GROWTH AND YIELD RESPONSE OF ONION (*Allium cepa* L.) TO VARYING LEVELS OF NITROGENOUS AND PHOSPHATIC FERTILIZERS

By

EZRA BAKO AMANS.

A thesis presented to the Faculty of Agriculture Ahmadu Bello University in partial fulfilment of the requirements for the degree of Master of Science in Agronomy

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE &
INSTITUTE FOR AGRICULTURAL RESEARCH
AHMADU BELLO UNIVERSITY, ZARIA,
NIGERIA

JUNE. 1982

THESIS CERTIFICATION

This thesis entitled GROWTH AND YIELD RESPONSE OF ONION (*Allium cepa* L.) TO VARYING LEVELS OF NITROGENOUS AND PHOSPHATIC FERTILIZERS *by* EZRA BAKO AMANS meets the regulations governing the degree of Master of Science (*Agronomy*) of Ahmadu Bello University and is approved for its contribution to scientific knowledge and literary presentation.

N. M. Fisher
Member, Supervisory Committee

Chairman, Supervisory Committee

Head of Department

Date 24th June 1982

DEPARTMENT OF AGRONOMY
FACULTY OF AGRICULTURE
AHMADU BELLO UNIVERSITY, ZARIA

(PG.12/MS/11857/80-82/5)

ACKNOWLEDGEMENT

I wish to express profound gratitude to Dr. M.K. Ahmed, Reader and Chairman of the Committee that supervised this work, for the valuable guidance and criticism during the course of this study. The same sincere gratitude is extended to Dr. N.M. Fisher and Mr. S.K. Karikari who made valuable contributions in the preparation of the thesis; and also to Mr. J.G. Quinn for his assistance during the initial stage of the study.

I sincerely thank Dr. H. Van Amstel and the entire staff of the Horticultural Section of the Institute for Agricultural Research for their assistance and co-operation in carrying out the field studies. To Dr. A.C. Ebenebe of the Department of Crop Protection who helped in assessing some disease problems, I also say thank you.

Gratitude is similarly extended to Dr. J.Y. Yayock, Head of Agronomy Department, for his interest, encouragement and suggestions for the progress of the work. Acknowledgement is also gratefully extended to the entire staff of the Department of Agronomy and particularly to Messrs Paul Nnorom and Sani Abubakar who assisted in the field operations, to Messrs Haruna G. Kundi and Anthony Dauda who typed earlier drafts and Mr. Cyril O. Egeolu who did the final typing.

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INTRODUCTION

A. Origin and adaptation of onion

The common bulb onion (Allium cepa L.) belong to the family Alliaceae. It is believed to have originated from Middle and South-east Asia where it is known to have been in cultivation since ancient times (Jones and Mann, 1963). Onion cultivars may be grouped into longday or temperate and shortday or tropical types (Uzo, 1978). Thus onions are cultivated virtually in almost every part of the temperate and tropical regions of the world (Purseglove, 1975).

B. Importance

Onion is grown mainly for its bulb which is used in every home, almost daily. It is rarely used as a sole dish or in large quantities. Its main use lies in flavouring and seasoning of a wide variety of dishes. Its popularity is due to its aromatic, volatile oil, the allyl-propyl sulphide which imparts a cherished flavour to food. As a constituent of a meal both the green leaves and bulbs can be eaten raw, cooked or fried, or in soups and salads. Onion also has an important role as a medicinal herb in many communities (Purseglove, 1975; Sinnadurai and Abu, 1977), and is claimed to minimize high blood pressure and other heart diseases due to its favourable action on the elasticity of blood vessels. As an item of world trade, onion ranks second in importance after tomatoes among the vegetables (Joubert and Strydom, 1968). In 1976 the total world export production amounted to over 1.3 million metric tonnes, and worth over 299 million U.S. dollars (Anon., 1976). Of this figure the contribution from Africa and West Africa were about 7 per cent and 1 per cent respectively.

C. Trend in production

The world production of onion has increased steadily from about 11 million metric tonnes produced on an area of nearly 0.9 million hectares in 1969 to over 19 million metric tonnes produced on an area of about 1.6 million hectares in 1979 (Table 1). These figures represent 72.7 and 77.7 per cent increases in total production and area, respectively, within a decade.

Table 1:Estimated onion production during the decade 1969-79

	1969		1979	
	Production (t),000	Area (ha) ,000	Production (t), 000	Area (ha) ,000
World	,11,039	856	19,494	1,580
Africa	914	72	1,241	121
W. Africa	47	4	144	15

Source: Anon., 1970 b; Anon, 1980

The world leading producers of onion are the United States of America, China, United Soviet Socialist Republic, India and Japan. Each of these countries produces an average of over one million metric tonnes annually (Anon., 1980). Other important producing countries include Turkey, Spain, Brazil, Italy and Egypt. West African countries producing substantial commercial quantities include Niger, Senegal, Ghana, Chad and Cameroon, with Niger contributing nearly 50% of the regional total output.

D. Production in Nigeria

At present there seem to be no official statistics available on onion production and trade in Nigeria. However, onion is known to be widely cultivated in Nigeria, and has been for long an important commercial vegetable in the northern parts of the country (Inyang, 1966). Even today onion continues to command a high position in the home and the market, Green (1971) described the potential and future prospects of onion production and marketing in Nigeria as very bright and promising.

The cultivation of onion in Nigeria has been mostly confined to the semi-arid Northern Guinea and Sudan Savanna ecological zones, especially between latitudes 8° and 12°

North. The bulk of the crop is produced during the dry season in lowland 'Fadama' and other irrigable areas. The average yield obtained by local farmers is estimated at about 10 to 15 tonnes/ha (Inyang, 1966; Green, 1971). This yield is considered to be low by world's standards.

E. Reasons for low yields

Serious disease and pest problems which are most favoured by hot humid weather prevailing during the rainy season have been one of the major limitation to yield and production. Other factors contributing to the low yields include (Green, 1971):

i) the use of seeds from bolted crop,
ii) the use of low plant population, and
iii) the lack or inadequate use of fertilizers.

The existing low level of production cannot adequately meet the increasing demand for onion bulbs. This situation is further worsened by poor storage facilities and storage ability of the crop. Therefore, there is the need not only to increase the yield, but also to improve the quality of onion to meet both local and export demands. Fertilizer use is known to be one of the most important cultural practices which affect yield and bulb quality that demand precise knowledge. Preliminary fertilizer trials and improved cultural practices on onion have shown that it is possible to increase yield from the low level obtained by farmers to as much as 45 t/ha (Green, 1971).

Inadequate mineral nutrition was pointed out as one of the major constraints to increased crop yield. Most Savanna soils are lateritic and low in cation exchange capacity which make them more prone to nutritional imbalance and deficiency (Jones and Wild, 1975). Detailed accounts of the fertility status of savanna soils have been presented by Heathcote and Stockinger (1970) and Jones and Wild (1975).

F. Objectives of Study:

Nitrogen and phosphorus are the most common limiting fertilizer elements in the soils which carry the onion crop and the present study was undertaken with the following objectives:

1) To study how varying levels of applied nitrogenous and phosphatic fertilizers affect onion growth and yield.
2) To study the interaction between nitrogen and phosphate fertilizer in order to identify the optimum levels of the two fertilizers.

REVIEW OF LITERATURE

A. Mineral nutrition in onion

The onion crop utilizes large amounts of soil nutrients during the period of its growth. The maximum rate of nutrient uptake occurs at the later half of the plant life, from bulb formation to maturity. Towards maturity there is usually an increased rate of nitrogen and phosphorus mobilization from the plant tops to the bulbs, consequently increasing the proportion of the two elements in the bulbs as compared with the other nutrient elements (Zink, 1966; Haag et al., 1970). Zink (1966) reported that a 57.7 tonnes/ha crop of onion removed 162 kg N, 26 kg P, 99 kg Ca and 15kg Mg from the soil. Such high level of nutrient removal necessitates increasing the sources of these nutrients through fertilizer application not only to meet the needs of subsequent crops but also to help maintain the soil fertility status.

Irrespective of the soil type, proper fertilizer application is profitable especially to a crop like onion which has limited root system. The root system of onion is fibrous and sparse, with most of the roots confined within 30 cm base of the stem (Jones and Mann, 1963; Purseglove, 1975). In the Savanna ecological regions of Nigeria, soil survey and fertility studies have revealed a generally low level of fertility with nitrogen and phosphorus being the most commonly limiting to crop production (Watson, 1963; Heathcote and Stockinger, 1970). Therefore, an adequte supply of these nutrients and other equally essential elements in the top soil becomes necessary to optimum onion production

B. Nitrogen fertilization

1. General effects

Nitrogen generally has its most profound influence on the vegetative development of plants. Supplied in adequate amounts, nitrogen ensures a healthy plant growth which is manifested by the increased vigour size and the deeper green colour of the foliage. A deficiency of nitrogen normally leads to a retardation of plant growth, yellowing of the leaves, and consequent reduction in yield. In the normal healthy onion plants the foliage (tops) fall over due to its own weight at maturity; however, in a nitrogen-deficient crop Shoemaker (1947) Harmer and Lucas (1955) observed that the tops remained erect at maturity. On the other hand, nitrogen supplied in excess is also detrimental to the development of the onion plants. For example, excessive nitrogen application may upset the soil nutrient balance, thus creating other nutritional problems (Lingle and Wight, 1961). Also, excessive nitrogen may increase crop susceptibility to disease and pest attacks, or have other adverse effects on crop quality (Singh and Kumar, 1969 a).

2. Effects on onion growth and development

Significant and positive responses to nitrogen fertilization have been reported in terms of onion plant height relative to bulb size (Pande *et al.*, 1969; Boy, 1971; Chowdappan, 1972; Hassan and Ayoub, 1978). The timing of nitrogen application is equally important in relation to optimizing onion growth. Shoemaker (1947) and Akashi *et al.*, (1977) pointed out that nitrogen fertilizer was most profitable when applied in the early than later stages of growth. The early supply of nitrogen hastened the usually slow rate of initial growth of the seedlings, thereby promoting the production of large and sturdy plants (El-Baradi, 1971; Tzeng, 1972). The rate at which nitrogen was removed from the soil normally corresponded to the rate of plant growth. Singh and Jain (1959) observed that in the first 30 days after transplanting 45.4 kg of N/ha was found to be adequate for optimum growth; but for older plants, at 90 to 120 days after transplanting when growth rate was higher, the optimum growth was supported by 90.8 kg of N/ha.

Delaying the application of nitrogen, especially of large doses, until the later stages of growth proved detrimental to the crop especially in terms of slowing the rate of bulbing and delaying maturity (Jones and Mann, 1963; Wilson, 1978).

3. Effects on yield

Result of most studies show that the yield of onion normally increases in response to increasing levels of nitrogen fertilization (Queddeng *et al*., 1963; Wayse, 1967; Pande and Mundra, 1971 and Narang and Dastane 1971).

