EFFECTS OF PLANT DENSITY. ROW SPACING AND SETT SIZE ON GROWTH, DEVELOPMENT, YIELD AND QUALITY OF GINGER (Zingiber Officinale Roscoe)

BY

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A thesis submitted to the; post (graduate school .Ahmadu Bello University,, in partial fulfilment of the requirement for the degree of Master of Science in Agronomy.

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FACULTY OF **AGRI**CULTURE

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ZARIA ....NIGERIA,,

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CERTIFICATION

This thesis entitled "EFFECTS OF PLANT DENSITY, ROW SPACING AND SETT SIZE ON GROWTH, DEVELOPMENT, YIELD AND QUALITY OF GINGER (*Zingiber officinale* Roscoe) by Banake Elisha Sambo meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, Nigeria and is approved for its contribution to scientific knowledge and literary presentation.

15/01/93

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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 in any previous application or publication for a higher degree.

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Date. 31/12/92 ......

The above declaration is confirmed.

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DEDICATION

...To those who for the sake of others gave up themselves in the service of humanity; maintaining a revolutionary heritage in the search for a new socio-economic order: Dom Helder Camara, Thomas Sankara, Steve Biko, Walter Rodney, Frantz Fanon, Fidel Castro, Che Guevara, Amilcar Cabral.

To my Brother, Zibai, Friends; Theo Onu and Eno Effiok ; in search of hope for tomorrow.

And to the likes of Pa and Ma E. Sambo, for possessing the exceptional belief in God and the power of patience.

SAMBO (JR)
(1992)

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The period of this study was not without its ups and downs; its pressures... what combining sports with academics to keep going... It is however, note worthy that amist all these, there is a FAMILY, RELATIONS, FRIENDS who will stand by ... believing in you... Moreso, that there is brotherly LOVE that binds one MAN-to-MAN...

Sambo(JR)
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ABSTRACT

This study was conducted at the Institute for Agricultural Research. Samaru, Zaria - Nigeria during the .1989 wet season to investigate the effects of plant density,row spacing and sett size on the growth, development,, yield and quality of ginger (Zingiber officinale Rose.) The variety of ginger used was "Tafin Giwa" and the treatment comprised of three plant populations (166,666; 333,333; and 500,000 plants/ha)| three row spacings (10, 20 and 30cm); and three sett sizes (7.5; 15.0 and 22.5gm). The design of the experiment was a split plot with plant density and row spacing combinations as the main plot treatments and sett size as the sub-plot treatment. These were replicated four times.

Results showed that generally the growth characters studied and the rhizome yield increased with increasing plant density. At final harvest, the rhizome yield at 500,000 plants/ha was 63% more than that obtained at 166,666 plants/ha.

The effect of row spacing on rhizome dry weight was not consistent. Leaf area index (LAI) was siqnifcantly higher at 30cm compared with the narrower row spacings throughout the growth period. Consequently, the yield obtained at 30cm row spacing was 39%. and 49%, higher than the yield recorded at 20 and 10cm respective[1]/.

Sett size signifcantly affected plant height and rhizome dry weight per plant. Higher growth rate were recorded with the largest sett weight (22.5gm) compared with the two smaller sett sizes- Final yield was not significantly influenced by sett size.

The quality of ginger was characterised by the oil and ash content in this study. Ginger planted at 333,333 plants/ha produced higher oil content (7.07%.) than those planted at the lowest(166,666 plants/ha) and highest (500,000 plants/ha) densities. Row spacing did not affect the quality of ginger while sett size significantly influenced the oil content. The highest mean oil content (6.9%.) was obtained with the smallest sett compared with the medium and largest sett weights.

This study indicated that growth, yield and quality of ginger could be enhanced by planting at high population (500,000 plants/ha) and wide row spacings (30cm). Sett size had no effect on final yield and qua1ity of ginger.

The row spacing X plant density and plant density X sett size interactions were significant.

