EFFECT OF NITROGEN FERTILIZATION AND INTRA-ROW PLANT SPACING ON GROWTH AND YIELD OF GARLIC *(Allium sativum* L.)

By

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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 "EFFECT OF NITROGEN FERTILIZATION AND INTRA-ROW PLANT SPACING ON GROWTH AND YIELD OF GARLIC" by Bashir Ahmad BABAJI meets the regulations governing the degree of Master of Science (Agronomy) of Ahmadu Bello University, Zaria and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

To my brother

Wing Commander Umar Ahmad BABAJI

Who showed me the value of life (by being the pillar behind my educational background right from grass-root) and whose dedication to helping others I try to portray.

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- Bashir Ahmad BABAJI

ABSTRACT

A field experiment was conducted under irrigation at the Institute for Agricultural Research (I.A.R), Ahmadu Hello University. Samaru, Zaria during 1993/94 (November-April) dry season to study the response of garlic *{Allium sativum* I..) to different levels of nitrogen (0, 40, 80 and I20kg/ha) and intra-row spacing (5x10, 10x10 and 15x10cm). Application of nitrogen significantly increased plant height, number *oi'* leaves/plant, fresh and dry leaf weight, fresh and dry bulb weight, % bolters, bulb diameter, number of cloves and total bulb yield/ha with optimum values at 40kg/ha rates of N. The number of days to crop maturity, dry matter contents of bulb and average weight per clove were, however, reduced by N application.

Increasing intra-row plant spacing from 5x10cm to 15x10cm significantly increased leaf fresh and dry weights between 6 to 15 weeks after planting (WAP), the mean weight/bulb at 15WAP, % bolters, bulb diameter, mean fresh weight of mature bulb, number of cloves/bulb and bulb yield/ha. However, spacing had no significant effect *on* plant height, number of leaves per plant, dry bulb weight between 6-15 WAP. days to crop maturity, bulb dry mallei- content and mean weight/clove. The interaelion of nitrogen and spacing was significant on number of leaves/plant, bulb diameter, mature bulb weight and number of cloves per bulb which were maximized by the combination of 80kgN/ha with 15x10cm, while the effect of these treatments *on* yield was optimum at N rate of 40kg/ha plus intra-row spacing of 5x10cm or 10x10cm depending on the quality of the crop needed.

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LIST OF ABBREVIATIONS

% = Percentage
°C = Degree centigrade
cm = Centimeter
DM = Dry matter
et al = and others
e.t.c = et cetera
g = Gram(s)
ha = Hectare
hrs = Hours
kg = Kilogram(s)
m = Metre (s)
m^2 = Metre square
mm = Millimetre
N = Nitrogen
NS = Not significant
P = Elemental phosphorus(page 15) and percentage (as appeared in tables footnote).
P_2O_5 = Oxide of phosphorus
S = Spacing
t = Tonnes
WAP = Weeks after planting.

CHAPTER ONE

1.0 INTRODUCTION

Garlic (*Allium sativum* L.) is a bulb crop belonging to the family Alliaceae. It is the second most widely used of cultivated Allium after onions (*Allium cepa*). It is an erect herb, 30 to 60cm tall, with superficial adventitious roots. It produces a bulb which is composed of small bulblets (cloves). The leaves consist of flat longitudinally folded leaf-blades diverging at widely spaced intervals from its false solid stem. The inflorescence, if present, consist of long pinkish flower but seldom produces seed(s). Small bulbils may, however, be produced in inflorescence (Purseglove, 1972).

1.1 Origin and Distribution

Garlic originated from central Asia (about 3,000 years) and is an important spice and condiment crop throughout countries bordering the Mediterranean and in areas which have been populated by southern Europeans, especially, China, India, Egypt, Philippines, Greece, Rome, Portugal and France (Purseglove, 1972 and Tindal, 1986) .

In Nigeria, garlic is not a new crop as it has been in cultivation for many decades in parts of Kano State (Kofa, Kiru etc), Sokoto State (Achida and Wurno) and Borno State. Today its cultivation is rapidly spreading to other savanna areas (Bauchi and Jigawa States).

1.2 Climatic requirements

Garlic is a cool weather loving crop with a moderate moisture requirement. It is susceptible to high soil moisture which may cause rotting of roots and bulb scales. In Nigeria it is grown during the cool dry season (November - February) under irrigation. However, bulbing and its maturity are favoured by long warm day (Jones and Mann, 1963).

1.3 Economic importance

Garlic cloves contain approximately 63% water, 7% protein, 0.2% fat, 28% carbohydrate, 0.8% fibre and 0.1% ash. It contains pungent sulphur compounds which make it popular in many countries where it is used as condiments for flavouring other foods (Purseglove, 1972).

According to Purseglove (1972), Spain is the world's largest producer with over 100,000 tonnes per annum. Other important producers are Egypt, France, Mexico, Japan, California, East Europe and Brazil. The crop is used in preparing salad, salami sausages and many other foods. In medieval Europe it was widely used for distinguishing the smell and flavour of salted meat and fish. In India and China, it is often used as curries, while in Philippines, eastern Asia and parts of the tropics, the green tops are used as well as the bulbs. Dehydrated garlic, in powdered or granulated form, is replacing the fresh bulbs for industrial and home use in the United State and many advanced countries.

The medicinal values of garlic was recognised since very early times, although no longer accorded strong status in modern Pharmacopoeias

(Purseglove, 1972). But in recent times 'Garlic salt' and other synthetic drugs mostly used by hypertensive patients is now flooding the markets in the developed as well as the developing countries. Garlic has been used as powerful antidote against poisons of all kinds as well as antibacteria. Garlic contains volatile sulphur oils, principally, diallyl thiosulphinate and lesser amounts of several other organic sulphides as well as allicin (Purseglove, 1972). In Nigeria, garlic is also popularly used for medicinal purposes, whether singly or in combination with some other herbs for curing colds, hypertension and hemorrhoids. It is also a commercial cash crop (personal communication). For example, a bag (approximately weighing 35-45kg) was sold for 1,600 and 1,800 naira (about 60 - 70 naira per kg) in 1993 at farmers level. The selling prices during off season is much higher.

1.4 Justification for this research

A number of workers in many parts of the world have shown that garlic production can be improved through plant spacing and nitrogen fertilization (Kusumo and Widjajanto, 1973; Lucero *et al.*, 1982; Aleksiev, 1989). However, the crop's responses to such cultural practices vary with the local conditions of weather and soil (Aljarou and Escaff 1976; Lazzari *et al.*, 1978; Maurya and Bhuyan, 1982; Nelson, 1983; Ruiz, 1985). Unfortunately, there is no evidence of research on garlic production in Nigeria where the crop has been in cultivation for decades. Even though, most of the garlic growers in Nigeria have developed their own cultural practices of cultivating the crop, there is a need to evaluate the efficiency and effectiveness of these practices particularly because

they vary greatly. For example, in Kofa area, plant spacing vary from approximately 6 - 11cm between row and 5 - 10cm within the row. Likewise, fertilizers are applied by broadcasting method without much care on the of type or rate of application. With good practice, it has been possible to obtain yield of 20.5t/ha (Maksoud *et al.*, 1984). The Nigerian farmer is currently obtaining about 5-7t/ha (field sample estimates) which is far lower than the world's average of 10 to 15t/ha (Jones and Mann. 1963. There is need to assess the crop reponses to variable production practices in order to obtain appropriate treatments for maximizing the yield. It is with this aim that the present work was under taken, specifically.

(1) To determine the effect of nitrogen fertilizer level and plant spacing on growth and yield of garlic and

(2) To determine whether there is any significant nitrogen by spacing interaction on the growth and yield of garlic.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Effect of nitrogen on growth and development of garlic

Nitrogen is very important element for plant growth and development which is usually quite limiting in most savanna soils. Thus, several workers have reported significant responses by garlic to N application.

Norvais *et al.*, (1974) in an experiment carried out in Brazil reported that increasing rates of ammonium sulphate fertilizer from 0 - 100Kg/ha increased the leaf nitrogen, phosphorus and magnesium contents. From Indonesia, Aliudin and Suminto(1978) reported that application of 240kgN/ha increased the growth and development of garlic plants. Bravo and Duimovic (1978) from Chile showed that garlic plants receiving 75 or 225kg/ha produced 62 and 75.9% of premium grade bulbs, respectively. In experiments reported from Indonesia by Aliudin (1980), the application of 50, 123 and 275kgN/ha produced increasingly positive effects on garlic growth and development, with the optimum nitrogen rate at 172.81kg/ha.