Variable reports have been made on the optimum dose of nitrogen for maximum yields. The optimum rate of nitrogen depends not only on the total available nitrogen in the soil, but also on cultivar grown and on other environmental factors. For example, soil moisture has a very significant role in mineral nutrition of plants. Onion plants must have an adequate supply of water in the root zone before they could derive the full benefits from fertilizer application. Fertilizers normally need to dissolve in the soil for their mobility and subsequent uptake by plants. For the shallow rooted plants like onion, it becomes more important that moisture and nutrients be constantly and adequately maintained within the reach of the roots (Thompson, 1921; Lorenzo *et al.*, 1955).

Riekels (1972) in Ontario, Canada, reported that for organic soils and under high rainfall the optimum nitrogen requirement for bulb yield was higher than 270 kg of N/ha; but in low rainfall years the optimum nitrogen rate was not more than 150 kg of N/ha. In one particularly dry year in Ontario, Riekels (1977) observed that increasing the nitrogen level beyond 22 kg of N/ha gave little or no response in terms of growth and yield. Singh and Singh (1969) reported a rate of 84 kg of N/ha as being the optimum requirement for bulb yield in India. In Bangladesh, Rahman and Farruque (1975) also in Bangladesh tried variable rates of nitrogen between 16 kg and 84 kg of N/ha and obtained the best yield from 67 kg of N/ha applied in two equal split doses at four week intervals. In the Sudan Gezira, Hassan (1977) obtained the best yields from the application of 95 kg of N/ha.

In Nigeria, the few preliminary fertilizer trials on onion revealed encouraging yield response to nitrogen fertilization.

In trials conducted near Bida, Inyang (1966) reported yield increases of 1.7 to 3.0 t/ha above the control in response to the application on 27 kg of N/ha. At Samaru, bulb yield of irrigated onion increased in response to increasing nitrogen levels up to 195 kg of N/ha at which level the yield was almost triple to that at the control (Anon., 1970a). In an irrigated crop at Gambaru, a significant increase by 37% was obtained when nitrogen level was increased from 0 to 65 kg of N/ha. There was a non-significant depression in yield at 130 kg of N/ha although the yield at this latter level of nitrogen was not statistically different from that of the control (Anon; 1970a).

Srivastava <u>et</u> <u>al</u>., (1965) in India reported that 100 kg of N/ha a gave better yields than lower rates. Pande <u>et</u> <u>al</u>., (1969) obtained increased yield in response to increasing nitrogen level up to 168 kg of N/ha on a soil already having a nitrogen content equivalent to 187 kg/ha.

There are many reports of the detrimental effects of excessive supply of nitrogen on the yield of onion. Wilson (1934) reported that bulb yield may be depressed by excessive nitrogen without apparently affecting leaf growth adversely. Riekels (1970 and 1972) mentioned that the negative effect of high nitrogen rates on onion yield would result either from the high concentration of salts at the root zone especially under low moisture condition or the resultant excessive top growth occuring at the expense of bulb and roots. In Idaho (U.S.A.), Painter (1977) observed that the application of 90 to 360 kg of N/ha to a soil already containing 16.6 - 21.9 ppm nitrate-nitrogen in the top 60 cm reduced both plant stand and bulb yield, with an increase in the yield of cull class. Hassan and Ayoub, (1978) reported that yields were increased up to 90 kg of N/ha and doubling this rate of fertilization depressed yields.

4. Effects on bulb quality

The ability of onion bulbs to store or keep well over time is normally considered as one of the most important and desirable qualities of onions. Such quality characteristics as rotting, sprouting, bulb density and size are influenced by many factors, both genetic and environmental.

Bolting, which defines the premature flowering of onion has adverse effects on the storage life of the bulbs (Jones and Mann, 1963). Bulbs from bolters usually have open necks caused by the flower stalks, and these create openings for rot organisms. Such bulbs also tend to have lower density than non-bolters as the plants utilize a good proportion of their food for flower and seed production with a depletion of bulb size (Jones and Mann, 1963). The tendency of onion to bolt varies among cultivars, and characteristic of a cultivar which had not been selected against bolting (Uzo, 1978), but is principally induced as a response to low temperatures after the plant has achieved a certain minimum growth. In long day cultivars bolting is enhanced by day-lengths shorter than the critical requirement for bulbing, but in the tropics where seasonal variation in daylengths are small, temperature becomes the most important factor in bolting (Abdallah, 1967; Robinson, 1971). At temperatures near the critical requirements for bolting, nitrogen was reported to enhance bolting in long day cultivars (Jones and Mann, 1963). The effect of nitrogen in increasing the rate of plant growth and also in delaying bulbing may tend to encourage bolting. However, other workers (Paterson et al., 1960; Hassan Ayoub, 1978) have observed significant reduction in the proportion of bolters as a result of application of nitrogen fertilizers.

Split bulbs and twin bulbs are often considered undesirable and thus classified among the low grades of onions. The tendency for bulbs to split or form twins is reportedly positively correlated with bulb size (Hassan and Ayoub, 1978). These workers found that the application of nitrogen fertilizers resulted in increased bulb size and the consequent increase in the proportion of twin-bulbs.

Bulbs can develop to variable sizes as influenced mostly by cultural practices or environmental conditions. Variations in plant population and fertilizers are examples of the more important factors that influenced bulb size. Generally, the very large bulbs, though having high preferance in the local markets, do not often store well (Jones and Mann, 1963). However, very small bulbs which often keep well are normally not favoured by the market. Pande _et al_., (1969) reported that nitrogen fertilization not only increased the yield of marketable bulbs, but also reduced the proportion of small and non-marketable onions.

Nitrogen has the effect of promoting tenderness in plants, thus may render the crop less resistant to diseases and other depredative agents. Vaughan (1960) reported that excessive nitrogen fertilization under high moisture regime was responsible for the increased incidence of neck rot disease. The bulb size responded positively to increasing nitrogen level, so did the disease intensity which was also positively correlated to bulb size. Wayse, (1967) reported that in addition to the increased yield from the application of 40 kg of N/ha, this moderate amount of nitrogen effectively reduced the rate of weight loss in stored bulbs; at higher levels nitrogen had the reverse effects of increasing the rate of water loss.

Excess nitrogen application not only delayed maturity, but also resulted in poorly matured bulbs which did not store well (Joubert and Strydom, 1968). Poorly matured bulbs often exhibit increased rates of post-harvest rotting, sprouting and weight loss (Singh and Kumar, 1969b; Painter, 1977). Akashi et al., (1977) contended that adequate and proper application of nitrogen fertilizers at the early stage of growth ensured not only good yields but also well shaped bulbs.

C. Phosphorus fertilization

1. General effects

Phosphorus is necessary for plant growth and development, especially with regard to the ability of roots to efficiently absorb water and nutrients from the soil. An early and rapid development of the root system ensures an overall good growth and development of the plant. In this regard, adequate and early supply of phosphorus becomes essential (Singh and Jain, 1959).

The deficiency of phosphorus in onion plants often results in slow growth and stunting with leaves becoming dull and mottled (Harmer and Lucas 1955; Anon., 1968).

2. Effects on onion growth and development

Timm and Riekels (1964) and Tzeng (1972) reported significantly positive responses of onion growth and maturation to be due to phosphatic fertilizers. At relatibely high rates of phosphorus, Downes (1959) similarly observed increased rate of bulb growth and an advancement to early maturity. He also noted that high phosphate levels, while advancing maturity, also tended to slow the rate of top growth, Singh and Kumar (1969a) and also Chowdappan and Mundra (1971) recorded significant increases in the leaf number as well as the fresh and dry weights of the plant in response to phosphate fertilizers; crop maturity was also advanced.

For phosphorus to be beneficial, Singh and Jain (1959) observed that it was necessary that it be supplied as early as possible in the life cycle of the plant. When phosphate was applied at a stage nearing maturity it was found to be ineffective, and even tended to arrest growth. Tzeng (1974) also noted that applying phosphate fertilizer as a side dressing failed to influenced onion growth significantly, though it did advance maturation.

3. Effects on bulb yield

A number of workers have reported significant increases in the bulb yield of onion in response to applications of phosphate fertilizers (Paterson et al., 1960; Tzeng, 1972; Rahman et al., 1976).

Shickluna et al., (1965) reported that by the application of 28.4 kg and 56.8 kg of P_2O_5/ha there was an increase in bulb yield by 5.5 and 12.6 t/ha, respectively, compared with unfertilized control. In a series of rainfed trials conducted near Bussa and Bida both in the Southern Guinea Savanna of Nigeria. Inyang (1966) obtained yield increases in response to 20 kg of P_2O_5/ha. Hassan and Ayoub (1978) in the Sudan Gazira obtained increases in yield ranging from 7 to 23 per cent from the application of 45 kg of P_2O_5/ ha on soils with average phosphorus content of 645-685 ppm. Similarly, Pande and Mundra (1971) reported as increase in yield by 16 per cent from the application of 86.6 kg of P_2O_5/ha on a soil containing almost 700 ppm of phosphorus.

Working in India Srivastava et al., (1965) noted that the yield response of onion was greater at lower (25 kg of P_2O_5/ha) than at higher levels (50 kg P_2O_5/ha) of phosphatic fertilizer. Pande et al., (1969) and also Singh and Singh (1969) however, observed greater positive responses at 112 and 168 kg of P_2O_5/ha, respectively, than at lower levels. Rahman and Faruque (1975) reported that a low rate of 22.5 kg of P_2O_5/ha was quite adequate to obtain profitable bulb yield in Bangladesh. Rahman, et al., (1976) reported 67.0 kg of P_2O_5/ha as an optimum phosphate level for yield in Bangladesh.

The observation of such other workers as Queddeng et al., (1963), Wayes (1967), Randhawa and Singh (1974) and Painter (1977) did not reveal any significant yield response to phosphatic fertilizer application. In Nigeria, trials conducted at Samaru and Gambaru showed no response to phosphate (Anon, 1970a). The lack of response was attributed to residual phosphate from previous cropping. Besides the variability in the amount and availability of soil phosphorus, many other factors do contribute to the differences in the observed onion crop response to phosphate fertilizer application. Narang and Dastance (1971) in India were of the view that the influence of phosphorus in enhancing the rates of root development, flower initiation and maturation could be at the expense of shoot growth and bulb yield. They also contended that the sulphur contained in single superphosphate tended to mask some of the small beneficial effects of phosphorus in some experiments thus making responses undetected. This contention arose from the observation that although sulphur was beneficial, high sulphur levels (approaching 100 ppm) had negative effect on bulb yield.

4. Effects on bulb quality

Bolting was reported to be significantly checked by phosphate fertilizers (Singh and Kumar, 1969b; Hassan and Ayoub, 1978). They suggested that phosphorus enhanced the rate of bulbing, thus suppressing the tendency to bolt. These workers also observed that in response to increasing phosphorus level, bulb size increased with the consequent increase in the yield of twin bulbs. Painter (1977) noted however, that bolting was increased in response to phosphate fertilization. Paterson et al., (1960) and Painter (1977) agreed with the previous workers that while phosphorus increased yield there was corresponding increase in the yield of culls (bolters and split bulbs). On the other hand, Pande et al., (1969) observed a reduction in the yield of small size bulbs as a result of phosphate fertilization.