There? was a positive correlation between yield and all yield contributing characters studied and a positive and significant correlation between leaf area index (LAI.) and final yield.

TABLE OF CONTENTS

LIST OF TABLES

(List of tables cont'd)

LIST OF APPENDICES

Chapter 1

INTRODUCTION

Ginger (*Z. officinale* Rosc.) was one of the earliest oriental spices known to Europe. Commercial ginger is prepared from the rhizome and marketed as dried or preserved ginger. The dried rhizome which may first be scraped or peeled before drying, constitutes the spice, esteemed for its flavour pungency and aroma. It is employed widely for culinary purposes in ginger bread, biscuits, cakes, puddings, soups, pickles, peppers, pies, sausages, chocolate, pasties and as a constituent ofcurry powder and other spices, flavours and seasoning mixtures. Industrially, it is ultilized in the production of ginger beer, ginger ale, ginger wine, and in the manufacture of beverages such as ginger tea. Preserved ginger is prepared from fresh immature rhizomes, harvested at varying stages of development before the attainment of full maturity. The tender fleshy peeled rhizomes are boiled, after which it is sugarised and sold as ginger syrup. The rhizome also yields an essential oil used in the manufacture of flavouring essences. The odour of the oil is long lasting,and as such , often blended with other types of oils in the manufacture of perfumes to impart a long lasting oriental tone. It is similarly used in the toilet waters of the spicy type. It is used in the manufacture of powders, cosmetics, hair oil and pomade.

An oil (oleoresin) extracted from ginger is of medicinal value. In Nigeria, a dye is extracted for use by boiling the crushed ginger rhizomes in water.

The crop plant was introduced by the Portugues~~e~~ to West Africa and then to other parrts of the tropics in the 16th century (Purseglove, 1972). Since its introduction into Nigeria it has become an established crop among the people of the Southern part of Kaduna State. Ginger is grown on a wide range of soil types provided there is adequate drainage. It however, thrives best in alluvial plain soils (Cho et al,1987), and in sandy loam clay soils with a lot of organic matter (Pauloso, 1972). It does well in regions with annual rainfall of 1000 - 1500mm, distributed over 6 - 8 months during the growing period with duinal temperatures of 23-35 ^{o}C (Anon.,1987), and soild PH values of 6.0 - 6.5 (Shamsul - Islam, 1981).

Though, ginger had for long been grown in Southern Kaduna, its production was vigorously started around 1927 (Gibbon, 1953). There was rapid expansion in production with increased cultivation and by 1935 - 36, Nigeria was reported to have produced about 7.8% of the total world output (Momber, 1942). In 1966, Nigeria was the second largest world exporter of ginger (Arene et al, 1987). Thereafter, exports fell to about 1500 tons in the early seventies due to the Nigerian civil war (Purseglove, 1972). Accordingly, export earnings similarly decreased from £2.27 million in 1974 to £1.8 million in 1977. This decline was so significant that by 1984, only 27 tons of dried ginger was reportedly exported (Anon., 198; Anon., 1987).

A survey of Kaduna State Agriculture by Abalu et al (1979) showed that, ginger production efficiency rating was very low. In Nigeria, estimated yield was only 5 - 12.5 t/ha of fresh ginger (Quinn, 1973), whereas in other parts of the world like Australia and India, high yields of up to 23 t/ha have been reported (Purseglove, 1972). The low yields obtained in Nigeria could be ascribed to several agronomic factors among which are, planting density, which could be manipulated by the intra and inter row spacings, sett (rhizome) size and the variety cultivated. Under improved cultural management, it is reported that yields of up to 20 - 30 t/ha are attainable under the Nigerian growing conditions (Anon., 1987).

With the scientific base provided by research, interest in ginger production in Nigeria has started to grow, especially with the findings that ginger performs well in the rainforest region of Nigeria and has a great potential as a major export crop. For instance, in 1986, Nigeria was reported to have earned £309,209 from the export of 218.4 tons of ginger while in 1987,

£2,240,826 was earned from the export of 846.7 tons of ginger (Okwuowulu and Ene, 1988).

