetative growth at the late stages of sampling. The varieties were however at par with respect to starch and crude protein content as well as the sweetness and texture of the tubers.

Variety TIS 2498 produced a mean total yield of 27.4 t/ha and a marketable yield of 18.4 t/ha which were 26.3 and 29.6 per cent more than the total and marketable yields of TIS 9265, respectively, (21.7 and 14.2 t/ha). The higher yield of TIS 2498 was as a result of significantly higher total number of tubers (19.2 per cent) and number of marketable tubers (21.1 per cent) per plant as well as mean tuber and mean marketable tuber sizes which though were statistically the same, were 5.9 and 25.9 per cent higher, respectively, in TIS 2498 compared with TIS 9265.

The higher leaf, stem, root and total dry weights of

variety TIS 2498 corresponds to its higher LAI and CGR at these late steges which enable it to accumulate more dry matter. The higher yield of variety TIS 2498 over TIS 9265 could also be attributed to difference in their maturity period and the favourable rainfall received towards the end of the season. While variety TIS 9265 is an early maturing variety that matured in October, TIS 2498 is a late maturing variety which benefitted from the high amounts of October rainfall to produce and accumulate more photosynthate before it matured.

5.4 Interactions

The interactions between nitrogen, phosphorus and variety on all parameters studied, with the exception of nitrogen x variety interaction on number of marketable tubers were not significant statistically. This suggests that the two varieties respond similarly with respect to nitrogen and phosphorus fertilization. Also the nitrogen and phosphorus fertilizers behave independently of each other.

Chapter 6

SUMMARY AND CONCLUSION

This investigation was carried out in order to determine the effect of nitrogen, phosphorus and variety on the growth, yield and quality of sweet potato (Ipomoea batatas). The experiment was conducted during the wet season of 1984 at the Ahmadu Bello University Farm, Samaru. A randomized complete block design with factorial arrangement was used. The treatments consisted of three levels each of nitrogen and phosphorus (0, 60 and 120kg N/ha; 0, 30 and 60kg P_2O_5/ha) which were tested on two varieties; TIS 9265 a white skinned variety that matures in 130 days and TIS 2498 a red skinned variety that matures in 160 days.

Rainfall during the period was adequate and well distributed with high amounts falling during the month of October (177.5mm) which was much higher than the average rainfall for the month (30.6mm). Application of nitrogen fertilizer affected the growth of sweet potato. The leaf, stem and total dry weights, length of vine, number of branches, leaf area index, crop growth rate and tuber growth rate were all significantly increased by the application of nitrogen.

Tuber yield per hectare increased significantly by the application of nitrogen up to 60 kg/ha which produced 30.7 t/ha and which was 58.2 per cent higher than the yield of the

control. However increasing the level to 120kg N/ha significantly reduced the yield by 23.5 per cent compared with the yield of 60kg N/ha level. Similarly the marketable yield was significantly increased with nitrogen application up to 60 kg/ha while the 120kg N/ha level significantly reduced the marketable yield when compared with the 60kg N/ha level.

The total number of tubers and marketable tuber were reduced significantly by the application of 120kg N/ha when compared with the control and the 60kg N/ha level, while the differences between the two levels were not significant statistically. Mean tuber weight was significantly increased by nitrogen application but the difference between the two levels was not significant. Similarly the mean marketable tuber weight was increased by nitrogen application. Low level of nitrogen (60kg N/ha) had no significant effect, but higher dose (120kg N/ha) significantly increased the marketable tuber weight.

The crude protein content was increased by nitrogen application but the difference between 0 and 60 on one hand and 60 and 120kg N/ha on the other was not significant. Phosphorus application had no significant effect on growth, yield and yield components but had a significant influence on the starch content and sweetness of both boiled and fried tubers. Of the two varieties, TIS 2498 appeared to be

superior over TIS 9265 in terms of total and marketable yields, total number of tubers and number of marketable tubers as well as vegetative characters of dry matter production, crop growth rate, leaf area index and tuber growth rate.

The investigation has shown that sweet potato responds to nitrogen application up to 60kg N/ha which gave the highest yield, while phosphorus was found to give no response at all. It seems that the amount of available phosphorus present in the soil of the experimental site was enough to satisfy the requirement of the crop. There is a need however for more work to be carried along this line so that an optimum response of nitrogen can be determined possibly by using smaller nitrogen regimes.

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Appendix A: Rainfall distribution (mm) during the 1904 crop growing period at Samaru.

Date	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.
1	-	-	-	3.7	0.1	-	16.0	-
2	-	-	-	-	Tr.	-	-	49.0
3	-	-	-	-	-	-	-	15.0
4	-	-	-	-	7.0	-	31.5	-
5	-	-	39.0	2.2	3.0	23.3	0.7	-
6	-	-	-	0.4	-	-	13.5	-
7	-	-	-	-	-	-	-	-
8	-	-	18.0	-	-	49	-	50.5
9	5.2	-	2.6	-	-	-	-	9.2
10	-	-	-	-	-	7.0	-	0.0
Total	5.2	-	59.6	6.3	10.9	80.1	61.7	124.5
11	-	-	-	-	17.9	-	-	-
12	-	-	-	18.3	0.9	-	-	-
13	-	-	-	19.0	13.0	-	-	-
14	-	-	-	-	20.1	-	-	-
15	-	-	-	-	-	-	-	-
16	-	-	-	-	-	0.1	-	-
17	-	-	25.0	-	-	10.0	27.0	53.0
18	-	-	-	-	-	-	-	-
19	-	-	-	0.4	7.2	14.4	-	-
20	-	Tr.	-	-	7.4	-	8.6	-
Total	-	-	25.0	30.5	66.5	32.5	27.6	53.0
21	-	1.3	-	-	-	12.6	33.6	-
22	-	-	-	10.0	4.2	-	-	-
23	-	3.9	-	0.2	0.4	-	-	-
24	-	0.2	-	-	23.5	5.7	-	-
25	-	-	5.7	-	1.2	0.6	-	-
26	-	14.0	3.5	0.4	-	Tr.	25.5	-
27	-	-	-	-	6.5	-	3.0	-
28	-	1.7	4.6	-	10.6	-	2.1	-
29	-	-	-	Tr.	-	14.5	35.5	-
30	-	9.0	0.5	-	34.0	12.1	-	-
31	-	-	-	-	-	-	-	-
Total	-	30.1	14.3	10.6	88.4	32.9	99.7	-
Grand total for the month	5.2	30.1	98.9	55.4	173.0	150.1	189.0	177.5