Phosphatic fertilizers have been reported to promote the formation of more protective, dry outer scales of onion bulbs (Shoemaker, 1947), to reduce post-harvest rot and sprouting (Singh and Kumar, 1969b) and to be necessary for early and good bulb maturation (Tzeng, 1972).

D. Interaction of nitrogen and phosphorus

1. Effects on plot

By encouraging rapid vegetative growth nitrogen also enhances the uptake and utilization of phosphorus (Grunes, 1959). Nitrogen is directly involved in phosphorus metabolism and as such the amount of nitrogen required by the plant depended to some extent on the level of available phosphorus. The results of Queddeng et al., (1963), Inyang (1966), Pande et al., (1969), Singh and Singh (1969), Anon, (1970a) and Pande and Mundra (1971) revealed that the application of both nitrogenous and phosphatic fertilizers together resulted in greater yield responses in onion as compared with the effect of either of the two fertilizers applied singly. Similarly, Singh and Kumar (1969a) noted that the application of both fertilizers together was more effective in reducing the proportion of bolters, than either type of fertilizer applied singly. However, nitrogen and phosphorus interaction effect may not always be observed especially when the soil contains an adequate amount of available phosphorus (Randhawa and Singh, 1974).

2. Effects on other elements

Lingle and Wight (1961) observed that applying high rates of nitrogen in the form of either calcium nitrate, ammonium nitrate or ammonium sulphate induced a rapid uptake of manganese by onion plants. The increased uptake of manganese often reaches toxic levels especially in acid soils, or when the more acidic ammonium sulphate form was used as a source of nitrogen. Downes and Carolus (1961) reported a similar observation, when manganese and iron accumulated in onion tissues as a result of the application of ammonium nitrate at high rates.

Excessive supply of phosphatic fertilizers has detrimental effects in onion nutrition. Asif et al., (1976) reported that high rates of phosphorus applied to onion plants depressed the uptake of zinc, thereby causing zinc deficiency symptom characterised by foliage twisting. Ajakaiye, (1975) further reported that although high rates of phosphorus tended to depress zinc uptake, the results were not consistent and as such phosphorus fertilization might not necessarily be detrimental to zinc nutrition.

The observed growth and yield response of onion to nitrogenous and phosphatic fertilizers varied mainly with the differences in soil and climatic environments. The treatments used in Samaru and Gambaru trials were o, 65, 130 and 195 kg/ha of N each with 0 or 40 kg of P_2O_5/ha (Anon., 1970a). The range between fertilizer levels seemed wide and led to the current recommendation of 65 kg of N with 40 kg of P_2O_5/ha for irrigated onion bulb production. Further trials with reduced range between fertilizer levels can be more helpful in determining not only the optimum for total bulb yield but also for bulb quality.

MATERIALS AND METHODS

A. Experimental site

Field investigations were conducted at the University Farm of Ahmadu Bello University, Samaru, under irrigation during 1980/81 dry season. Samaru is in the Northern Guinea Savanna ecological zone of Nigeria, and situated at 11° 10'N, 07° 38'E and 685m above sea level. Samaru has soils which are mostly sandy-loam with low organic matter and cation exchange capacity. The experimental field was put under barley the previous dry season 1979/80, and left fallow in the wet season preceeding the experiment.

The result of physico-chemical analysis of the soil taken from the experimental site prior to planting is presented in Table 2.

Table 2: Physical and Chemical analysis of the soil from the experimental site, at Samaru, 1980-81 dry season

Soil Characteristic	Value
pH in water	6.8
pH in KCl	5.8
Particle size: Clay	24.0%
: Silt	38.0%
: Sand	38.0%
Organic carbon	0.25%
Total Nigrogen	0.11%
Total Phosphorus	2.14%
Available Phosphorus	Nil
Exchangeable Potassium	0.37 meq/100 gm

B. Treatments and experimental design

Each of the four levels of nitrogen (0, 40, 80 and 120 kg of N/ha) was combined with three phosphate levels (0, 40 and 80 kg of P_2O_5/ha) to give a total of 12 treatments. The twelve treatments were replicated five times in a randomized complete block (factorial) design. Nitrogen was supplied as calcium ammonium nitrate (26% N) and the phosphate was applied as single superphosphate (18% P_2O_5).

C. Nursery Management

The nursery plot was cultivated in the last week of October 1980; and prepared into 1.0 x 3.0 m beds, Well rotted farmyard manure at 0.5 kg/m^2 supplemented by 15:15:15 compound fertilizer at 20 g/m^2 was incorporated into the nursery beds before seeding.

Seeds of an available local onion cultivar, "Maiduguri Improved", were drilled in rows 15 cm apart on the 10th November, 1980. Nursery beds were kept mulched with dry grass for 10 days after seeding. For the first three and half weeks after seeding the nursery was watered by the use of watering (fine-rosed) can, thereafter water was supplied by flood irrigation. The nursery was kept weed free by hand weeding.

D. Preparation of experimental site

The experimental field received two floodings on the 17th and 19th December (1980) to make the hard soil cultivable. The field was then ploughed and harrowed. Experimental plots were prepared in the form of basins, whose gross and net sizes were 1.0 x 3.0 m and 0.6 x 2.5 m, respectively.

E. Transplanting

Seedlings were transplanted from the nursey bed to the field on the 3rd January, 1981 when they were eight weeks old. Plants were spaced at 10 cm apart in rows 20 cm apart thus giving a calculated population of 500,000 plant/ha. Seedlings were irrigated immediately after transplanting and after water was applied each week by surface flood irrigation.

F. Fertilizer application

Phosphate fertilizer was applied in bands, 5 cm deep between rows, one day before transplanting. Nitrogen fertilizer was applied in two equal split doses at 2 and 6 weeks after transplanting in a similar manner as described for phosphate fertilizer.

G. Irrigation

Irrigation was by surface controlled flooding. Water was allowed into the furrows between the basins and then into each individual basin. The field was irrigated at 5 - 7 day interval.

H. Weeding

The crop was hoe-weeded within the first 9 weeks of transplanting when bulbs were yet small. Thereafter, weeds were controlled by hand pulling as the need arose to minimise damage to roots and the growing bulbs.

I. Harvesting and curing

The crop was harvested manually by digging and pulling out the plants, on the 2nd May, 1981, (17 weeks after transplanting). By this time the early showers made field (windrow) curing inadvisable. Therefore, the harvested crop was kept indoors on partly shaded curing flatforms. The tops were cut leaving about half inch at the base; the bulbs were spread out for 2 weeks to cure.

J. Ancillary observation

Data were collected on the following characters as described below:

1) Plant height

Six plants randomly selected within the net plot were tagged after transplanting for the purpose of height measurement. Their height from ground level to the tip of the tallest leaf were measured at fortnightly intervals, beginning at 5 weeks till 13 weeks after transplanting.

2. Leaf number

The visible levels for each of the tagged plants used for height measurement, were counted every fortnightly beginning at five weeks till 13 weeks after transplanting.

3. Bolting

Plants that shoot-out flower were said to bolt. Bolted plants were counted at three weeks before harvest. To minimize diversion of food for bulbing to seed formation, the flower umbels were cut-off before they open up, and the flower stalks that persisted were used to identify bolters during the later counting.

4. Bulb yield

The three central rows constituting the net plot were harvested for yield. Bulb weight was taken after curing.

5. Bulb size grades

Harvested bulbs were graded into three sizes with the help of a mechanical grader. The yield for each grade was recorded. The classification of onion grades include:

i) Large bulbs with diameter greater than 4.5 cm,

ii) Medium bulbs with a diameter less than 4.5 cm but not more than 3.0 cm.

iii) Small bulbs with less than 3.0 cm in diameter.

6. Split bulbs

Some bulbs get splitted at the top; some others form two (or three) bulblets on the same stem. In the latter case they are often refered to as 'twin bulbs' or 'doubles'. In this experiment the split and twin bulb are being grouped under them term split bulbs. The number of split bulbs were recorded.

7. Rotted bulbs

At 5 weeks after harvest the number of rotted bulbs were recorded.

K. Statistical analysis

The data collected were subjected to statistical analysis of variance as described by Snedecor and Cockran (1967). Levels of significance of the mean differences were determined by the Duncan's Multiple Range test (Duncan, 1955).

RESULTS AND DISCUSSION

A. General observations

The plant leaves were observed to dieback on all plots in the second week after transplanting. Leaf tips appeared pale yellow, then gradually died backwards leaving dead straw-coloured tissues. This was first attributed to prolonged transplanting shock and then to the weather. But when the condition persisted, an intensive investigation done revealed that the leaf dieback was as a result of root and basal rot caused by the soil borne fungus Fusarium oxysporum Schlecht. No fungicide was available for its control at this stage of the attack.

Thrips were also noticed on the crop during the tenth week after transplanting. Two sprayings with Malathion at the rate of 1.30 kg a.i/ha on the 12th and 25th of March effectively controlled the pests before any noticeable damage could be done.

A summary of the Meteorological records were kept during the period November 1980 to May 1982 (Table 3). The weather was cool and dry during the first half of the growth period (November to February). During crop maturation (April) the weather became wet, hot and humid.

B. Plant height

Data for plant height recorded at 5, 7, 9, 11 and 13

Table 3: Some summary of meteorological data observed at Samaru during the period November 1980 to May 1981 and presented for every 10 days

MONTH	Date	Total Rainfall (mm)	Total Pan Evaporation (mm)	Mean Air Temperature (^oC)		Mean Soil Temp. at 5 cm depth (^oC)		Mean Relative humidity(%)	
				Max.	Min.	10 AM	4 PM	10 AM	4 PM
NOV	1-10	0.0	86.6	32.9	14.6	25.6	33.0	30.3	22.5
	11-20	"	78.3	32.5	13.0	24.5	32.5	28.2	20.6
	21-30	"	91.6	30.4	30.4	23.6	30.9	26.9	17.6
DEC	1-10	"	90.8	32.1	13.5	23.3	31.6	19.0	16.7
	11-20	"	87.5	26.2	11.2	20.9	27.2	23.8	18.4
	21-31	"	91.4	27.2	10.5	21.4	27.4	21.2	17.3
JAN	1-10	"	89.3	27.1	11.1	20.3	27.4	19.0	15.9
	11-20	"	92.5	29.3	11.4	19.7	29.0	16.3	14.8
	21-31	"	96.0	28.1	12.1	20.1	29.7	15.4	11.2
FEB	1-10	"	116.0	29.6	14.7	21.8	30.2	11.7	12.2
	11-20	"	107.4	34.0	15.0	23.2	34.0	11.2	10.2
	21-28	"	130.5	33.8	17.3	25.5	34.8	10.8	10.8
MAR	1-10	"	158.5	34.4	18.0	26.2	36.1	11.4	11.6
	11-20	"	132.8	39.9	19.7	26.0	35.4	31.4	20.7
	21-31	"	160.7	36.0	19.1	28.5	38.2	18.5	14.5
APR	1-10	"	145.3	37.0	18.6	30.1	38.3	21.0	3.6
	11-20	26.2	123.3	36.8	19.8	29.2	39.1	35.1	22.6
	21-30	74.5	111.6	34.2	22.0	27.8	35.2	67.3	47.0
MAY	1-10	48.7	70.5	28.0	20.5	25.7	30.5	71.9	59.6
	11-20	37.3	68.2	32.9	21.4	29.1	30.9	69.3	35.9
	21-31	4.7	84.0	32.0	20.7	28.3	36.5	65.9	52.8

Source: Soil Science Section, Institute for Agricultural Research, Samaru.

weeks after transplanting are presented in Tables 4 - 8. Differences in the mean plant height as influenced by nitrogenous and phosphatic fertilizers were significant at all the periods of measurement.