The quality of the Nigerian ginger is reported to compare favourably well with those of other countries in the world market except for its size and fibrous texture. These defects can be improved by selection and the use of improved agronomic practices; especially planting density, row spacing and sett size, as has been demonstrated in Australia and Nigeria, where significant response to spacing and sett size have been reported. (Whiley, 1981; Menta, 1987; Orkwor et al, 1988). Ginger growth was reportedly enhanced by close plant spacing while yield per unit area was increased with closer intra row spacing and large setts (Whiley, 1981; Menta, 1987; Orkwor et al, 1988).

Inspite of the long history of ginger cultivation by the people of the Southern part of Kaduna State, Nigeria, quantitative information on various aspects of the agronomy of ginger is very scanty.

In view of the above, the objectives of this study were to investigate;

(i) The effect of plant density, row spacing and sett size on the growth, development, yield and quality of ginger. And

(ii) The interaction of these factors on the growth , development, yield and quality of ginger.

Chapter 2.

LITERATURE REVIEW

2.2 Effect of plant density on the growth and yield of ginger

An important aspect in the production of crop plants is plant density which could be manipulated by both inter and intra row spacings. Though density usually refers to the number of plants per unit area, their spacial arrangement is of equal importance. Changes in plant density usually affects inter plant competition and mutual shading which in turn affects both vegetative reproductive and other developmental processes of the crop (Tetio-Kagho and Gardner, 1988).

Plant density studies in most crops have shown that generally, individual plant yield decrease with increasing density (i.e with closer crop spacings) while the yield per plant increase with increased spacing (Menta, 1987, Chiezey, 1989). However, the increase in production by individual plants grown under wide spacing, may not compensate for the total yield reduction per unit area as a result of the adoption of less than optimium plant density. Thus, for most crops, yield per unit area has been reported to increase with increasing plant density (Irritani et al 1972;Hopen and Paterson, 1974; Mangual - Crespo et al,1979; Brewster and Slater, 1980; Nelson and Thoreson, 1982; Rahman and Talukdar, 1986; Zharekhina, 1987). However, the total dry matter yield per unit area increases with increasing density until a level of yield is attained. Thereafter, further increase in density does not result in any yield increase (Bleasdale, 1966; Gupta, 1982; Chiezey, 1989). Bleasdale (1966) referred to the plant density level at which yield becomes constant as the point of maximum fixation of energy attainable by a crop in the period between planting and harvest. In this regard, he concluded that, the spacing of individual plants of a crop more than any single factor determines the resources available to each plant and whether or not the total resources are fully utilized. Therefore, to attain a high yield potential, it is not only adequate to plant at optimum densities but also optimum inter and intra row spacings most be adopted.

The effect of narrow rows on yield have often been explained in terms of the enhanced close canopy which results and may intercept a larger percentage of the incoming solar radiation thereby reducing soil evaporation and increasing photosynthesis (Loomis and Williams, 1963; Williams and Joseph, 1974; Mandal and Sahu, 1977;Harshem and Gill, 1987). Thus, though plant densities have been shown to affect various aspect of crop growth and yield, the nature and magnitude of this effect are as varied and conflicting as the crops and the regions (Alessi and Power, 1982).