Lachica (1982) reported that application of 30kg or 45kgN/ha produced optimal rate of growth in garlic crop. However, in an experiment carried out in India by Singh *et al.*, (1984), using 6 levels of N (0,50,100,150,200 and 250kg/ha), it was observed that plant height increased with increase in N levels from 0 - 100kg/ha, while further increase beyond this level was excessive and depressed growth . Maksoud *et al* .. (1984) in Egypt found a significant influence of N on garlic growth and development. Buwalda (1986) from New Zeland

reported that increasing N-rates increased the rate of leaf production and leaf extension, particularly for the first leaf. In a field trial carried out in Ukraine, Borabash and Kochina (1987) found that application of 90kgN increased the assimilatory leaf area and photosynthetic productivity.

2.2 Effect of nitrogen on yield and development of garlic

Nitrogen fertilizer when applied in adequate quantities is essential for high bulb yield in garlic crop. In a field trial carried out in Brazil, cultivar "Amarante" showed the greatest yield response to the application of ammonium sulphate followed by the cultivar "Barbado" and "Branco" (Menezes *et al.* 1974). In another trial at Bahia Blanca, Argentina, top dressing with 75kgN/ha applied in June followed by 75kgN in September with or without irrigation was compared. It was observed that the best yield of high quality garlic was obtained from plots receiving nitrogen plus irrigation(Lazzari *et al* 1978).

Aliudin (1980), reported that varying rates of nitrogen at 50,125, 200 and 275kg/ha were applied once at 0 and 30 days only or in three splits at 0,15 and 30 days, or 15, 30 and 45 days after planting. The results showed that the time of application did not affect growth or yield; but the relationship between nitrogen rate and bulb yield (dry weight) was quadratic with the maximum yield at 172.81kgN/ha.

Kibreab and Hiranburana (1981) in a two year trial, carried out in Thailand compared 4 levels of N-fertilization (30, 60, 90 and 120Kg/ha). Prior to sowing, a high level of manure was also applied , (7.5t/ha in 1978 and 6.5t/ha in 1979/80). In both years, there was no response to increasing levels of nitrogen.

This may be an indication that optimum nutrient supply was achieved even at the lowest rate of fertilizer with manure. From Chile Escaff and Aljarou (1982) found that 90kgN/ha had no effect on yield or quality of garlic in one trial. But in a second fertilizer experiment with varying rate of N (0, 75, 150 and 225kgN/ha), the application of up to 150kg/ha increased the yield and quality of the bulbs.

In a trial by Nelson (1983) from New Zealand application were made of nitrogen at 100, 150 and 200kg/ha as a base dressing, and 0, 50 and 100kg as side dressing at 100 days after planting. The application of fertilizer both basal and side-dressing improved yield and bulb size. Singh *et al.*, (1984) in an experiment using 6 different N rates (0, 50 100, 150, 200 and 250kgN/ha)reported that yield of bulbs as well as individual bulb size increased with increase in N level up to 150kg/ha, but beyond this level the yield was decreased. Maksoud *et al.*, (1984) also reported a significant favourable effects of N application on yield, bulb diameter and weight per bulb. These workers observed that the addition of N at 360kg/ha increased the yield of cured marketable bulbs from 12.4 to 20.5t/ha in one trial, and from 13.6 to 17.3t/ha in another trial. Ruiz (1985) in a field trial carried out in Chile reported that increasing rates of applied N from 0 to 150 Kg/ha increased bulb yield from 4.6 to 10.6 tonnes/ha. The bulb quality was also increased with increasing nitrogen application up to 225kg/ha.

2.3 Effect of plant spacing on growth and development of garlic

Varying the spacing between plants have been found to have a great influence on growth and development of many cultivated crops (Thompson, 1939). Crops planted at wider spacing tend to establish better compared with those closed spaced, because the widely spaced plants are able to intercept more light and suffer less of competition for nutrients, hence, yielded more per individual stand (Singh *et al*, 1984).

Om and Srivastava (1977), in India observed an increase in plant height and diameter, leaf number, bulb size and clove number when cloves of local garlic cultivar were planted at the widest spacing. While Bravo and Duimovic (1978) reported a decrease in the number of garlic bulbs with lateral shoots when plant density was increased from 333,000 plants per hectare to 830,000 plants/ha.

However, Lachica (1982) found that optimal spacing of 15 x 15cm and 20 x 20cm improved growth of garlic crop. Field trials were carried out by Maksoud *et al*., (1983) at three locations with garlic cultivar "Egyptian" and "Chinese" with the plants spaced at 5,10 and 15cm within ridge and 50 and 60cm between ridges. The results showed that the fresh and dry weight of plant were greatest at the wider (15cm) than at the closest (5cm) spacing.

2.4 Effect of plant spacing on yield and yield attributes of garlic crop

Garlic crops planted at the widest spacing were found to give the maximum yield of bulb per stand (Rahman and Talukdar,1986) but lower yield per unit area in comparison to closer spacing. This showed that the improvement in individual plants at wider spacing did not compensate for the reduction in yield due to decrease in plant population. On the other hand, closer spacing may produce highest yield but the quality of produce may be adversely affected and may not attract better price in the market(Singh *et al* , 1984). Duranti and Barbieri (1986) in Italy reported that garlic crop at 16.7 and 33.3 plants/m^2. produced the highest yield but lower mean bulb weight than at lower plant densities. Kusumo and Widjajanto(1973) in Indonesia obtained best yields at spacing of 15 x 15 and 15 x 10cm. From Ukraine Bogantirenko (1976) obtained the highest yield at spacing of 45 x 4cm.

Duimovic and Bravo (1979) reported that when cloves were planted at 330,000, 450,000 and 830,000/ha, the yield of exportable bulbs (greater than 5.1cm in diameter) was reduced although the total yield (t/ha) was increased with increasing plant density. These workers recommended the lower plant density of 333,000 plants/ha for maximum yield of exportable bulbs. It was also reported by Lucero *et al* (1982) that when garlic cloves of 5.8, 4.6 or 3.6g mean weight were planted at densities of 160,000 or 200,000/ha, the total bulb yield was highest (7400kg/ha) using 5.8g cloves at the maximum planting density. But for

each clove weight category, the lower planting density produced the maximum proportion of large bulbs (46 - 55mm diameter). Also Singh *et al.*, (1984) reported that decreasing intra-row plant spacing from 15-10cm increased total bulb yield but the individual bulb size was decreased. However, Maksoud *et al.*, (1984) observed that total bulb yield was largest at the closest (5cm) spacing compared to a spacing of 15cm.

In field trail carried out in Indonesia by Wardjito *et al.*, (1988), garlic cloves of weight 0.6 - 1.0, 1.1 - 1.5 or 1.6 - 2.0g were planted at spacing of 10 x 10, 15 x 10, 20 x 10, 15 x 15, 20 x 15 or 20 x 20cm. The results obtained showed that garlic yield tended to be lower when smaller cloves were used at the closest spacing than at the other wider spacing . However, clove size and spacing had no effect on individual bulb weight. This is because, yield increased as the size of mother bulbs was changed from small to large and planted at closer spacing.

Lammerink (1989), in another experiment carried out in New Zeland, planted large garlic cloves at 10cm apart in row and small cloves at either 10 or 5cm apart (giving population densities of 200,000 and 400,000 plants/ha, respectively). The small cloves gave lower total yield than larger cloves at the wider spacing of 10cm. But the small cloves (2 - 3g) at 5cm apart gave the best total yield and the highest yield of large bulbs of 50 -60mm diameter.

However, Orlowski and Rekowska (1989) in an experiment carried out in Poland indicated that when garlic cloves weighing 2.5, 3.5 or 5.0g were planted at 30 x 6,30 x 8, 30 x 10 or 30 x 12cm spacing, the highest yield was obtained

from 5.0g cloves planted at 30 x 12cm but the 5.0g cloves planted at 30 x 8cm gave the best yield of marketable bulbs.

From Bulgaria Aleksiev (1989) found that when garlic cloves were planted at various spacings between 12 x15 and 12 x 7.8cm, better results were produced at wider or closer intervals.

2.5 Nitrogen and spacing interaction

The interaction among environmental factors often produce great influences on crop performances (Cooke, 1975).

Pall and Padda (1972), in a work on onions in India reported that when mother bulbs were planted at spacing of 20, 35 or 50cm,and given 20, 40 or 60kgN/ha, the seed yield obtained was highest with the combination of the closest spacing of 20cm and N at 40kg/ha. In another field trial plants were spaced at 10 or 15cm apart and received N at rates varying from 64 - 256kg/ha, the result indicated the best bulb size was obtained at 15cm spacing with 256kgN/ha compared with other treatments (Sotomayor, 1975).