1. Effect of N

At an early period of crop growth (5 weeks after transplanting) the initial nitrogen dose of 40 kg of N/ha did not affect plant height significantly when compared with the control (Table 4). At the two higher N levels (80 and 120 kg/ha) plants were significantly taller than the control. There were, however, no significant differences among the three levels of applied nitrogen (40,80 and 12o kg/ha).

From 7 to 13 weeks after transplanting all the three rates of applied N (40, 80 and 120 kg/ha) produced significantly taller plants than the control (Tables 5 - 8). Except at the 13th week, plants at 80 and 120 kg of N/ha were significantly taller than at 40 kg/ha. There was no significant difference between 80 and 120 kg of N/ha. At the 13th week as maturity approached and the nitrogen requirement for top growth declined, no significant difference were observed among the three levels of applied N.

The response of plant height was found to be inconsistent and even unlogical. As the plants get aged the height was found to be reduced in most of the cases. This inconsistent response was attributed to the severity of infection of the basal bulb rot which resulted in the death of the leaf tips. Further this observation was mainly reflected in the control plots where no nitrogen or phosphate was applied. Therefore the mean height at seven and nine weeks after transplanting was less than the height at five weeks after transplanting. At thirteen weeks after transplanting as maturity approached the rate of leaf senescence increased resulting in lower plant height.

There was very little increase in height through the the growth period for those plants grown at the zero level of N (Figure 1). At the early stages of height measurements the tallest plants occurred at the highest level of N (120 kg/ha). In the older plants (from the ninth week) the greatest height was sustained by the lower level of 80 kg/ha, though not significantly different from the height at 120 kg/ha.

2. Effect of P_2O_5

The application of 40 and 80 kg of P_2O_5/ha significantly increased plant height above the control. At 5 weeks after

Table 4: Effect of nitrogen and phosphate levels on the height (cm) of onion plants grown under irrigation at Samaru, 5 weeks after transplanting.

	P_2O_5 (kg/ha)			
N (kg/ha	0	40	80	Nitrogen Means (± 0.6)
0	17.8	19.8	19.7	19.1 b
40	18.7	20.6	22.5	20.6 ab
80	17.5	21.5	23.4	20.8 a
120	18.8	21.9	24.7	21.8 a
Phosphate Means (± 0.5)	18.2	21.0 b	22.6 a	

S.E. (N x P interaction) = ± 1.0

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

Table 5: Effect of nitrogen and phosphate levels on the height (cm) of onion plants grown under irrigation at Samaru, 7 weeks after transplanting.

N (kg/ha)	P_2O_5 (kg/ha) 0	40	80	Nitrogen Means (± 1.3)
0	14.2 c	18.3 c	17.5 c	16.6 c
40	15.9 c	27.1 b	26.9 b	23.3 b
80	17.0 c	34.8 a	38.6 a	30.1 a
120	18.3 c	35.0 a	37.6 a	30.3 a
Phosphate Means (± 1.2)	16.3 b	28.8 a	30.1 a	

S.E.(N x P interaction) = ± 2.2

Means followed by unlike letter(s) within a treatment or their interactions are significantly different at the 5% level of significance

Table 6: Effect of nitrogen and phosphate levels on the height (cm) of onion plants grown under irrigation at Samaru 9 weeks after transplanting.

N (kg/ha)	P_2O_5 (kg/ha) 0	40	80	Nitrogen Means (± 0.9)
0	16.2 c	19.0 c	18.7 c	18.0 c
40	20.0 c	38.4 b	33.6 b	28.7 b
80	18.7 c	38.4 a	43.1 a	33.4 a
120	21.0 c	38.6 a	40.3 a	33.3 a
Phosphate Means (± 0.8)	19.0 b	32.1 a	33.9 a	

S.E. (N x P interaction) = ± 1.5

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

Table 7: Effect of nitrogen and phosphate levels on the height (cm) of onion plants grown under irrigation at Samaru, 11 weeks after transplanting.

N (kg/ha	P_2O_5 (kg/ha) 0	40	80	Nitrogen Means (± 1.0)
0	18.6 d	19.9 d	20.4 d	19.6 c
40	23.5 d	34.9 c	38.6 bc	32.3 b
80	22.7 d	42.0 ab	46.0 a	36.9 a
120	23.6 d	41.6 ab	39.6 bc	34.9 ab
Phosphate Means (± 0.8)	22.1 b	34.6 a	36.2 a	

S.E. (N x P interaction) = ± 1.7

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

Table 8: Effect of nitrogen and phosphate levels on the height (cm) of onion plants grown under irrigation at Samaru, 13 weeks after transplanting.

	P_2O_5 (kg/ha)			Nitrogen Means (± 1.2)
N (kg/ha)	0	40	80	
0	16.8 c	19.0 c	18.3 c	18.0 c
40	19.2 c	27.9 c	26.5 b	24.6 c
80	18.2 c	34.3 a	29.3 ab	37.3 a
120	16.4 c	29.3 ab	27.7 b	24.5 a
Phosphate Means (± 1.0)	17.7 b	27.6 a	25.5 a	

S.E. (N x P interaction) = ± 2.0

Means followed by unlike letter(s) within a treatment group or their interaction are significantly different at the 5% level of significance.

transplanting the difference between the two levels of applied P_2O_5 was significant; plants at 80 kg/ha were taller compared with those at 40 kg/ha. At this stage the mean plant height at 80 kg of P_2O_5/ha was 24.2 per cent greater than in the control. Phosphorus enhanced the initial root development (Singh and Jain, 1959; Tzeng, 1972) necessary for the establishment of the transplants, thereby increasing nutrient absorption and consequently resulted in taller plants. At the other stages of height measurements (the 7th to 13th weeks) difference between the two levels of applied P_2O_5 was not significant.

As mentioned earlier the plants were taller at five weeks after transplanting when compared with seven and nine weeks after transplanting in control treatments. This was mainly attributed to the lack of available phosphate which unabled the onion crop with its limited root system to grow vigorously coupled with the effect of leaf dieback.

For plants grown at the zero level of P_2O_5 there was very little increase in height over the period of growth (Figure 2) plants at the highest P_2O_5 level (80 kg/ha) were slightly taller than at 40 kg/ha.

3. Interaction

The N x P interaction was significant except at the

5th week after transplanting. The application of nitrogen in the absence of phosphate had no significant effect on plant height. At 40 or 80 kg of P_2O_5/ha increasing the N level from 0 to 40 kg/ha increased plant height significantly. Further addition of N to 80 kg/ha also significantly increased height except at the highest P_2O_5 level (80 kg/ha). At the 13th week when crop was maturing there were no significant differences among the three levels of applied N at the 80 kg level of P_2O_5/ha (Table 8). At this stage of height measurement increasing N level from 80 to 120 kg/ha resulted in slightly shorter plants; the difference between the two levels of N was, however, not significant.

Similarly, increasing the phosphate levels in the absence of applied nitrogen had no significant effect on plant height. In the presence of either of the three levels of applied N (40, 80 and 120 kg/ha) increasing P_2O_5 from 0 to 40 kg/ha increased height significantly. Further addition of P_2O_5 to 80 kg/ha had no significant effect.

The tallest plants were those at the 80 kg level of N in the presence of the highest level of P_2O_5 (80 kg/ha). This treatment produced plants 2.5 times taller than control at the peak stage of growth (11 weeks after