The planting rates of ginger among farmers vary from one locality to the other depending on the method of cultivation adopted and the local conditions; especially climate and environment (Rodrignez, 1971; Pauloso,1972). For instance at Zonkwa, in the Southern Guinea Savanna Zone of Nigeria , Quinn (1973) who planted ginger at intra row spacings of 15, 23 and 30cm and at a constant row spacing of 45cm, found that fresh ginger yields increased with decreased spacing. In another experiment conducted in the Northern Guinea savanna ecological zone, Menta (1987) investigated the effect of spacing ginger at intra row spacings of 10, 20 and 30cm and at a contant inter-row spacing of 15cm .He found that the vegetative growth and yield of the crop were significantly influenced by spacing. However, the medium spacing (20 x 15cm) gave the highest yield (587.85kg/ha) of fresh ginger per unit area. In similar experiments conducted at three locations in Nigeria, namely; Umudike in the rainforest region and Kubacha and Kagarko districts of Kaduna State, in the southern guinea savanna zone,Orkwor et al (1988) found that row spacings varying from 10 to 30cm, had no significant effect on crop growth and yield at all the locations. However, the 10 to 15cm intra row spacings yielded better than wider spacings. In Queensland, Austrialia, Whiley (1981) studied the effect of intra row spacings ranging from 11.2 to 22.4cm and at a constant inter row spacing of 20cm, on the agronomic performance of ginger. He reported yields of 63.8, 55.3 and 44.6 kg/plot at 11.2, 17.0 and 22.4cm intra row spacings respectively. Moreover, close planting of ginger (11.2cm) improved crop growth and increased rhizome yield without having deleterious effect on rhizome size.

2.2 Effect of sett size on the growth and yield of ginger.

Seed size is known to affect various aspect of crop growth and yield. However, information on the effect of sett size on crop development and yield is conflicting. Bleasdale (1979) indicated that though larger and heavier seed smaples are more likely to be viable, they do not necessarily give the highest percentage field emergence. Whiley (1981) reported that yield and rhizome size of ginger, increased with increasing sett weight. Similarly,Orkwor et al (1988) in another study, found that the larger seed weight (20gm) of ginger gave higher yield than the smaller (10gm) sett piece weight.

In his work on yam, Onwueme (1972) found that the high food reserved material contained in large setts results in the production of large plants with greater vine diameter, number of leaves per stand and leaf area per stand (i.e more elaborate and vigorous shoot structures) than small sett plantings. These structures formed, parrticularly the greater leaf area produced in turn resulted in the production of larger tubers. Similar findings have been reported for several crops (Nelson, 1970; Irritani et al, 1972; Irritani et al, 1983; Bielinska - Czarnecka et al, 1981; El-Emery, 1985; Musa, 1990).

Although, there is no available information on the effect of planting whole rhizome setts of ginger, studies in yam showed that cutting large tubers into setts for planting resulted in certain problems . For instance, when the tubers are cut, setts that are heads, middles and bottoms automatically result. Even among the heads, some will already have sprouts, while the rest have none. When all the setts are planted, the heads sprout first, followed by the heads without sprouts and finally the tails and middles will emerge. Hence, even though the setts may be homogeneous in origin, they are heterogeneous in performance. On the field this results in plants being at various stages of development and this could be disadvantageous to the overall performance of the crop (Onwueme, 1978). In onions, Adjei-Iwum (1980) in a study over a two year period, reported that bulb yield, rate of sprouting and the number of leaves which developed, increased as the mother bulb size increased. He noted that though cutting mother bulbs raised the rate of sprouting during the initial plant growth period, it was generally detrimental to bulb yield.

On the whole, it has been indicated that after the establishment of the crop plant, the response of the plant would depend on the intensity of interplant competition that sets in. If competition is low, the initial advantage of the large and vigorous plants produced from large setts could be maintained over a longer period or even throughout the growing season. Therefore, the yield difference between plants from larger and small setts appear to arise from differences in the length of the growing season rather than the rate of dry matter accumulation (Irritani et al,1983). Thus, the advantage of using large setts may diminish over time and setts from large and small seed piece wieghts may catch up and eventually attain similar yield levels (Wood et at, 1977).

2.3 Interaction of plant density, row spacing and sett size on the growth and yield of ginger..

Very little information is available on the interaction of plant density, row spacing and sett size on the growth and yield of ginger. Whiley,(1981) and Orkwor et al (1988) reported that the conbination of close spacing and large rhizome seed piece weight was optimal for good rhizome yield. Similar studies on onions by Rusev (1978) showed that yield increased with increasing bulb weight and decreasing growing space. Also in another experiment using cloves of garlic Diumovic and Bravo (1979) found that yield increased with increasing clove weight (1 to 8g) and increasing plant density (333,000; 450,000; 830,000 plants/ha) However, the highest yield was obtained using a clove weight of 4.5g and plant density of 333,000 plants/ha.