Aljarou and Escaff (1976) reported that high yield and optimum bulb size were obtained from plants receiving N at 150kg/ha and spaced at 10 x 10cm than at other treatments. In the work reported by Minard (1978) in New Zealand, the highest bulb yield was obtained with the closest spacing (10 x 25cm) and the highest N level (210kg/ha) than at the treatment with widest spacing of (15x 25cm) fertilized with 210kgN/ha. But the percentage dry matter content was highest from the unfertilized plots under the closest spacing (10 x 25cm). In the work reported by Bravo and Duimovic (1978) on garlic crop planted at spacings

varying between 6 x 5cm - 9 x 9cm and fertilized with either 75 or 225kgN/ha, plots spaced at 8 x 8 cm and receiving 75 or 225kgN/ha produced 62 and 75.9% bulbs with lateral shoots, respectively; thus gave bulbs with more number of cloves. From India Maurya and Bhuyan (1982) reported the highest yield of 8.2t/ha, was obtained when garlic plants were closely spaced at 10 x 10cm and receiving fairly high level of N at 150kg/ha than at wider spacing of 20 x 10 or 15 x 10cm receiving N fertilizer higher or lower than 150kgN/ha.

In a three year trials carried out in Zaria, with onion, a specie related to garlic, Amans (1989) observed that the highest number of leaves per plant and weight/bulb was produced from the treatment combination of 80kgN/ha and the widest spacing of 25 x 15cm, but the total yield/ha was best at closer spacing of 15 x 15cm with same N level.

Vishu and Prabhakar (1989) found in another three years trial carried out in India that onion plants spaced at 15 x 10, 15 x 15 and 15 x 25cm and received N at 0, 75 or 150kg/ha. The highest yields were generally highest with the closest spacing (15 x 10cm) and 150kgN/ha, but the cost: benefit ratio was optimal at the closest spacing and N at 75kg/ha.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental site

The experiment was carried out during the 1993/94 dry season under irrigation at the Institute for Agricultural Research (IAR)farm, Samaru (11° 12'N, 07° 38'E) in the Northern Guinea Savanna ecological zone of Nigeria.The effective sunshine hours during period of experimenting varied from 7.4 hrs in November/December to 6.1hrs in the month March/April. The mean daily relative humidity was generally low (between 54.5 - 10.5). Detailed data on the weather factors taken from the I.A.R farm meteorological station is shown in Appendix I.

Samples of soil from the experimental site were taken at depths of 0-15cm and 15-30cm before planting . The bulked samples for each depth range were analysed for some physical and chemical characteristics (Appendix II). The nature of the top soil was sandy loam, slightly acidic (5.4), low in organic carbon(0.55), low percent total nitrogen (0.08) and available phosphorus (5.56).

3.2 Test-crop variety

A local variety of garlic "Ex-Kofa", popularly grown around Kofa village in Kano State was used. The mature bulb is globular in shape with white outer covering. The cloves have pink or light pink outer skins.

3.3 Treatments and experimental design

The treatments consisted of four levels of nitrogen (0,40,80 and 120kg/ha) and three plant spacing (5x10, 10x10 and 15x10cm),in factorial combinations that were arranged in a randomized complete block design with three replications. Each plot was of 1.0m x 3.0m dimension (3.0 square meter) in gross size,having nine rows of plants, spaced at 10cm apart. The intra-row spacing was varied as per treatment at 5,10 and 15cm. The net plot at harvest consisted of five central plant rows (0.5x3.0m).

3.4 Land preparation

The field was ploughed, harrowed and marked out with parallel rows of plots separated by 0.5m channels or foot paths. The plots were bounded by low bunds to form a slightly low basins to contain irrigation water. The basins were properly levelled and pre-irrigated a day prior to planting.

3.5 Pre-plant and planting operation

Planting was carried out on 26th November, 1993. A day before planting, bulbs were separated into individual cloves with only the large and healthy ones selected and soaked in water overnight. Planting was done manually on the prepared plots, with one clove planted per stand. At 2 weeks after planting(WAP), gaps from non-germinated cloves were replanted.

3.6 Fertilizer application

Single superphosphate (18% $P_2 0_5$) at the rate that provided 19.4kgP/ha was incorporated into the basins as basal fertilizer before planting. Calcium ammonium nitrate (26%N) was used as source of N-treatment which was applied

at the rates of 40, 80 and 120kgN/ha in two equal split doses by band placement between the rows. The first application was at 3 WAP while the other half was applied at 6WAP.

3.7 Irrigation and weed control

Irrigation was supplied by surface flooding the basins at a 6-7 days interval. Weeding was done manually using both hand picking and hoe weeding. A special narrow bladed "onion hoe" was used during hoe-weeding. In all, three hoeing were carried out at 3, 6 and 9 WAP. The most predominant and obnoxious weed observed was nut sedge (*Cyperus rotundus*).

3.8 Pest and Diseases

There was no observable incidence of either pest or disease attack on the crop throughout the growth period.

3.9 Maturity and harvest

Maturity was indicated by healthy browning and drying or wilting of the crop foliage. The crop was harvested on 31st of March and 1st of April 1994 by hand pulling, assisted by hoe-digging the bulbs.

3.10 Observations recorded

A sample of 5 plants per plot were taken randomly at 3 weeks interval from 6-15WAP for the purpose of determining the height, number of leaves, leaf fresh and dry weight and bulb fresh and dry weight per plant.

3.10.1 Plant height

Plant height was measured as "stem" height from ground level to the tip of the tallest leaf, using a metre-rule. The average heights of the 5 plant samples were expressed in centimetre per plant.

3.10.2 Number of leaves per plant

The number of leaves per plant was recorded as the average number of fully open leaves from the five plant samples.

3.10.3 Foliage (top) fresh weight

The tops of the 5 plant samples per plot were cut at ground level and weighed using a 'Mettler' balance. The average weight per plant top was recorded in grams.

3.10.4 Foliage (top) dry weight

The fresh tops after weighing were cut into pieces and placed in an oven set at 70°C, to dry to a constant weight. The dry materials were weighed and average weight expressed in grams per plant.

3.10.5 Bulb fresh weight

The bulbs of the sampled plants were separated from the tops, washed, air-dried on tissue paper for few minutes. The plant roots were trimmed off and bulbs weighed on balance. The mean weight per bulb was expressed in grams.

3.10.6 Bulb dry weight

The fresh bulbs after weighing were cut into small pieces and oven-dried at 70°C to a constant weight. The dry material was weighed and the average weight per plant expressed in grams.

3.10.7 **Proportion of bolted plant**

As from 15WAP some plants were found to initiate reproductive growth by shooting up flower stalks (bolting). Eventually none of these bolters actually formed flowers or seeds but the number of such plants were counted per plot and their proportion expressed as percentages of the total plants per plot.

3.10.8 **Number of days to crop maturity**

The number of days to crop maturity was estimated by visual observation made every 2-3 days. When more than 50% of the total plants per plot have changed colour from green to yellow, began to wilt and dry, the plot was assumed to have matured. The number of days from planting to crop maturity were averaged across plots per treatment.

3.10.9 **Mature bulb diameter**

Five bulbs were randomly sampled per plot after the mature crop was harvested and air-cured for 7 days. The diameter of the sampled bulbs were measured using a vernier calliper and the average bulb diameter expressed in centimetres.

3.10.10 **Mature bulb weight**

After crop harvest, the five mature and air-cured bulbs sampled per plot were weighed on balance. The average weight per bulb was expressed in grams.

3.10.11 **Mature bulb dry weight**

The 5 bulb samples used in 3.10.10 were cut into small pieces and oven dried to a constant weight at 70°C. The average dry weight/plant was expressed in grams.

3.10.12 **Percentage dry matter content/bulb**

The dry matter content of the mature bulbs using the 5 samples, was expressed as percentage of the dry weight per initial fresh weight per bulb.

3.10.13 **Number of cloves per bulb**

Cloves were separated from each of the five bulbs sampled per plot. The averaged number of cloves/bulb were determined and recorded.

3.10.14 **Average weight/cloves**

The mean weight per clove was determined after counting and weighing the total cloves obtained from the 5 bulbs sampled per plot. The average weight per clove was expressed in grams.

3.10.15 **Bulb yield per hectare**

The total bulbs harvested from the net plot (0.5m x 3.0m) were weighed after 7 days of air-drying (curing). These plot yields were then expressed in tonnes per hectare.

3.11 Statistical analysis of data

All the crop data recorded were statistically analysed and any where the F-value was found to be significant, the treatments means were compared using Duncan's Multiple Range Test (Steel and Torrie, 1981).

CHAPTER FOUR

4.0 RESULTS

4.1 Plant height

Table 1 shows the effect of treatments on the height of plant at various sampling dates. Plant height was significantly increased by N application at all stages of sampling. However, no significant difference in height was recorded between 40 and 120kgN/ha.

Increasing intra-row spacing had no significant effect on plant height at all the sampling periods. Likewise, the nitrogen x spacing interaction was not significant on plant height.

4.2 Number of leaves

The number of leaves per plant as affected by the treatments is shown in Table 2. Nitrogen application significantly increased the number of leaves at all sampling periods except 6WAP. However, there was no significant differences among the applied N levels (40,80 and 120kg/ha), except at 9WAP when the difference between 40 and 80kgN/ha was found to be significant.