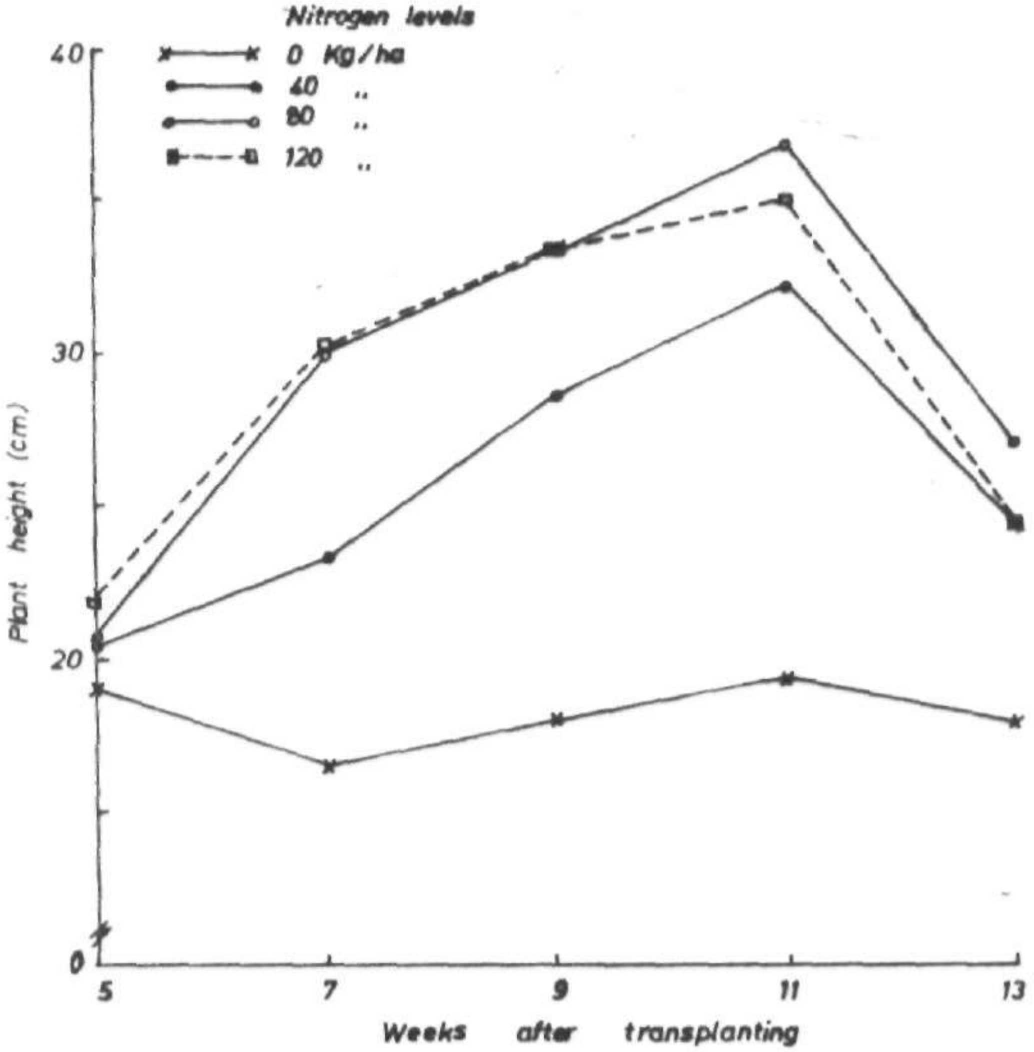

FIG 1 THE HEIGHT OF ONION PLANTS GROWN AT SAMARU UNDER IRRIGATION AS INFLUENCED BY NITROGEN LEVELS

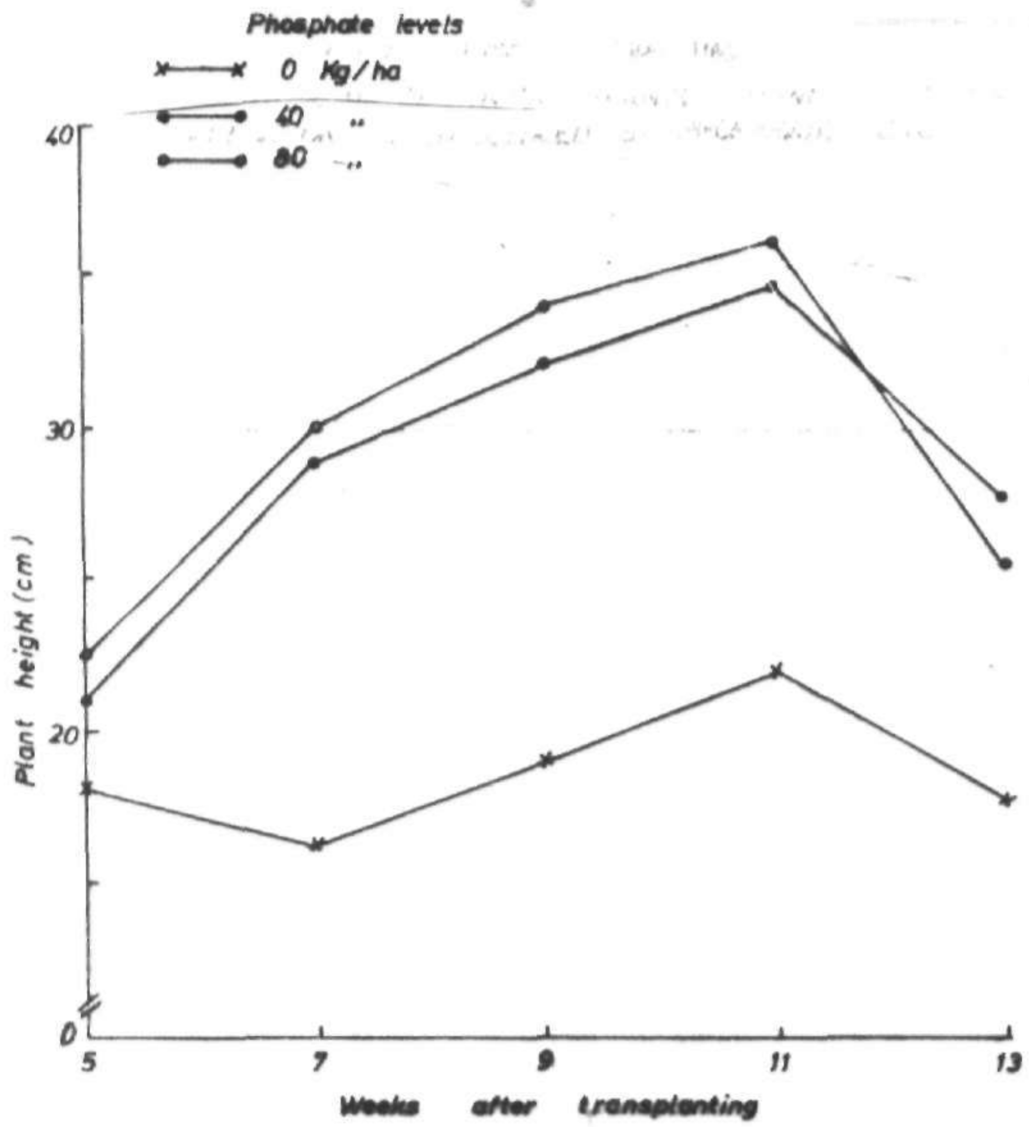

FIG 2 THE HEIGHT OF ONION PLANTS GROWN AT SAMARU UNDER IRRIGATION AS INFLUENCED BY PHOSPHATE LEVELS

transplanting). Applying 80 kg of N or P_2O_5 alone increased height by 2.0 and 1.6 times respectively above the control.

In a bulb crop of onion leaves alone will make up the onion top growth and the small stem is hidden in the thicken leaf bases. Hence the top growth is a very good index of crop performance and finally the yield. A high degree of association was found to exist between the height of onion plant and the bulb yield. The phosphatic fertilizer was found to have a pronounced effect on top growth by enhancing the limited root system of onion. Similar results of significant role of phosphate on crop performance and yield were reported by Pande et al., (1969).

At 13 weeks after transplanting as maturity approached the leaves started to die resulting in the lower mean heights recorded compared with the height at 11 weeks.

C. Leaf number

As was the case with plant height, the number of leaves per plant was recorded at 5, 7, 9 11 and 13 weeks after transplanting. The data on leaf number as influenced by nitrogen and phosphate levels are presented in Tables 9 - 13.

1. Effect of N

The application of nitrogenous fertilizers significantly increased the mean leaf number compared with the control, except at the 13th week after transplanting when the crop approached maturity. Applying the initial dose of 40 kg of N/ha significantly increased leaf number above the control except at the 7th week when it was not until 80 kg of N/ha was applied was the mean leaf number greater than in the control. Further increase in N from 40 to 80 or 120 kg/ha had no significant effect on the leaf number, except at the 7th week where the highest level (120 kg/ha) produced more leaves than the lower level (40 kg/ha).

The number of leaves per plant continued to increase until after the 11th week when the crop began to age (Figure 3).

2. Effect of P_2O_5

The application of phosphatic fertilizer also significantly increased the leaf number when compared with the control. The application of 40 kg of P_2O_5/ha significantly increased mean leaf number above the control. Further addition of P_2O_5 to 80 kg/ha had no significant effect, except at the early stage (5 weeks after transplanting).

Table 9: Effect of nitrogen and phosphate levels on number of leaves per onion plant under irrigation at Samaru, 5 weeks after transplanting.

	P_2O_5 (kg/ha)			Nitrogen Means (± 0.2)
N (kg/ha)	0	40	80	
0	5.0 d	5.3 cd	5.0 d	5.1 b
40	5.4 cd	5.5 cd	6.4 ab	5.8 a
80	5.0 d	5.8 bcd	6.6 a	5.8 a
120	5.3 cd	6.1 abc	6.8 a	6.1 a
Phosphate Means (± 0.1)	5.2 c	5.7 b	6.2 a	

S.E.(N x P interaction)= ± 0.3

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

Table 10: Effect of nitrogen and phosphate levels on number of leaves per onion plant under irrigation at Samary, 7 weeks after transplanting.

N (kg/ha)	P_2O_5 (kg/ha) 0	40	80	Nitrogen Means (± 0.3)
0	5.7 cb	5.8 cd	5.9 d	5.6 c
40	5.1 d	6.9 bd	7.0 abc	6.3 cb
80	5.1 d	7.8 ab	8.1 ab	7.0 ab
120	6.3 cd	7.8ab	8.3 a	7.5 a
Phosphate Means (± 0.2)	5.5 b	7.1 a	7.2 a	

S.E. (N x P interaction)= ± 0.4

Means followed by unlike letter(s) within a treatment group of their interactions are significantly different at the 5% level of significance.

Table 11: Effect of nitrogen and phosphate levels on number of leaves per onion plant under irrigation at Samaru, 9 weeks after transplanting.

	P_2O_5 (kg/ha)			Nitrogen Means (± 0.2)
N (kg/ha)	0	40	80	
0	6.0	6.6	6.5	6.4 b
40	6.3	8.3	7.8	7.5 a
80	5.9	8.1	8.4	7.5 a
120	6.4	8.4	8.4	7.7 a
Phosphate Means (± 0.2)	6.1 a	7.8 a	7.8 a	

S.E. (N x P interaction) = ± 0.4

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

Table 12: Effect of nitrogen and phosphate levels on number of leaves per onion plant under irrigation at Samaru, 11 weeks after transplanting.

	P_2O_5 (kg/ha)			Nitrogen Means (± 0.2)
N (kg/ha)	0	40	80	
0	7.2	7.8	6.9	7.3 b
40	7.6	8.2	8.2	8.0 a
80	6.8	8.9	8.9	8.2 a
120	7.0	8.5	8.3	8.0 a
Phosphate Means (± 0.2)	7.2 b	8.3 a	8.1 a	

S.E. (N x P interaction) = ± 0.4

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

Table 13: Effect of nitrogen and phosphate levels on number of leaves per onion plant under irrigation at Samaru, 13 weeks after transplanting.

	P_2O_5 (kg/ha)			Nitrogen Means
N (kg/ha)	0	40	80	(± 0.3)
0	7.1	8.3	6.3	7.3
40	7.3	7.9	8.1	7.8
80	7.4	7.6	8.4	7.8
120	6.6	8.3	7.1	7.3
Phosphate Means (± 0.3)	7.1 b	8.1 a	7.5 ab	

S.E. (N x P interaction) = ± 0.5

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

At 5 weeks the successive increased in P_2O_5 from 0 to 40 and further to 80 kg/ha resulted in significant increases in the leaf number. The leaf number continued to increase until after the eleventh week when crop began to age (Figure 4).

3. Interaction

The N x P interaction was significant only at 5 and 7 weeks after transplanting. In the absence of phosphate fertilizer increasing the nitrogen level from 0 to 120 kg/ha had no significant effect on leaf number. At 40 kg of P_2O_5/ha, the application of nitrogen also had no significant effect at 5 weeks after transplanting. At 7 weeks it was until the N level was raised to 80 or 120 kg/ha was the mean number of leaves per plant more than in the control. There was no significant difference between the 80 and 120 kg of N/ha treatments. At 80 kg of P_2O_5/ha, the application of 40 kg of N/ha increased the leaf number significantly above the control. The differences among the three levels of applied N (40, 80 and 120 kg/ha) were not significant.