Total for the year = 000.00 TR = Trace Number of rainy days = 67.

Source: I.A.R. Met. Station.

Appendix B: Maximum and minimum temperatures (^{0}C) during the 1984 cropping period at Samaru.

	June		July		August		Sept.		Oct.		Nov.	
Date	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1	33	21	30	20	30	20	29	19	30	20	31	13
2	33	20	27	18	28	20	30	20	31	20	31	11
3	30	21	32	19	29	21	27	19	30	18	32	12
4	32	22	32	21	30	20	27	20	30	19	33	12
5	32	22	29	19	29	20	25	17	30	20	32	11
6	32	20	31	20	29	19	30	19	31	19	31	13
7	28	20	32	19	30	21	30	19	31	21	32	16
8	32	20	29	21	30	20	30	19	30	21	30	15
9	28	21	31	19	28	17	30	20	31	18	31	12
10	34	21	31	21	30	19	28	20	30	19	32	14
11	34	22	28	20	30	19	30	18	30	20	32	14
12	33	22	25	18	31	19	31	20	30	20	32	15
13	29	20	30	19	30	20	31	18	31	21	32	15
14	31	18	29	19	30	20	30	20	32	20	33	13
15	32	22	27	18	31	20	30	20	31	20	33	11
16	31	21	25	19	30	19	31	20	20	20	33	12
17	31	21	28	19	29	19	30	20	31	21	32	15
18	32	22	29	20	30	18	30	19	30	17	33	15
19	34	21	30	20	30	20	30	19	31	20	32	14
20	30	21	28	19	29	19	30	19	32	19	32	16
21	32	20	30	18	30	20	30	19	31	21	32	17
22	30	20	30	21	30	18	30	18	30	19	32	12
23	31	19	25	19	30	20	30	19	31	16	32	14
24	32	20	30	18	32	21	31	20	30	17	29	17
25	33	19	20	17	29	20	31	19	31	15	20	17
26	31	20	24	19	31	19	28	20	31	16	26	16
27	31	20	29	19	31	18	29	19	31	19	20	12
28	31	19	31	21	32	21	29	19	30	17	29	10
29	32	20	27	17	31	22	29	20	30	15	31	12
30	31	19	29	21	30	19	20	18	30	16	31	12
31	-	-	29	18	26	18	-	-	30	14	-	-

Source: I.A.R. Met. Station

Appendix C: Sunshine hours during the 1984 crop growing period at Samaru.

Date	June	July	August	September	October	November
1	8.2	6.3	7.6	7.7	0.7	8.6
2	8.3	4.3	7.9	9.2	9.6	9.2
3	7.6	9.5	10.5	5.7	8.5	9.0
4	7.6	9.8	7.0	1.8	9.0	10.0
5	7.7	5.6	7.9	2.0	9.8	9.7
6	2.4	8.1	10.4	7.6	9.9	10.1
7	1.4	10.2	5.4	10.4	9.1	10.1
8	7.6	2.9	6.1	9.4	8.0	9.0
9	9.3	2.7	3.9	6.2	0.4	0.0
10	7.9	8.6	10.4	3.1	4.7	5.1
11	7.7	0.7	5.6	9.2	8.3	5.5
12	6.9	0.4	9.5	6.7	0.3	5.5
13	7,6	10.0	0.0	9.3	0.7	6.0
14	5.0	9.4	4.4	0.2	0.0	7.7
15	0.9	7.6	10.5	6.3	9.6	10.1
16	9.3	2.1	9.0	7.2	0.0	0.5
17	9.2	7.2	7.5	5.0	0.4	10.0
18	7.0	0.0	10.9	6.1	6.0	7.2
19	6.4	0.2	10.1	5.9	10.6	9.2
20	9.9	5.6	9.4	6.4	7.4	9.1
21	8.0	10.5	8.5	9.9	5.0	10.1
22	6.0	9.1	7.1	9.0	4.6	9.0
23	5.0	0.9	7.4	7.4	7.7	10.0
24	9.1	10.3	9.5	8.3	3.5	7.0
25	9.2	3.2	9.3	10.0	5.3	0.0
26	5.0	3.2	8.7	4.2	3.2	0.0
27	4.4	1.6	6.9	6.1	5.6	4.0
20	8.4	10.3	10.1	7.3	0.0	9.3
29	9.5	0.7	7.0	6.1	0.0	10.1
30	6.3	1.4	10.5	4.2	3.6	10.1
31	-	6.9	2.9	-	4.0	-
Mean	7.3	6.4	8.1	6.9	6.7	7.7

Source: I.A.R. Met. Station.

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