The variation in intra-row spacing had no significant effect on the number of leaves per plant at all the stages of samplings. However, the interaction of nitrogen with

Table 1: Effect of nitrogen and spacing on plant height (cm) of garlic at Samaru during the 1993/94 dry season.

	Weeks after planting			
Treatments	6	9	12	15
Nitrogen rate (kg/ha)				
0	34.0b	40.6b	38.1b	38.9b
40	42.0a	49.7a	48.9a	48.7a
80	46.5a	52.7a	49.6a	50.2a
120	47.0a	51.0a	45.2ab	46.3a
S.E ±	1.51	1.02	2.34	2.50
Spacing (cm)				
5x10	40.1	46.9	44.6	44.2
10x10	43.4	49.6	42.9	44.8
15x10	43.5	49.0	48.8	49.1
S.E ±	1.31	0.88	2.02	2.16
Interaction				
N x S	NS	NS	NS	NS

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P=0.05). NS = Not significant.

Table 2: Effect of nitrogen and spacing on number of leaves per plant of garlic at Samaru during the 1993/94 dry season.

	Weeks after planting			
Treatments	6	9	12	15
Nitrogen (kg/ha)				
0	4.38	5.60c	8.52b	11.08b
40	4.78	5.87bc	12.81a	19.33a
80	4.71	6.31a	13.22a	22.70a
120	4.78	6.21ab	11.70a	19.70a
S.E±	0.16	0.09	1.08	1.54
Spacing (cm)				
5x10	4.47	5.96	11.39	14.06
10x10	4.83	5.90	10.92	19.03
15x10	4.68	6.13	12.39	21.53
S.E ±	0.14	0.08	0.94	1.34
Interaction				
N x S	NS	*	NS	NS

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05). NS = Not significant, * = Significant differences at P = 0.05

spacing was significant at 9WAP(Table 3). At the closest spacing (5x10cm), the maximum leaf number was obtained with the highest N rate (120kg/ha). But at wider spacing the highest leaf number was from 80kgN/ha, although at par with the 120kgN/ha treatment. The effect of changing the crop spacing at fixed rates of N revealed that spacing had no significant effect on leaf number at 80 or 120kgN/ha. But at low N rate of 0 and 40kg/ha, widening the spacing from 10x10 to 15x10cm increased leaf production.

Table 3: Interaction of nitrogen and spacing on number of leaves per plant (9WAP) of garlic at Samaru during the 1993/94 dry season.

	Spacing (cm)		
Treatments	5x10	10x10	15x10
Nitrogen rate (kg/ha)			
0	5.67cde	5.27e	5.87bcd
40	5.87bcd	5.53de	6.20ab
80	6.07abc	6.47a	6.40a
120	6.23ab	6.33ab	6.07a-c
S.E± = 0.15			

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05)

4.3 Fresh leaf weight

The response of leaf fresh weight to treatments is shown in Table 4. The application of nitrogen significantly increased leaf weight. At 6WAP, the application of 40kgN/ha, however, did not cause a significant increase in leaf weight. The differences between N rates ranging from 40 to 120kg/ha were also not significant.

Varying the intra-row plant spacing at 9 and 12 WAP had no significant effect on leaf fresh weight. But at 6 and 15WAP increasing intra-row plant spacing from 5 to 15cm led to a significant increase in leaf fresh weight. No significant difference was observed between 5 x 10 and 10 x 10cm or between 10 x 10 and 15 x 10cm. The nitrogen and spacing interaction was not significant on leaf fresh weight.

4.4 Leaf dry weight

Data on leaf dry weight as affected by treatments is shown in Table 5. Dry leaf weight was not significantly affected by nitrogen application at 12 and 15WAP. But, at 6 and 9WAP, N application significantly increased leaf dry weight, though the differences between 40, 80 and 120Kg N/ha were not significant. At 6WAP, there was also no significant difference between 0 and 40Kg N/ha.

Intra-row plant spacing produced no significant plant response interms of leaf dry weight at 9 and 12WAP. But, at 6 and 15WAP, increasing spacing from 5 x 10cm to 15 x 10cm led to a significant increase in leaf dry weight per plant. The interaction between nitrogen and spacing on leaf dry weight was not significant.

Table 4: Effect of nitrogen and spacing on leaf fresh weight per plant (g) of garlic at Samaru during the 1993/94 dry season.

	Weeks after planting			
Treatments	6	9	12	15
Nitrogen rate (Kg/ha)				
0	1.95c	4.35b	7.80b	7.70b
40	2.75bc	9.52a	15.50a	15.60a
80	3.39ab	9.49a	15.10a	18.30a
120	3.87a	8.78a	13.20a	14.40a
S.E±	0.24	0.76	2.00	2.26
Spacing (cm)				
5x10	2.55b	7.74	11.40	9.30b
10x10	2.93ab	8.40	11.40	14.30ab
15x10	3.50a	7.96	16.00	18.40a
S.E ±	0.21	0.66	1.73	1.96
Interaction				
N x S	NS	NS	NS	NS

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P=0.05). NS = Not significant.

Table 5: Effect of nitrogen and spacing on leaf dry weight per plant (g) of garlic at Samaru during the 1993/94 dry season.

Treatments	Weeks after planting			
	6	9	12	15
Nitrogen rate (Kg/ha)				
0	0.36b	0.77b	1.41	1.60
40	0.45ab	1.39a	2.76	2.77
80	0.54a	1.37a	2.48	3.40
120	0.60a	1.26a	2.11	2.37
S.E ±	0.04	0.11	0.34	0.46
Spacing (cm)				
5x10	0.41b	1.20	1.93	1.66b
10x10	0.48ab	1.22	1.88	2.52ab
15x10	0.57a	1.18	2.76	3.43a
S.E ±	0.03	0.09	0.29	0.39
Interaction				
N x S	NS	NS	NS	NS

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test($P=0.05$). NS = Not significant.

4.5 Bulb fresh weight

The effect of the treatments on mean weight per bulb is shown in Table 6. At 6WAP, application of nitrogen produced no significant influence on mean weight per bulb of garlic. However, at later stages of sampling, nitrogen application significantly increased bulb weight. There was however, no significant difference among the applied rates of 40, 80 and 120KgN/ha.

Varying the intra-row plant spacing had no significant effect on bulb weight except at 15WAP when the widest spacing produced significantly heavier bulbs than the closest spacing. But no significant difference was found between 5x10 and 10x10cm or between 10x10 and 15x10cm. There was no significant interaction between nitrogen and spacing on the fresh bulb weight.

4.6 Bulb dry weight

Application of nitrogen at 6 and 9 WAP had no significant effect on dry bulb weight (Table 7). However, at 12 and 15WAP application of nitrogen significantly increased dry bulb weight but with no significant difference observed among the 40, 80 and 120KgN/ha. The variation in spacing at 6, 9,12 and 15WAP had no significant effect on the dry bulb weight per plant. Likewise, the interaction between nitrogen and spacing on dry bulb weight was not significant.

Table 6: Effect of nitrogen and spacing on mean weight per bulb (g) of garlic at Samaru during the 1993/94 dry season.

	Weeks after planting			
Treatments	6	9	12	15
Nitrogen rate (Kg/ha)				
0	1.29	2.66b	4.53b	7.48b
40	1.26	4.72a	6.99a	13.69a
80	1.51	4.41a	7.35a	14.28a
120	1.85	3.96a	7.00a	12.61a
S.E ±	0.19	0.21	0.65	1.33
Spacing (cm)				
5x10	1.26	4.05	6.42	9.36b
10x10	1.54	4.10	5.72	12.91ab
15x10	1.64	3.67	7.26	13.77a
S.E ±	0.18	0.19	0.56	1.16
Interaction				
N x S	NS	NS	NS	NS

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P=0.05). NS = Not significant.

Table 7: Effect of nitrogen and spacing on bulb dry weight (g) of garlic at Samaru during the 1993/94 dry season.

	Weeks after planting			
Treatments	6	9	12	15
Nitrogen rate (Kg/ha)				
0	0.27	0.54	0.95b	2.09b
40	0.25	0.84	1.52a	3.18a
80	0.28	0.80	1.52a	3.56a
120	0.34	0.73	1.49a	3.08a
S.E ±	0.04	0.08	0.15	0.32
Spacing (cm)				
5x10	0.24	0.83	1.40	2.49
10x10	0.30	0.68	1.21	2.99
15x10	0.32	0.68	1.51	3.46
S.E ±	0.03	0.07	0.13	0.28
Interaction				
N x S	NS	NS	NS	NS

Means followed by the same letter within same treatment group are not statistically different using Duncan's multiple range test(P=0.05). NS = Not significant.

4.7 Percentage of bolted plant

The effect of nitrogen application as well as varying intra-row plant spacing on bolting were significant (Table 8). Increasing the rate of N from 0 to 40 resulted in significant increase in bolting. There was however, no significant difference between 40 and 80KgN/ha or between 80 and 120KgN/ha.