The application of phosphate in the absence of applied nitrogen also had no significant influence on the leaf number. At 40 kg of N/ha the application of 40 kg of

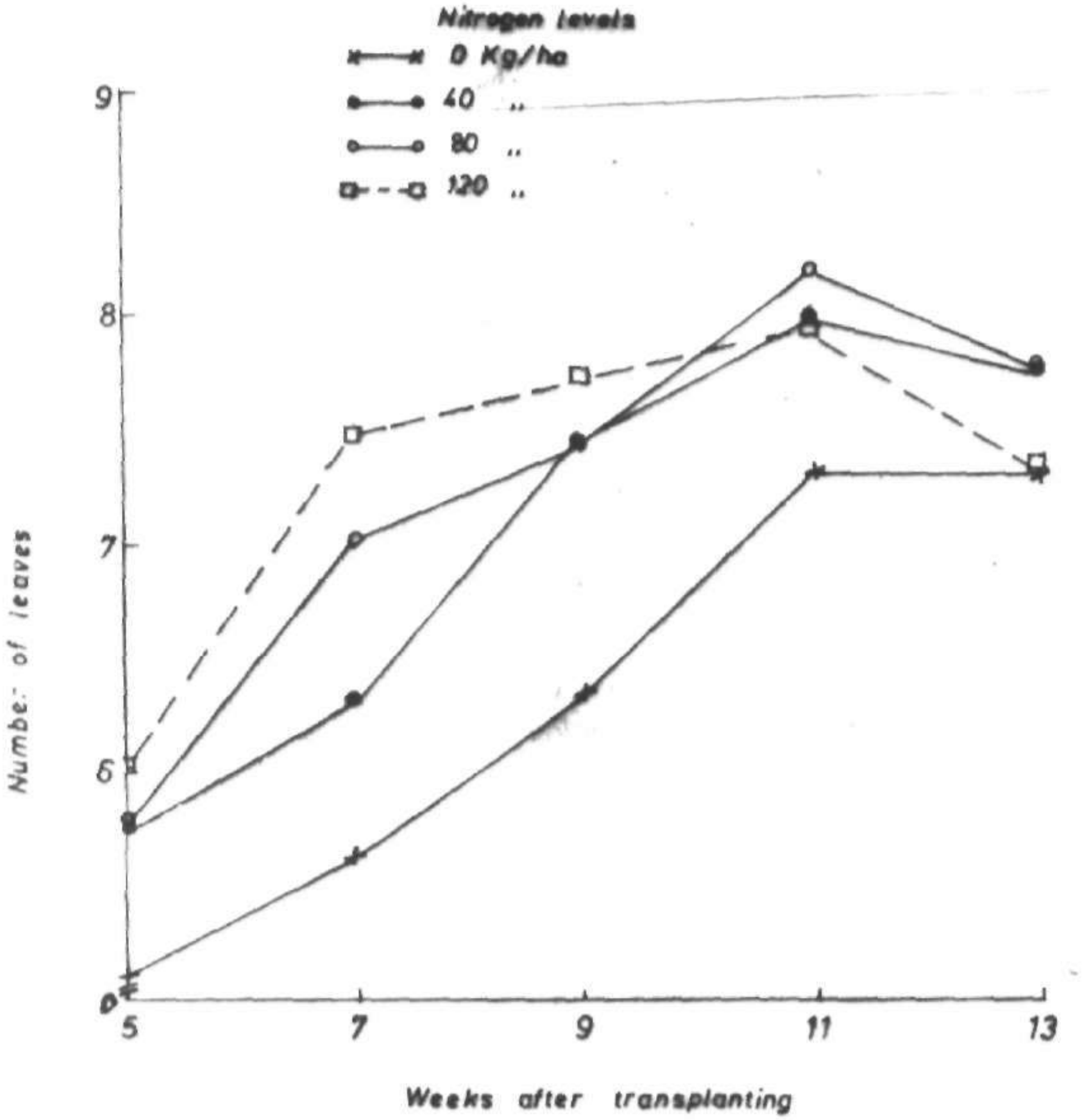

FIG. 3 : THE MEAN NUMBER OF LEAVES PER PLANT IN ONION GROWN AT SAMARU UNDER IRRIGATION AS INFLUENCED BY NITROGEN LEVELS

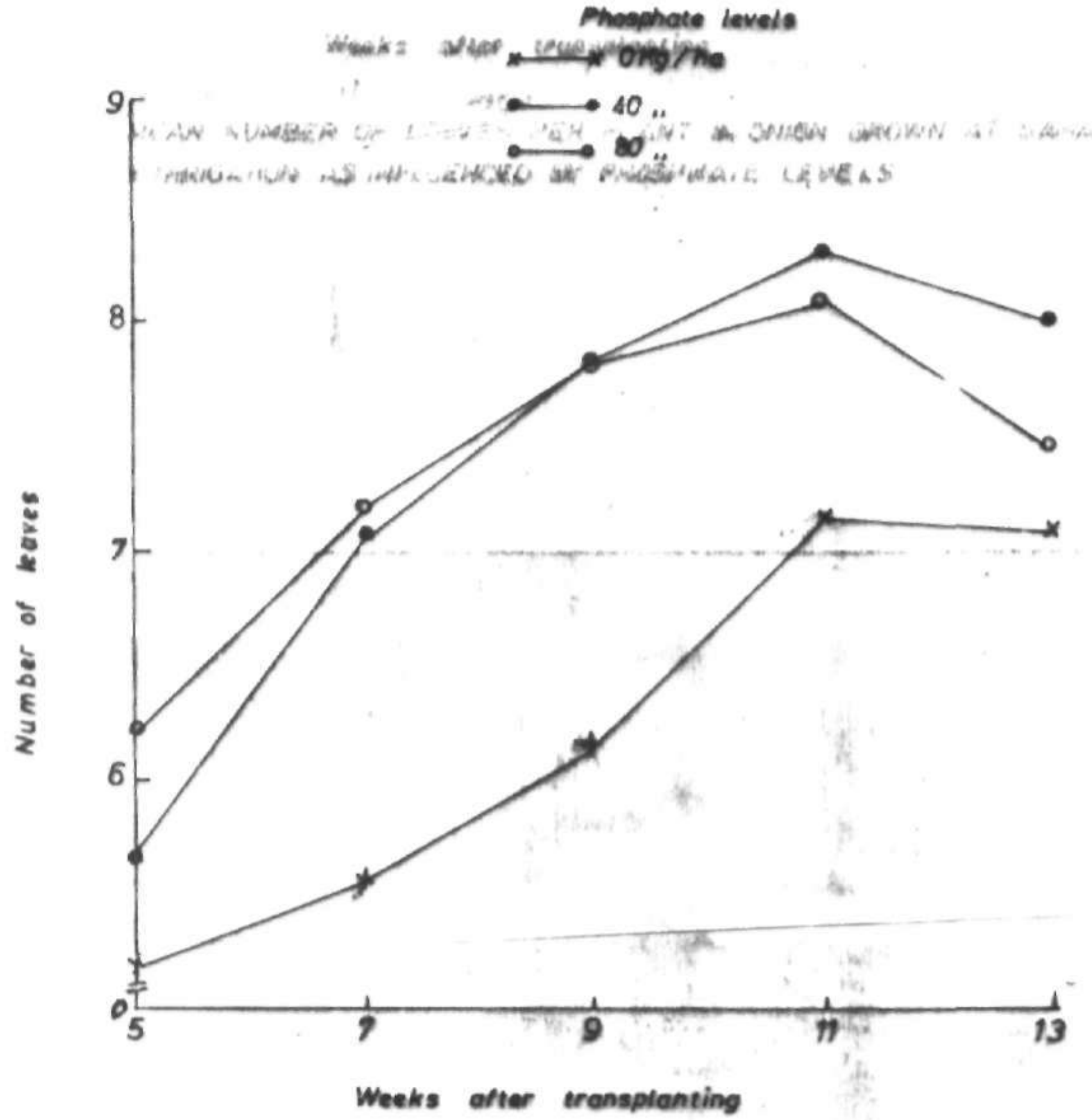

FIG. 4: THE MEAN NUMBER OF LEAVES PER PLANT IN ONION GROWN AT SAMARU UNDER IRRIGATION AS INFLUENCED BY PHOSPHATE LEVELS

P_2O_5/ha had no significant effect on the leaf number. It was not till at 80 kg of P_2O_5 was leaf number greater than in the control. The 80 kg of P_2O_5/ha also produced more leaves per plant than 40 kg/ha at 5 weeks after transplanting. When 80 or 120 kg or N/ha was applied increasing the P_2O_5 level from 0 to 40 kg failed to influence the leaf number significantly, at 5 weeks after transplanting. Further increase in P_2O_5 to 80 kg/ha produced significantly more leaves than 40 kg/ha or the control. At the 7th week of transplanting - applying either 40 or 80 kg of P_2O_5/ha increased the leaf number significantly when compared with the control. The difference between the two levels of applied P_2O_5 was not significant.

The increase in number of leaves per plant in response to nitrogen and phosphorus agreed with those reported by Pande et al., (1969) and Chowdappan and Mundra (1971). Similarly, the number of leaves per plant was found to be positively correlated to bulb yield and was in conformity with the conclusion drawn by Pande et al., (1969).

D. Bolting

The data on crop bolting as influenced by nitrogenous and phosphatic fertilizers are presented to Table 14. Both fertilizers influenced bolting significantly, but not their interactions.

1. Effect of N

The application of 40 kg of N/ha increased the percentage of bolters significantly when compared with the control. A further increase in nitrogen level to either 80 or 120 kg of N/ha did not increase bolting significantly. Bolting in onion is principally induced by low temperatures, especially in cultivars which had not been selected against bolting. The cultivar 'Maiduguri Improved' like many other local or tropical cultivars showed a high degree of susceptibility to bolting; in addition the aged transplants are more susceptible to bolt than younger seedlings. These observations were in conformity with other researchers (Robinson, 1971; Green 1973; Uzo, 1978). At transplanting the seedlings used in the present investigation were fairly large having been in the nursery for eight weeks. This fact coupled with the cool weather during December and January months (Table 3) led to the generally high incidence of bolting. In the unfertilized plots the mean bolting was as high as 31.7 per cent. The increase in bolting in response to nitrogen application could be as a direct result of the increase in plant size. Jones and Mann (1963) also reported that at temperatures near the critical requirement for bolting, nitrogen has the effect of enhancing

Table 14: Effect of nitrogen and phosphate levels on the percentage bolters per plot in onion grown under irrigation at Samaru.

N (kg/ha)	P_2O_5 (kg/ha) 0	40	80	Nitrogen Means (± 3.2)
0	31.7	39.8	35.5	35.7 b
40	46.2	55.8	53.8	51.5 a
80	40.3	59.7	63.1	54.4 a
120	41.1	61.8	50.5	51.1 a
Phosphate Means (± 2.7)	39.8 b	54.3 a	50.7 a	

S.E. (N x P interaction) = ± 5.5

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

bolting. The present observation does not seem to support the results of other workers like Paterson et al., (1960), Singh and Kumar (1969a) and Hassan and Ayoub (1978) who reported reductions in bolting as a result of nitrogen fertilization. However, in this study the increase in bolting at the highest nitrogen level was slightly less than at the lower levels. This may indicate the possibility that high rates of nitrogen tended to suppress bolting. The reduction in bolting reported by the above workers were observed at high rates of nitrogen, in excess of 100 kg/ha. Shishido and Saito (1976) explained that despite the fact that larger plants are more prone to bolting, plants at high nitrogen rates required longer cold treatment to bolt.

2. Effect of P_2O_5

The application of phosphate fertilizer also significantly increased bolting when compared with the control. There was no significant differences between the two levels of applied P_2O_5 (40 and 80 kg/ha). Like nitrogen, phosphorus fertilizer increased the tendency of onion to bolt as it increased plant growth. This confirms the observation of Painter (1977) who reported increased bolting in response to phosphatic fertilizer. As was observed with nitrogen, the increase in bolting at the highest phosphate level was slightly, less than at the lower level. However, the present observation did not confirm those of Singh and Kumar (1969 a) and Hassan and Ayoub (1978) in which bolting was suppressed with increasing phosphate levels.

No significant interaction between nitrogen and phosphate on bolting was observed.

E. Bulb yield

The data on total bulb yield as influenced by nitrogen and phosphate fertilizers are presented in Table 15. The main effects and their interaction were highly significant.

1. Effect of N

The application of 40 kg of N/ha significantly increased yield compared with the control. A further addition of N to 80 kg/ha also increased the yield. The highest nitrogen level (120 kg/ha) had a slightly depressing effect on yield and it was not different from either 80 or 40 kg N/ha. When the initial dose of 40 kg of N/ha was applied the yield doubled when compared with the control. This confirmed the contention that nitrogen was a common limiting factor for crop yields. The yield was highest at 80 kg of N/ha. The yield increase at 80 kg of N/ha was

2.5 times above the control. The slight lowering in the yield at the highest level was possibly a reflection of nutrient imbalance created by the high N rate, thus adversely affecting yield as were reported by Wilson (1934), Riekles (1970), Painter (1977) and Hassan and Ayoub (1978).

2. Effect of P_2O_5

The application of phosphate fertilizer increased bulb yield significantly when compared with the control. At 40 and 80 kg of P_2O_5/ha the yield were 4.0 and 4.2 times higher than control, respectively. The high positive yield response to phosphorus revealed the extent to which available P was lacking in the soil. The result of the analysis of soil from the experimental field (Table 2) showed that there was no available phosphorus. Positive yield responses to phosphorus have been reported by many workers like Paterson *et al.*, (1960), Shickluna *et al.*, (1965), Inyang (1966) Pande and Mundra (1971), Tzeng (1972), Rahman *et al.*, (1976) and Hassan and Ayoub (1978). The later workers reported good yield responses to additional phosphate fertilizers in soils with moderate to high level of available phosphorus. Kageyama and

Table 15: Effect of nitrogen and phosphate levels on total bulb yield (t/ha) of onion grown under irrigation at Samaru

	P_2O_5 (kg/ha)			Nitrogen Means (± 1.73)
N (kg/ha)	0	40	80	
0	8.93 c	10.73 c	12.54 c	10.73 c
40	7.27 c	28.00 b	28.54 b	21.27 b
80	5.19 c	35.20 ab	39.43 a	26.61 a
120	4.94 c	30.54 ab	30.80 ab	22.09 ab
Phosphate Means (± 1.47)	6.58 b	26.12 a	27.83 a	

S.E.(N x P interaction)= ± 3.00

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

Arai (1962) the responses of various vegetables to phosphate fertilizers, ranked onion and peas as exhibiting the most marked yield response compared with carrot, radish, turnips and several cucurbits.

3. Interaction

In the absence of either applied nitrogen or phosphorus the application of the other element did not increase the bulb yield significantly. The response to both nitrogen and phosphate were very similar. Within each level of applied N there was a significant increase in bulb yield when the P_2O_5 level was increased to either 40 or 80 kg/ha. The differences between 40 and 80 kg was not significant. Similarly at a specific level of applied P_2O_5 bulb yield was higher when the nitrogen level was increased to 40 and from 40 to 80 kg of N/ha. A further increase in the N level to 120 kg/ha did not increase the bulb yield significantly. In the absence of nitrogen, phosphorus addition had positive effect on yield unlike nitrogen which tended to depress yield in the absence of phosphorus. The highest bulb yield (39.43 t/ha) was recorded when both N and P_2O_5 were applied at 80 kg/ha each. In the presence of the highest N level (120 kg/ha) bulb yield was slightly depressed.

The yield data was found to fit the quadratic expression:

$$Y = a + b_1 N + b_2N^2 + b_3N^2 + b_4P^2 + b_6 N^2P^2;$$

where N and P are coded values of the fertilizer rates (level of N or P_2O_5 per 40 kg); the regression constants are

$a = 6.72$ $b_4 = -3.23$

$b_1 = 2.53$ $b_5 = 12.25$

$b_2 = -1.26$ $b_6 = -1.39$

$b_3 = 8.62$

The omission of the N^2P^2 term in the above expression reduced the goodness of fit possibly because of the negative response of yield to nitrogen application in the absence of phosphate.

From the above equation the technical optimum yield of 38.66 t/ha is obtained at 85 kg of N/ha and 73 kg of P_2O_5/ha; both fertilizer levels were within the range of the treatments used.

F. Large bulbs

Bulbs with diameter greater than 4.5 cm were classified as large. The data on the yield of large bulbs as influenced by nitrogen and phosphate fertilizers are presented in Table 16. The differences in the mean yield as affected by the main effects and their interaction were highly significant. Their influence was similar to that on the total bulb yield. A major proportion of the total bulb yield resulting from the fertilizer application was made up of large bulbs.

1. Effect of N

The application of nitrogen increased the yield significantly above the control. The yield response was positive up to 80 kg of N/ha. At 80 kg of N/ha large bulbs accounted for about 75 per cent of the total bulb yield. A further increase in the N level to 120 kg/ha had a slightly depressing effect on the yield of large bulbs. However, there was no significant differences among the three levels of applied N (40, 80 and 120 kg N/ha). This observation agreed with the result of Pande *et al.*, (1969), Singh and Kumar (1969 a), Chowdappan and Mundra (1971) and Hassan and Ayoub (1978) which showed that the increase in bulb yield due to nitrogen application was accompanied by a proportional increase in the yield in the yield of large bulbs. Painter (1977) reported a reduction in both the total yield and yield of bulbs greater than 7.0 cm in response to high rates of N (90 - 360 kg/ha). In the present experiment, there was also a negative response of both total and large bulb yields as N was increased from 80 to 120 kg/ha which tend to lend support to the idea of the adverse effect of excessive nitrogen on onion bulb yield.

2. Effect of P_2O_5

The application of phosphate fertilizer also significantly increased the yield of the large bulbs when compared with the control. There was no significant difference between the two levels of applied P_2O_5 (40 and 80 kg/ha). Large bulbs accounted for nearly 74 per cent of the total bulb yield at 80 kg of P_2O_5/ha.

3. Interaction

In the absence of either applied N or P_2O_5 the application of the other did not influence the yield of large bulbs. Within each level of applied nitrogen there was a significant increase in the yield when P_2O_5 level was increased to either 40 and 80 kg/ha. The differences between the two phosphate levels was not sngnificant. At 40 kg of P_2O_5/ha the application of nitrogen significantly increased the yield of large bulbs, there was however no significant differences among the N levels applied. At the highest phosphate level increasing N from zero to 40 kg and from 40 to 80 kg/ha increased the yield. A further

Table 16: Effect of nitrogen and phosphate on the yield of large bulbs (t/ha) of onion grown under irrigation at Samaru

N (kg/ha)	P_2O_5 (kg/ha)			Nitrogen Means (± 2.20)
	0	40	80	
0	1.80 c	3.20 c	3.40 c	3.80 b
40	1.40 c	19.60 b	21.07 b	14.00 a
80	0.53 c	26.27 ab	33.30 a	20.03 a
120	0.60 c	22.67 ab	24.40 ab	15.87 a
Phosphate Means (± 1.87)	1.07 b	17.03 a	20.54 a	

S. E.(N x P interaction)= ± 3.80

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

increase in N to 120 kg/ha did not influence the yield significantly. About 84 per cent of the total bulb yield at 80 kg each of N and P_2O_5/ha was made up of the large bulb grade.

G. Medium bulbs

Bulbs with diameter of 3.0 to 4.5 cm were classified as of medium size. The data on the yield of this grade of bulbs as influenced by nitrogen and phosphate fertilizers are presented in Table 17.

1. Effect of N

The effect of nitrogen on the yield of medium bulbs was not significant. The yield trend showed gradual decline as nitrogen level was increased at both zero and 80 kg of P_2O_5/ha. Thus nitrogen application had increased the yield of large bulbs without significantly influencing that of the medium grade.

2. Effect of P_2O_5

Phosphorus on the other hand had highly significant influence on the yield of medium bulbs. The application of either 40 or 80 kg of P_2O_5/ha significantly increased the yield above the control. There was no significant differences between the two levels of applied P_2O_5. The

Table 17: Effect of nitrogen and phosphate levels on the yield (t/ha) of medium size bulbs of onion grown under irrigation at Samaru

N (kg/ha)	P_2O_5 (kg/ha) 0	40	80	Nitrogen Means (± 0.57)
0	4.73	5.60	7.07	5.80
40	3.87	7.67	6.80	6.13
80	2.73	8.80	6.00	5.87
120	2.67	7.40	5.80	5.27
Phosphate Means (± 0.49)	3.53 b	7.40 a	6.40 a	

S.E.(N x P interaction) = ± 1.00

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

experimental field (soil) was deficient in available phosphorus. Therefore the addition of phosphate not only promoted the yield of large bulbs but also of the medium size bulbs.

No interaction between N and P_2O_5 was observed on the yield of the medium bulbs.

H. Small bulbs

Bulbs with diameter of less than 3.0 cm were classified as small. These bulbs are generally considered too small for the market and therefore normally culled. The data on the yield of small bulbs as influenced by nitrogen and phosphate fertilizer are presented in Table 18. The main effects, nitrogen and phosphorus were highly significant, but their interaction was not.

1. Effect of N

The application of 40 kg of N/ha significantly reduced the yield of small bulbs when compared with the control. The differences among the three levels of applied N (40, 80 and 120 kg/ha) were not significant. The influence of nitrogen application confirms the results of Pande et al., (1969) and Hassan and Ayoub (1978). Nitrogen application increased yield by increasing bulb size with

Table 18: *Effect of nitrogen and phosphate levels on the yield (t/ha) of small size bulbs of onion grown under irrigation at Samaru*

	P_2O_5 (kg/ha)			Nitrogen Means (± 0.20)
N (kg/ha)	0	40	80	
0	2.40	1.93	2.07	0.32 a
40	2.00	0.73	0.67	0.17 b
80	1.93	0.13	0.13	0.11 b
120	1.67	0.47	0.60	0.14 b
Phosphate Means (± 0.13)	2.00 a	0.80 b	0.87 b	

S.E.(N x P interaction)= ± 0.30

Means followed by unlike letter(s) within treatment group or their interactions are significantly different at the 5% level of significance.

the consequent reduction in the proportion of the small bulbs.

2. Effect of P_2O_5

The application of either 40 or 80 kg of P_2O_5/ha also significantly reduced the yield of small bulbs compared with the control. The differences between the two levels of applied P_2O_5 (40 and 80 kg/ha) was not significant. The observation confirmed those by Paterson et al., (1960) and Pande et al., (1969). Like nitrogen phosphate fertilizer increased bulb growth with the consequent reduction in the yield of small bulbs.

I. Split bulbs

Bulbs that are either split or form doubles (twin) are normally culled for the more sophisticated markets. The split creates entry for pathogenic organisms, so also the twin bulbs when they get broken apart during handling. In the present experiment the split and twin bulbs have been grouped together and referred to as split bulbs. The data on the mean number of split bulbs as influenced by nitrogen and phosphate fertilizers are shown in Table 19. The main effects and their interaction were highly significant.