Increasing intra-row plant spacing from 5x10 to 15x10cm significantly increased the proportion of bolted plants. But, there was no significant difference in the proportion of bolted plants between the 10x10cm and 15x10cm spacing. The interaction between nitrogen and spacing was not significant.

4.8 Number of days to crop maturity

The effect of treatments on the number of days to crop maturity, as indicated by foliage turning straw colour or leaves fall over is shown in Table 9. The number of days to crop maturity was significantly reduced by nitrogen application. However, there was no significant difference in this effect among the applied N rates of 40, 80 and 120KgN/ha.

Spacing had no significant effect on the number of days to crop maturity. Similarly, the interaction of nitrogen and spacing had no significant effect on the number of days to crop maturity.

Table 8: Effect of nitrogen and spacing on proportion of garlic plants that bolted (%) at Samaru during the 1993/94 dry season.

Treatments	Percentage of bolted plant
Nitrogen rate (Kg/ha)	
0	16.8c
40	48.4b
80	60.8ab
120	69.3a
S.E ±	3.35
Spacing (cm)	
5x10	40.9b
10x10	52.5a
15x10	53.1a
S.E ±	2.91
Interaction	
N x S	NS

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test($P = 0.05$). NS = Not significant.

Table 9: Effect of nitrogen and spacing on number of days to maturity in garlic crop at Samaru during the 1993/94 dry season.

Treatments	Days to maturity
Nitrogen rate (Kg/ha)	
0	120.7a
40	105.7b
80	106.0b
120	106.3b
S.E ±	1.85
Spacing (cm)	
5x10	107.3
10x10	109.8
15x10	111.8
S.E ±	1.60
Interaction	
N x S	NS

Means followed by the same letter within same treatment group are not statistically different using Duncan's multiple range test (P=0.05). NS = Not significant.

4.9 Mature bulb diameter

Table 10 shows the effect of treatments on mean bulb diameter per bulb. The differences in bulb diameter among N levels ranging from 40 to 120Kg/ha were not significant but they produced significantly larger bulbs than 0 N level.

Increasing the intra-row spacing from 5x10 to 10x10cm resulted in a significant increase in bulb diameter. Further increase in intra-row spacing to 15x10cm had no effect on bulb diameter.

A significant interaction between nitrogen and spacing on bulb diameter was observed (Table 11). At low level of N(0-40Kg/ha), an increase in spacing from 5x10 to 10x10cm had no significant effect on bulb diameter while further increase in spacing to 15x10cm resulted in a significant increase in bulb diameter. At moderate level of N(80Kg/ha), there was a significant increase in bulb diameter when spacing was increased from 5x10 to 10x10cm, but no increase in diameter occurred when spacing was further increased to 15x10cm. At the highest N level (120Kg/ha) bulb diameter was unaffected by spacing. The largest bulb size was however obtained with the combination of the widest spacing 15x10cm and 40 - 80KgN/ha. When the effect of N was examined at the same spacing, it was found that bulb diameter responded positively to N up to the highest rate only under the closest spacing of 5x10cm. At the 10x10cm spacing the maximum bulb diameter was at 80KgN/ha which was statistically better than 40Kg but similar to 120KgN/ha . At the widest plant spacing, the maximum

Table 10: Effect of nitrogen and spacing on mean bulb diameter (cm) of garlic at Samaru during the 1993/94 dry season.

Treatments	Bulb diameter
Nitrogen rate (Kg/ha)	
0	2.72b
40	3.68a
80	3.82a
120	3.72a
S.E±	0.08
Spacing (cm)	
5x10	3.22b
10x10	3.72a
15x10	3.76a
S.E ±	0.07
Interaction	
N x S	*

Means followed by the same letter within same treatment group are not statistically different using Duncan's multiple range test(P=0.05). * = Significant difference at P = 0.05

bulb diameter occurred at 40KgN, followed by 80KgN/ha. The highest N rate depressed bulb growth compared with the 40 and 80KgN/ha under the widest spacing.

Table 11: Interaction of nitrogen and spacing levels on mean bulb diameter (cm) of garlic at harvest in Samaru during the 1993/94 dry season.

	Spacing (cm)		
Treatments	5x10	10x10	15x10
Nitrogen rate (kg/ha)			
0	2.40g	2.65g	3.13f
40	3.27ef	3.59cde	4.18a
80	3.43def	3.89ab	4.13a
120	3.78abc	3.77a-d	3.60b-e
S.E ± = 0.14			

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05)

4.10 Mature bulb weight

The mean bulb weight of matured garlic as significantly affected by the treatments is shown in Table 12. Nitrogen increased bulb weight only up to 40KgN/ha. Further increase in N rates produced no significant influence on bulb weight. Increasing in intra-row spacing from 5x10 or 10x10 to 15x10cm resulted in significantly increase in bulb weight at harvest. The interaction

Table 12: Effect of nitrogen and spacing on mean weight per bulb(g) of garlic at Samaru during the 1993/94 dry season.

Treatments	Fresh weight per bulb (g)
Nitrogen rate (kg/ha)	
0	7.7b
40	14.0a
80	14.6a
120	13.7a
S.E±	0.65
Spacing (cm)	
5x10	10.5b
10x10	12.2b
15x10	14.7a
S.E±	0.56
Interaction	
N x S	*

Means followed by the same letter within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05). * = Significant difference at P = 0.05

between nitrogen and spacing on bulb weight was significant (Table 13). Increasing intra-row plant spacing from 5x10 to 10x10cm produced no significant effect on bulb weight except at 80KgN/ha. But a further widening the spacing to 15x10cm maximized bulb weight except at the highest level of N(120kg/ha). At 120KgN/ha, increasing intra-row spacing from 5x10 to 15x10 produced similar bulb weight. At fixed spacing of 5x10 and 10x10cm there was a significant increase in bulb weight only up to 40KgN/ha. But differences between this level

Table 13: Interaction effect between nitrogen and spacing on mean fresh weight per bulb (g) of garlic at Samaru during the 1993/94 dry season.

	Spacing(cm)		
Treatments	5x10	10x10	15x10
Nitrogen rate (kg/ha)			
0	5.6e	6.6e	10.8d
40	11.4d	12.7cd	17.9a
80	11.1d	15.7abc	17.1ab
120	14.1bcd	13.9bcd	13.1cd
S.E± = 1.12			

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05).

and 80 or 120kgN/ha were not significant. At the widest spacing (15x10cm), the response of bulb weight to increasing N was positive only up to 40kgN/ha which was at par with 80KgN/ha. Thereafter higher rate of N tend to depress bulb weight, such that bulb weight at the 120kgN/ha was significantly less than at 40 and 80kgN/ha. The highest bulb weight was obtained when the widest spacing was combined with 40kgN/ha, followed closely by 80kgN/ha.

4.11 Mature bulb dry weight

The effects of the treatments on oven dry weight of bulb at harvest is shown in Table 14. Dry bulb weight was significantly increased when N was raised above 0kg/ha. But there was no significant difference in dry bulb weight when the fertilizer level was increased from 40 to 120kgN/ha. Bulb dry weights were similar at 5x10 and 10x10cm plant spacings. But a further increase in spacing to 15x10cm resulted in a significant increase in bulb dry matter production. There was no significant interaction between nitrogen and spacing on bulb dry weight.

4.12 Bulb dry matter content (%)

The effect of treatments on dry matter (DM) content of bulb is shown on Table 15. Increasing the level of N from 0 to 80kg/ha produced no significant effect on % dry matter content of bulb. However, the highest level of N (120kg/ha) significantly reduced the % DM content compared with 0 and 40KgN/ha. 20-40kgN/ha. Spacing had no significant effect on bulb DM content. - Likewise, the nitrogen x spacing was not significant .

Table 14: Effect of nitrogen and spacing on bulb dry weight (g) of garlic at Samaru during 1993/94 dry season.

Treatments	Mean oven dried weight/bulb (g)
Nitrogen rate (kg/ha)	
0	3.3b
40	6.2a
80	6.1a
120	5.5a
S.E±	0.35
Spacing (cm)	
5x10	4.3b
10x10	5.1b
15x10	6.4a
S.E±	0.316
Interaction	
N x S	NS

Means followed by the same letter within same treatment group are not statistically different using Duncan's multiple range test(P=0.05). NS = Not significant.

Table 15: Effect of nitrogen and spacing on bulb dry matter content (%) of garlic at Samaru during 1993/94 dry season.

Treatments	Bulb DM content (%)/bulb
Nitrogen rate (kg/ha)	
0	43.4a
40	43.6a
80	41.4ab
120	39.8b
S.E±	0.84
Spacing (cm)	
5x10	41.7
10x10	41.6
15x10	43.0
S.E±	0.71
Interaction	
N x S	NS

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P=0.05). NS = Not significant.

4.13 Number of cloves per bulb

Clove number was significantly increased by the application of N - fertilizer but the differences among N rates ranging from 40-120kg/ha were not significant (Table 16).