1. Effect of N

The application of nitrogen significantly increased the number of splits when compared with the control. The differences between 40 and 80 and between 80 and 120 kg of N/ha were not significant. However, the highest N level (120 kg/ha) produced significantly more split bulbs when compared with 40 kg of N/ha.

2. Effect of P_2O_5

The application of phosphate fertilizer also increased the number of splits when compared with the control. The difference between the two levels of applied P_2O_5 (40 and 80 kg/ha) was not significant. The influence of both nitrogen and phosphate fertilizer on bulb splitting appear to have confirmed the observation of Hassan and Ayoub (1978). They reported that the tendency for bulb to split or form doubles was positively correlated to bulb size; and as the bulb size increased in response to nitrogen and phosphorus application so did the proportion of the split bulbs.

3. Interaction

In the absence of applied phosphorus, the number of splits increased in response to the application of 40 kg of N/ha when compared with the control. However, at the higher levels of N the number of splits were not significantly

Table 19: Effect of nitrogen and phosphate levels on the number of split bulbs of onion grown under irrigation at Samaru

N (kg/ha)	P_2O_5 (kg/ha) 0	40	80	Nitrogen Means (± 0.25)
0	1.60 ef	2.80 de	2.80 de	2.40 c
40	2.80 d	3.80 cd	4.20 c	3.60 b
80	1.20 f	4.60 bc	6.20 a	4.00 ab
120	1.40 ef	5.80 ab	6.00 a	4.40 a
Phosphate Means (± 0.22)	1.75 b	4.25 a	4.80 a	

S.E.(N x P interaction) = ± 0.44

Means followed by unlike letter(s) within a treatments group or their interactions are significantly different at the 5% level of significance.

different compared with the control. At 40 kg of P_2O_5/ha increasing the N level from zero to 40 kg/ha was not significant. A further increase in the N level to 120 kg resulted in significantly more splits compared with the 40 kg/ha At the highest level of P_2O_5 (80 kg/ha) increasing the N level from zero to 40 kg and further to 80 or 120 kg/ha produced more splits than at the control. There was no differences between the 80 and 120 kg of N/ha at all levels of phosphate.

In the absence of nitrogen increasing the P_2O_5 level did not influence the number of split bulbs. At 40 kg of N/ha increasing the P_2O_5 level from zero to 40 kg/ha was not significant. A further increase to 80 kg of P_2O_5/ha produced more splits than at the control. At 80 kg of N/ha increasing phosphate from zero to 40 and further to 80 kg of P_2O_5/ha resulted in significantly more splits. Similarly at the highest N level (120 kg/ha) increasing the P_2O_5 level from zero to 40 kg/ha increased the number of splits. A further increase of P_2O_5 to 80 kg/ha was not significant.

J. Bulb rot in storage

As a result of an early attack by *Fusarium oxysporum* Schlecht on the onion crop in the field, few bulbs were found to have started rotting at harvest. At five week after harvest, the rotted bulbs were culled. The data on the proportion of rotted bulbs per treatment as influenced by nitrogen and phosphate fertilizers are presented in Table 20.

1. Effect of N

The differenced in the mean per cent rotted bulbs as influenced by nitrogen were not significant. Singh and Kumar (1969 b) and Painter (1977) observed increased incidence of bulb rot in response to increasing levels of nitrogen fertilization. While the present study could not confirm their observation, there was a slight increase (13.8%) in the percentage of rotted bulbs at the highest level of applied N as compared with the control. Excess or high rates of nitrogen can be expected to render the crop more susceptible to pathogenic attack (Vaughan, 1960). On the other hand moderate nitrogen fertilization can be beneficial to storage quality (Celestine, 1961).

2. Effect of P_2O_5

Phosphate fertilizer had a positive influence on the rotting of bulbs in store. The application of 40 and 80 kg of P_2O_5/ha significantly lowered the percentage of rotted bulbs when compared with the control. There was no

Table 20: Effect of nitrogen and phosphate levels on the per cent bulbs rotting in onion grown under irrigation at Samaru, 5 weeks after harvest

	P_2O_5 (kg/ha)			Nitrogen Means (± 2.2)
N (kg/ha)	0	40	80	
0	36.3	29.9	34.1	33.4
40	41.4	33.1	27.4	34.0
80	35.3	32.0	26.7	31.3
120	41.1	30.9	41.9	38.0
Phosphate Means (± 1.9)	38.5 a	31.5 b	32.5 b	

S.E.(N x P interaction)= 3.8

Means followed by unlike letter(s) within a treatment group or their interactions are significantly different at the 5% level of significance.

difference between the effect of the two levels of applied P_2O_5. This result confirms the finding of Ashour et al., (1973) who reported significant reduction in bulb rotting caused by Fusarium oxysporum on onion in the field crop and in store. The application of phosphate fertilizer was reported to improve the storage ability of onion bulbs (Singh and Kumar, 1969 b; Thompson et al., 1972).

The N x P interaction was not significant. Celestine (1961) reported that the temperature at which onion bulbs were stored had the greater overriding effect on rotting than did nitrogen fertilizer or the irrigation schedule used. Onion stored under "ordinary" temperatures had a 90% rotting compared with those stored at lower temperature (2.3°C). Onion bulb rot is much encouraged by high temperatures, and Stow (1975) fail to observe any evidence of heritable resistance of rot among the 20 cultivars stored at 30°C. The high percentage of rotting, observed in the present trial can be attributed to two main factors. First and foremost was the fact that the crop had been infected from the field by the basal rot pathogen, Fusarium oxysporum Schlecht. Secondly the period just before and after harvest (April and May months) was warm (mean air and soil temperatures above 28°C) and more humid compared with the earlier periods of crop growth (Table 3).

CORRELATION ANALYSIS

Simple correlation coefficients were calculated between bulb yield, plant height, number of leaves per plant, twin bulbs and bolters (Table 21). Partial correlation coefficients were also calculated between yield, plant height and leaf number. All correlation coefficient were positive and significant at 1% level, except partial correlation between bulb yield and number of leaves per plant keeping plant height as constant (-0.088). When the association of bulb yield was considered with plant height and number of leaves per plant it was revealed that there was a very high positive correlation between the bulb yield and the plant height (0.88). The correlation between bulb yield and the number of leaves per plant was also positive and significant at 1% level (0.526). A study of partial correlation coefficient in conjuction with simple correlation coefficient revealed that 77.4 per cent of the yield was associated with plant height, and 27.7 per cent to number of leaves. When the two factors were considered together their combined contribution was 77.6 per cent which shows that the plant height was more closely related to yield.

Table 21: Simple and partial correlation coefficient between plot means for bulb yield, and yield characters of irrigated onion grown at Samaru during 1980-81.

Variable correlated	'r' value
Simple correlation	
Bulb yield Vs plant height	0.880**
Bulb yield Vs number of leaves per plant	0.526**
Bulb yield Vs split bulbs	0.661**
Bulb yield Vs. bolters	0.578**
Plant height Vs number of leaves per plant	0.634**
Plant height Vs split bulbs	0.673**
Plant height VS bolters	0.699**
Number of leaves/plant Vs split bulbs ..	0.472**
Number of leaves/plant VS bolters	0.493**
Twin bulbs Vs bolters	0.397**
Partial correlation	
Bulb yield Vs plant height with number of leaves/plant constant	0.831**
Bulb yield Vs number of leaves/plant, with plant height constant	0.088$^{N.S.}$
Bulb yield when both plant height and number of leaves/plant were kept constand	0.881**

** = highly significant (1%)

N.S. = not significant

This was further confirmed by partial correlation. The contribution of plant height on bulb yield was 69 per cent when the effect of number of leaves per plant was kept as constant. The relative contribution of number of leaves per plant was 0.77 per cent when the effect of plant height was eliminated. There was also a high degree of association between bulb yield and twin bulb; plant height and number of leaves per plant, twin bulbs and bolters. The degree of association was lowest between twin bulbs and bolters among all the characters studied.

SUMMARY AND CONCLUSIONS

A field experiment was carried out at the University Farm of Ahmadu Bello University, Samaru, under irrigation during the 1980/1981 dry season. The objectives of the experiment was to study the effects of nitrogenous and phosphatic fertilizers applied at varied levels on the growth and yield of onion. Four levels of N (0, 40, 80 and 120 kg/ha) each at three levels of P_2O_5 (0, 40 and 80 kg/ha) were applied to a local onion cultivar 'Maiduguri Improved'. A randomized complete block design was adapted and each of 12 treatment was replicated five times.

The application of nitrogen increased the growth of onion in terms of plant height, number of leaves and the size of bulbs. The yield of bulbs was also significantly increased by the application of nitrogen. The initial dose of 40 kg of N/ha doubled the yield at the control. The yield of large sized bulbs which in response to 80 kg of N/ha constituted 75 per cent of the total yield, was significantly increased by nitrogen application. The proportion of small bulbs was consequently reduced. Thus, nitrogen increased the yield of marketable bulbs. However, bolting and the proportion of split bulbs both of which are undesirable characters were also increased.

The application of phosphatic fertilizer like nitrogen increased the height, leaf number and size of the bulbs of onion. The yield of bulbs was significantly increased. The initial dose of 40 kg of P_2O_5/ha resulted in a four-fold increase in yield compared with the control. This high response of onion to phosphate was probably because of low native phosphorus in an available form, as was revealed by the analysis of soil from the experimental site, was lacking. The yield of large size bulbs was significantly increased over the control. This grade of bulbs made up 74 per cent of the total yield at 80 kg of P_2O_5/ha. The yield of medium size grade was also increased while that of the small bulbs was decreased in response to P_2O_5 application. Bolting and the formation of split bulbs were also favoured by phosphate and nitrogen application.

The application of phosphate fertilizer had a favourable effect on the storage life of the bulbs. The percentage of rotted bulbs after five weeks of harvest was not influenced by nitrogen, but the application of phosphate significantly reduced rotting.

The interaction of nitrogen and phosphate was significant on the growth and yield of onion. The application of either nitrogenous or phosphatic fertilizer alone had no significant influence on growth or yield. Instead, increasing levels of nitrogen in the absence of phosphate tended to depress bulb yield. The highest level of nitrogen (120 kg of N/ha) was also observed to have a slight depressing effect on the growth and yield compared with the effect of 80 kg/ha. The difference between 80 and 120 kg of N/ha or between 40 and 80 kg of P_2O_5/ha on yield was not significant. The application of 80 kg of N at P_2O_5/ha produced the tallest plants, the most leaves and the highest bulb yield. At this treatment large size bulbs contributed 84 per cent of the total bulb yield. Fitting the yield data into a quadratic expression showed that the optimum yield can be obtained at 85 kg of N and 73 kg of P_2O_5/ha.

The treatment which produced the best growth and the highest yield, also increased the proportion of bolters and split bulbs. The correlation between yield, plant height, leaf number, bolters and split bulbs were positive and significant. Therefore, applying nitrogenous or phosphatic fertilizers to increase yield, invariably increased the proportion of bolters and split bulbs.

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