Widening the intra-row plant spacing from 5x10 to 10x10cm produced no significant effect on the number of cloves. But further widening of spacing to 15x10cm resulted in the production more cloves compared with 5x10cm.

The interaction between nitrogen and spacing on the number of cloves was significant (Table 17). The effect of increasing N levels at fixed plant spacing shows that at the closest spacing of 5x10cm, there a was positive response of clove number to increasing N up to 80KgN/ha though at par with 120KgN/ha. At the 10x10cm spacing, although the application of N increased clove number, significant response was only recorded up to 40KgN/ha. At the widest spacing (15x10cm), the maximum positive response of clove number to N occurred as N was increased from 0-40kgN/ha. The higher N levels depressed clove number particularly at 120kgN/ha where clove number was significantly less than at 40 or 80kgN/ha.

Table 16: Effect of nitrogen and spacing on number of cloves per bulb of garlic at Samaru during 1993/94 dry season.

Treatments	Number of cloves/bulb
Nitrogen rate (kg/ha)	
0	13.5b
40	31.8a
80	34.8a
120	31.7a
S.E±	1.56
Spacing (cm)	
5x10	23.8b
10x10	29.0ab
15x10	31.1a
S.E±	1.35
Interaction	
N x S	*

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05). * = Significant difference at P = 0.05.

At fixed N levels, the change in intra-row plant spacing produced no significant effect in clove number at the higher N levels of 80 and 120kgN/ha. But at the lower levels of 0 and 40kgN/ha, increasing plant spacing from 5x10 to 15x10cm increased clove number.

Table 17: Interaction effect between nitrogen and spacing on number of cloves per bulb of garlic at Samaru during the 1993/94 dry season.

Treatments	Spacing(cm)		
	5x10	10x10	15x10
Nitrogen rate (kg/ha)			
0	8.5g	13.3fg	18.7ef
40	22.1de	32.9abc	40.2a
80	30.5bc	36.2abc	37.7ab
120	33.9abc	33.7abc	27.6cd
S.E± = 2.69			

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05).

4.14 Weight per clove

Mean clove weight was significantly depressed by nitrogen application (Table 18). The no-N control produced the heaviest clove weight. While the

Table 18: Effect of nitrogen and spacing on mean clove weight (g) of garlic at Samaru during 1993/94 dry season.

Treatments	Mean weight per clove(g)
Nitrogen rate (kg/ha)	
0	0.59a
40	0.46b
80	0.42b
120	0.44b
S.E±	0.04
Spacing (cm)	
5x10	0.50
10x10	0.44
15x10	0.49
S.E±	0.03
Interaction	
N x S	NS

Means followed by the same letter within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05). NS = Not significant.

three levels of applied N (40,80 and 120kg/ha)reduced clove weight; differences among three N rates were however, not significant. Variation in the intra-row plant spacing had no significant effect on clove weight. Likewise, the interaction between nitrogen and spacing had no significant effect.

4.15 Total bulb yield per hectare

Data on yield of bulbs (t/ha) as affected by the treatments is shown in Table 19. Nitrogen application significantly increased bulb yield only up to 40 KgN/ha. Plant spacing had no significant effect on the bulb yield. However, decreasing the intra-row plant spacing from 15x10 to 5x10cm significantly increased total bulb yied/ha.

Likewise, a significant nitrogen x spacing interaction on bulb yield was also recorded (Table 20). However, at fixed spacing of 5x10 and 10x10cm a significant response was recorded only up to 40kgN/ha. While at the wider spacing of 15x10cm, increasing N-level from 40 to 120kg/ha significantly depressed bulb yield. But when the effect of various N levels at varying intra-row plant spacing was studied, it was observed that, at 0 and 40kgN/ha the yield was found to be depressed only by widening the plant spacing from 5x10 to 10x10cm. While at higher N levels of 80 and 120kgN/ha, widening the intra-plant spacing from 5x10 to 15x10cm depressed the total bulb yield. The highest yield value was obtained by fertilizing the crop with highest N rate of 120kg/ha at the closest spacing of 5x10cm , though at par with 40 and 80kgN/ha treatments.

Table 19: Effect of nitrogen and spacing on bulb yield (tonnes/ha) of garlic at harvest in Samaru during the 1993/94 dry season.

Treatments	Total bulb yield (t/ha)
Nitrogen rate (kg/ha)	
0	6.9b
40	13.2a
80	13.7a
120	13.8a
S.E±	0.52
Spacing (cm)	
5x10	17.1a
10x10	10.3b
15x10	8.2c
S.E±	0.45
Interaction	
N x S	**

Means followed by the same letter within same treatment group are not statistically different using Duncan's multiple range test($P = 0.05$). ** = Significant difference at $P = 0.01$.

Table 20: Interaction between nitrogen and spacing on garlic bulb yield (t/ha) at Samaru during the 1993/94 dry season.

Treatments	Spacing(cm)		
	5x10	10x10	15x10
Nitrogen rate (kg/ha)			
0	9.20c	5.52e	6.00e
40	19.06a	10.7bcd	9.93b
80	18.42a	13.09b	9.49c
120	21.70a	12.00bc	7.54de
S.E± = 0.90			

Means followed by the same letter(s) within same treatment group are not statistically different using Duncan's multiple range test(P = 0.05).

4.16 Correlation analysis

The result of the partial correlation analysis among the various growth and yield parameters of garlic is shown in Table 21. There were significant and positive correlations between bulb yield/ha and plant height (r = 0.40), fresh leaf weight(r = 0.35), bulb diameter (r = 0.52), mature bulb (r = 0.60) and dry (r = 0.52) weights of matured bulb and number of cloves per bulb (r = 0.58). However, the relationship between yield and number of leaves, leaf (dry and fresh weight) and dry bulb weight at 15WAP and % of bolters though positive were not significant. The yield/ha was negatively correlated to number of days to 30 50%

Table 21: Simple correlation coefficients analysis among growth and yield characters of garlic grown at Samaru during the 1993/94 dry season.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	1.00														
2.	0.64**	1.00													
3.	0.75**	0.75**	1.00												
4.	0.69**	0.73**	0.98**	1.00											
5.	0.89**	0.58**	0.81**	0.76**	1.00										
6.	0.81**	0.65**	0.86**	0.81**	0.91**	1.00									
7.	0.62**	0.34*	0.52**	0.42**	0.53**	0.58**	1.00								
8.	-0.52**	-0.36*	-0.20	-0.10	-0.43**	-0.40**	-0.49**	1.00							
9.	0.73**	0.55**	0.67**	0.59**	0.68**	0.65**	0.72**	-0.41**	1.00						
10.	0.66**	0.54**	0.66**	0.59**	0.59**	0.57**	0.56**	-0.28	0.96**	1.00					
11.	0.62**	0.48**	0.65**	0.59**	0.58**	0.56**	0.52**	-0.20	0.93**	0.97**	1.00				
12.	-0.08	-0.18	0.04	0.07	0.00	0.02	-0.14	0.35*	0.01	0.02	0.26	1.00			
13.	0.67**	0.54**	0.59**	0.50**	0.66**	0.63**	0.68**	-0.49**	0.93**	0.88**	0.83**	-0.09	1.00		
14.	-0.28	-0.23	-0.16	-0.08	-0.30	-0.25	0.50**	0.42**	-0.40*	-0.25	0.20	0.22	-0.62**	1.00	
15.	0.25	0.40*	0.35*	0.31	0.28	0.27	0.22	-0.30	0.52**	0.60**	0.52**	-0.17	0.58**	-0.20	1.00

1. No. leaves/plant; 2. Plant height; 3. Fresh leaf wt (15WAP); 4. Dry leaf wt (15 WAP); 5. Fresh bulb wt(15 WAP); 6. Dry bulb wt (15 WAP); 7. Bolter(%); 8. Maturity (days); 9. Bulb diameter; 10. Wt/bulb (Mature); 11. Dry wt/bulb; 12. DM of bulb (%); 13. No. of cloves/bulb; 14. Weight/clove; 15. Total bulb yield/ha.

Data for parameters 1 - 6 were taken at 15 weeks after planting. * = Significant at 5% level (df = 34)

** = Significant at 1% level (df = 34).

maturity (r = 0.30), % of bulb dry matter (r = -0.17)and mean clove weight (r = -0.20), although not significantly.

The number of cloves per bulb was also found to be highly and positively correlated (P = 0.01) with all growth and yield characters except percent DM content of bulb (r = -0.09). A significant but negative correlation was found between clove number and the number of days to crop maturity (r = -0.49).

The number of leaves per plant was found to be significantly correlated with all other growth and yield parameters except % DM content of bulb (r = -0.08) and weight per clove (r = -0.28). But a highly significant and negative correlation exist between number of leaves per plant and number of days to crop maturity (r = -0.52). Fresh bulb weight at 15WAP was significantly and positively correlated with all growth and yield attributes except % DM content of bulb (r = 0.00), clove weight (r = -0.30) and yield of bulbs (r = -0.38). A highly significant but negative relationship exist between fresh bulb weight at 15WAP and number of days to crop maturity (r = -0.43).

The average weight/clove was negatively related to other growth and yield characters except bolting (r = 0.50) and number of days to crop maturity (r = 0.42) to which it was positively and significantly correlated. The negative correlation between clove weight and number of cloves per bulb (r = -0.62) was highly significant. The relationship between clove weight and bulb diameter (r = -0.40) was also significantly negative.

The number of days to crop maturity was observed to be negatively correlated with all parameters except % DM content of bulb (r = 0.35) and weight/clove (r = 0.42) to which it was significantly and positively correlated. The negative correlation between the days to crop maturity and number of leaves- (r = -0.52), plant height (r = -0.36), bulb fresh weight (r = -0.49)bulb diameter (r = -0.41) and number of cloves/bulb (r = -0.49) were significant. There were however, no significant relationships between the number of days to crop maturity and fresh or dry leaf weight at 15WAP, fresh or dry weight of mature bulbs and bulb yield.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Effect of nitrogen on growth characters

The result of this study showed a significant influence of nitrogen application on all the growth parameters of garlic measured. Nitrogen is an essential nutrient necessary for the stimulation of rapid vegetative growth because of its importance in photosynthesis and formation of chlorophyll, nucleic acid and amino acid (Samuel, 1980). Considering the poor N-status of the native soil (N less than 0.10), it is not surprising that the application of N improved increase the growth performance of the crop. The lack of significant response to nitrogen fertilization by number of leaves and mean weight of bulb at 6WAP was probably due to the fact that the second dose of N fertilizer was just applied before this sampling period and, thus, the plant may not have benefited at this early stage.

At the later growth stages, the effect of N application was manifested but the N need was met by 40kgN/ha since higher rate of application produced no further significant increase on leaf number. The marked response of leaf number due to N application of led to an increase in photosynthetic productivity and hence, increased bulb development. This result agrees with those of Novais et al (1974), Aliudin and Suminto (1978), Maksoud(1984), Buwalda (1986) and Borabash and Kochina (1987) who reported that application of N fertilizer increased the assimilatory leaf area and photosynthetic productivity.

However, there was no significant differences when N was applied beyond 40kg/ha on plant height as well as fresh leaf weight at all sampling periods. Increasing plant height was accompanied by an increase in leaf weight. This is due to highly and positive correlation ($r = 0.73$) that existed between the two parameters and also because N application helped in increasing the leaf assimilatory area and thus its photosynthetic activity. Similar observation were reported by Singh *et al.*, (1984) and Borabash and Kochina (1987).

Nitrogen application significantly increased leaf dry weight during the early growth stage of the plant (6 to 9WAP) but not at later stage (12 to 15WAP). The reverse was the case with bulb dry weight, where positive response to N application was significant only at later growth phase. This may be due to the fact that during the early crop growth stages most of the assimilate produced was directed toward vegetative growth. But at the later growth stage, when the plants had started bulbing, most of the assimilates produced by the plant was partitioned to bulb development. This result conforms with the findings of Aliudin and Suminto (1978), Lachica (1982), and Maksoud (1984)and Buwalda (1986) who reported similar pattern of garlic response to N fertilization.

For most of the plant's growth characters assessed, it was observed that the maximum values were obtained at 80kg/ha of N, although there was no significant difference between this level and the lower (40kg/ha) or higher (120kg/ha) levels of applied N. The response of bolting to N was similar to that of other vegetative growth characters except that the maximum percentage of bolting occurred at 120kg/ha of N. This indicates that although bolting is

triggered by low temperature conditions (Aoba, 1966), it benefited like other parameters of plant growth from increased supply of nitrogen.

The number of days to crop maturity was significantly reduced by the application of N. In other words, plants supplied with N fertilizer matured much earlier (106 days)than the unfertilized crop (121 days). This means that the application of N enhanced not only the growth but also the development of the plant with the result that maturity was advanced (Samuel, 1980).

5.2 Effect of nitrogen on yield characters

The diameter, fresh and dry weight of matured bulbs, the number of cloves per bulb as well as total bulb yield per hectare significantly responded to N application. Other workers elsewhere have also reported significant increase in yield of garlic in response to N application (Menezes, 1974; Nelson, 1983; Singh *et al.*, 1984; Maksoud *et al.*, 1984 and Buwalda, 1986). However, in the present study, the differences among rates of applied N were not significant, although, 120 and 80kgN/ha gave maximum values for yield and other yield characters, respectively.

The percent dry matter content of bulb was, however, higher at 0 - 40kg than at higher N level. In fact the application of 120kgN/ha significantly lowered the % dry matter. Increase in bulk and succulence of the bulb in response to nitrogen fertilization was partly responsible for the dilution and, thus lower % dry matter content. It is also possible that the increasing supply of N actually had negative effect on carbohydrate synthesis and therefore, on dry matter accumulation. The adverse effect of a high N:C (Nitrogen; Carbon) ratio on

carbohydrate synthesis is an established fact (Janick, 1972; Hewitt and Smith, 1975 and Gupta, 1977). In this experiment the significant depression in the % DM due to application of 120kgN/ha was a likely indication of this phenomenon. In addition, there was a significant reduction in weight per individual clove in response to N fertilization which seem to be a reflection of the reduction in dry matter (usually inform of carbohydrade) accumulation resulting from an excess N supply. However, the number of cloves/bulb was increased by the application of N. Although the reason is not clear, this may indicate a compensatory mechanism in the distribution of photosynthates, under increasing N supply, in favour of more clove buds (a vegetative growth function) rather than for DM accumulation which tend to be discouraged by excess N supply (Hewitt and Smith 1975; Larcher, 1975 and Borabash and Kochina, 1987). But it may also mean that an increase in number of cloves in response to N application increased the level of inter-clove competition for the limited assimilate thus, lowering the amount of dry matter going into individual cloves.

5.3 Effect of spacing on growth characters

Spacing had no significant effect on number of leaves and height of plant. The lack of response of these above ground characters may be due to the morphological characteristics of the plant. The plant stem and leaves are held upright, thus creating minimal interplant competition for light. This may explain why the number of leaves produced as well as the plant height were similar under the range of plant population per unit area tested. The leaf weight at later growth

stages (15WAP) was, however, adversely affected by the closest plant spacing indicating a reduction in assimilate production under increasing plant density.

The lack of leaf and bulb (fresh and dry) weight response to spacing at the early period of growth (6-12WAP) can be attributed to the fact that at these growth stages plants were less likely to suffer from the population pressure than when they are older and actively competing for limited environmental resources particularly under close intra-row plant spacing. At wider spacings (10x10 and 15x10cm) plants produced higher leaf and bulb weight compared with close spacing (5x10cm) due to lower degree of interplant competition. Similar observations have been reported by Om and Srivastava(1977), Lachica (1982), Maksoud *et al.*, (1983) and Rahman and Talukdar (1986).

The percentage of garlic plant that bolted was significantly increased when the intra-row plant spacing was increased from 5x10 to 10x10 or 15x10cm. Although, bolting is triggered by low temperature (Aoba, 1966), it is an aspect of growth and development of the plant. The reduction in level of bolting at the closest intra-row plant spacing may be a reflection of an adverse effect of competition which generally depresses growth.

5.4 Effect of spacing on yield characters

A significant response was recorded on the effect of spacing on bulb diameter, mean (fresh and dry) weight per bulb, number of cloves per bulb and total bulb yield. Increasing spacing from 5x10 to 15x10cm generally led to an increase in individual crop response. Widening the gap between plant stands reduced interplant competition for growth factors and thus, resulted in a better

crop performance. This result is in conformity with the work reported by Om and Srivastava(1977), Lucero *et al.*, (1984), Rahman and Talukdar (1986) and Lammerink (1989).

Intra-row plant spacing had no significant effect on percentage DM and mean clove weight per bulb. Though bulb growth was encouraged generally by wider crop spacing, the larger bulb size may have been accompanied by slight dilution effect on the concentration of dry matter. This is supported by the fact that there were negative, though insignificant, correlation between % DM and number of leaves (r = -0.083) or plant height (r = -0.176) which make up the assimilatory organ of the plant. In case of clove development, the positive effect of wider spacing appear to favour more cloves per bulb rather than weight per individual clove. The correlation between number of cloves and weight per clove infact indicated a strong and significant negative value (r = -0.62).

Plant spacing also had a significant effect on the total bulb yield per hectare. More yield was obtained with the closely spaced treament than when widely spaced despite the fact that the growth of the individual bulb was significantly greater at widest (15x10cm) spacing than at the closest (5x10cm)-spacing. As spacing was increased, individual plant performance was better due to the declining level of interplant competition. But wider spacing meant less number of harvestable bulb per hectare. Thus, the significant yield response to spacing may be attributed to the fact that the increase in individual bulb weight in response to wider spacing was not sufficiently enough to compensate for a reduction in overall yield due to less plant population. Similar observations have

been reported by Duimovic and Bravo (1979), Singh *et al.*. (1984),Lammerink (1989) and Aleksiev (1989).

5.5 Nitrogen and spacing interaction on growth and yield

The interaction between nitrogen level and plant spacing caused significant responses in number of leaves, bulb diameter, weight per (mature) bulb, number of cloves per bulb and total bulb yield/ha. At the closest interplant spacing (5x10cm), a significant increase in either growth or yield characteristic occurred only with N at the maximum rate of 120kg per hectare or the next higher rate of 80kgN/ha. But as the intra-row plant spacing was widened to 15x10cm, maximum growth or yield parameters were supported by lower N rates(40-80kgN/ha) except total bulb yield/ha which increased only up to 40kg N/ha. This is an indication that increasing plant population is dependent on the level of soil fertility required to support growth and development. In the work reported by Bravo and Duimovic (1978) as much as 75 to 250kgN/ha was required to support the production of more laterals (cloves) when garlic plants were planted 657,000 plants/ha (or 8 x 8cm spacing).

Conversely, the demand or competition for soil nutrient resources was intensified as the plant population per unit area was increased. Under low level of N supply (0-40kg/ha), only the widening of intra-row plant spacing from 5x10cm to 15x10cm resulted to a significant improvement in number of leaves, bulb diameter, mean bulb weight and the number of cloves per bulb except total bulb yield/ha which showed a reduction due to decreasing number of plant stands. The reduction in plant spacing under such low level of N supply only resulted to

depressing the growth and development of the plant. Similar findings on onion (a related crop) was reported by Amans(1989) who observed an optimum leaf number/plant and weight/bulb with the application of 80kgN/ha at intra-row plant spacing of 15cm. Sotomayor (1975) also found similar response. On the other hand, when 80-120kgN/ha was supplied, the reduction in intra-row plant spacing was found to have no significant effect on the growth and development of the crop though the yield dropped with every increase in intra-row spacing due to lower plant population. In fact with the higher N supply, growth of plant and bulb development at the closer spacing of 10x10cm was as good or better than at the widest spacing. Similar observations were reported by Aljarou and Escaff (1976) in which application of 150kgN/ha improved bulb growth of garlic plant at 10x10cm spacing but failed to influence bulb growth when the spacing was decreased to 7.5 x 10cm. Other workers like Pall and Padda (1972) and Vishu, Prabhakar (1989) and Amans (1989) also obtained similar result on onion.

The interaction between N and plant spacing was, however, not significant on the total bulb yield per ha. Yield was optimum at the closest spacing of 5x10cm and application of N up to 40kg/ha. This conformed with the work reported by Pall and Padda (1972) and Bravo and Duimovic (1978) who obtained the best yields at the closest spacing plus very low N rate (40kg/ha).

5.6 Correlation among growth and yield characters

The significant correlation that existed between bulb yield/ha and plant height or fresh leaf weight signifies the degree of importance of leaf growth and its function as an assimilatory organ that produce assimilates which forms the

basis of yield. The positively strong relationship between the total yield and bulb diameter, weight per bulb (cured), dry weight per bulb and or number of cloves per bulb shows that these characters constitute the major yield contributing factors.

There was a weak relationship between the number of leaves per plant and total bulb yield. A similar observation has been reported in onion (Amans, 1989). The continuos production of leaves during bulb development created an adverse competition for assimilates partitioning, more of what should go for bulbing goes into leaf production. The negative correlation between the number of days to maturity and most of the growth and yield characters (except % DM and weight per clove) may indicate that early attainment of maximum growth and development of the plant is necessary for good yields in garlic. The delay in maturity may be associated with higher percent dry matter content and heavier cloves which invariably led to poor yields.

CHAPTER SIX

6.0 SUMMARY AND CONCLUSION

A field experiment was carried out dry season under irrigation at the Institute for Agricultural Research (IAR), Ahmadu Bello University, Samaru, Zaria to study the response of garlic (*Allium sativum* L) to different levels of nitrogen fertilizer and intra-row plant spacing.

The treatments consisted of factorial combinations of four levels of nitrogen (0,40,80 and 120kg/ha) and three intra-row plant spacing (5 x 10,10 x 10 and 15x10cm), laid out in a randomized complete block design with three replications.

Nitrogen application significantly increased growth and yield characters. The vegetative growth characters represented by plant height and number of leaves, bulb growth characters and total bulb yield/ha increased up to 40kgN/ha. On the other hand, the number of days to crop maturity, %DM/bulb and average weight per clove was reduced by N application.

Increasing intra-row plant spacing from 5x10cm to 10x10cm or the widest spacing of 15x10cm significantly increased leaf fresh and dry weight at 15WAP, bulb fresh weight (15WAP), % bolted plant, bulb size and weight at maturity, and total bulb yield/ha. But the plant height, number of leaves, days to maturity, % bulb DM and clove weight was not significantly affected by the change in plant spacing.

The interaction between nitrogen levels and plant spacing was significant on number of leaves, bulb diameter, mature bulb weight, number of cloves per

bulb and total bulb yield/ha. The interactions indicated an increasing demand for N as the intra-row plant spacing was reduced from the widest to the closest spacing. The plant response to N application was more marked under closer than the widest spacing. The maximum bulb size, weight and number of cloves per bulb occurred at a combination of the widest spacing (15x10cm) and moderate N level (40-80kgN/ha). The interaction was significant on the total bulb yield/ha with the maximum yield occurred at 5x10cm plus N up to 40kg/ha.

A significantly positive correlation was observed between plant height, leaf fresh weight, bulb diameter, fresh and dry weight of bulb, number of cloves/bulb and total bulb yield. But the days to maturity, % DM content of bulb and weight/clove were significantly but negatively correlated with yield/ha.

Based on the results obtained from this study, the application of 40kgN/ha and use of an intra-row plant spacing of 5x10 or 10x10cm is suggested for maximum bulb yield of garlic at Samaru, under similar soil and weather conditions as used for the trial.

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Appendix I:

Meteorological data showing sunshine hours, minimum, maximum and mean temperature and relative humidity at Samaru during the 1993/94 dry season.

Period	Sunshine Hours	Minimum Temp. (°C)	Maximum Temp. (°C)	Mean Temp. (°C)	Relative Humidity (%)		Mean RH %
Nov. 1993							
1 - 10	10.7	13.0	33.8	23.4	NA	NA	NA
11 - 20	7.4	13.1	33.1	23.1	NA	NA	NA
21 - 30	7.8	16.1	33.8	25.0	NA	NA	NA
Dec. 1993							
1 -10	5.9	15.5	30.4	23.0	25.5	25.5	25.5
11 - 20	5.3	13.8	28.4	21.1	38.9	32.5	35.7
21 - 31	7.3	13.1	28.5	41.6	27.5	19.0	22.3
Jan. 1994							
1 - 10	5.9	12.8	28.1	20.5	28.5	20.9	29.7
11 - 20	6.5	13.0	28.7	20.8	23.7	20.7	22.2
21 - 31	7.3	15.5	31.7	23.6	17.70	14.8	16.3
Feb. 1994							
1 - 10	3.2	16.0	30.3	23.2	19.2	14.1	16.7
11 - 20	8.6	15.7	33.0	24.35	11.3	11.1	11.2
21 - 28	5.8	6.3	31.4	18.85	8.4	12.6	10.5
Mar. 1994							
1 - 10	7.3	17.9	36.7	27.3	21.0	18.8	19.9
11 - 20	5.0	20.4	37.2	28.8	22.9	26.8	24.9
21 - 31	6.7	21.4	37.8	30.0	16.2	31.1	23.7
Apr. 1994							
1 - 10	2.73	21.1	35.5	28.3	19.4	28.5	24.0
11 - 20	7.38	22.8	36.6	29.7	60.0	39.3	49.7
21 - 30	7.46	23.3	35.2	29.3	67.7	41.2	54.5

NA = Information not available.
RH = Relative Humidity.

Appendix II:

Physical and chemical properties of the soil on which experiment was carried out in Samaru.

	Soil depth(cm)	
Soil characteristics	0 -15	15 - 30
pH in water (1:2.5)	5.4	6.4
pH in CaCl (1:2.5)	4.7	5.1
Organic carbon (%)	0.55	0.48
Total nitrogen (%)	0.08	0.05
Available phosphorus (ppm)	5.56	3.82
Exchangeable bases (meq/100g)		
Ca	3.35	2.86
Mg	0.72	0.68
K	0.29	0.24
Na	0.11	0.09
CEC	5.58	5.33
Particle size of distribution		
Sand (%)	51.0	49.7
Silt (%)	33.3	30.0
Clay (%)	15.7	20.3
Textural class	Sand loam	Sandy loam

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