2.4 Ginger quality

The quality of ginger could be assessed by its physical attractiveness (i.e the possession of large, firm, uniform, unwrinkled "hand, races" or rhizomes; free from blemishes or mildews) and/or its chemical composition. In this regard, the Jamaican ginger has been rated among the best offered in international trade and as such, other gingers are assessed by the standard of the Jamaican ginger

The analytical standards of the British Pharmacopoeia is as follows:

Ash (not more than 6.0%); water soluble ash (not less than 1.7%); water soluble extractive (not less than 10.7%); alcohol (90%); soluble extract (not less than 4.5%); while the United States standards are as follows:

Starch (not less than 42%); crude fibre (not more than 8%); lime (not more than 8%); cold water extract (not less than 12%); total ash (not less than 2%).

In general, ginger for export must comply with the regulations of the importing country. Such regulations may vary, but those of the United States of America and the United Kingdoms are probably the most typical and perharps the most important (Rodriguez, 1971). The quality of the Nigerian ginger has been reported to meet these standards in the world market where it compares favourably well with those of other countries (Fanlkner and Mackies, 1933).

2.4.1 Effect of plant density, row spacing and sett size on the quality of ginger.

In view of the paucity of literature on the effect of density, row spacing and sett size on the quality of ginger, findings on other horticultural crops with similar growth habits and method of propagation have been reviewed.

Ruser (1978) reported that bulb weight and growing space had little effect on the seed quality of onions . On the other hand, Zharekhina (1987) found that onion bulbs showed wide variations in morphological characteristics at plant densities ranging from 178 to 269 plants/m^2. However, plant density had no effect on onion flavour. In garlic, Duimovic and Bravo (1979) reported that the yields of exportable bulbs (>5.1cm in diameter) increased from 21 to 46% with increased clove weight. Yield also increased with decreasing spacing; but the number of exportable garlic bulbs decreased.

Chapter 3.

MATERIALS AND METHODS

3.1 Location of experimental site.

A study on ginger (*Zingiber officinale* Rosc.) was carried out during the 1989 rainy season at the horticultural farm of the Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria - Nigeria (11^o 10' N, 7^o 35' E, 685m above sea level) in the northern guinea savanna ecological zone of Nigeria.

The total rainfall at Samaru during the 1989 season was about 751.8mm. This was concentrated almost entirely in the five months of May to September. Details of the weather conditions including rainfall, temperature, relative humidity and sunshine hours are given in appendix 1.

3.2 Treatments and experimental design

The treatments were made up of the following; Three plant populations (166,666; 333,333 and 500,000 plants/ha); three inter-row spacings (10, 20 and 30cm; viz: the intra row spacings varied in each inter-row spacing to achieve the required plant density); and three rhizome sett weight ($7.5\pm$ 2, 15.8 ± 2 and 22.5 ± 2gm). The ginger variety "Tafin Giwa" whose superiority over other varieties has been established in recent research works were used in this study

(Anon.,1969; Musa, 1986; Menta, 1987; Okwor et al, 1988).

The treatment combinations totaled 27 (3 x 3 x 3). These were laid out in a split plot design with plant density and row spacing as the main plot treatments while rhizome sett size was the sub plot treatment. These were replicated four times.

The treatment combinations were as follows;

D1R1S1	D2R1S1	D3R1S1
D1R1S2	D2R1S2	D3R1S2
D1R1S3	D2R1S3	D3R1S3
D1R2S1	D2R2S1	D3R2S2
D1R2S2	D2R2S2	D3R2S2
D1R2S3	D2R2S3	D3R2S3
D1R3S1	D2R3S1	D3R3S1
D1R3S2	D2R3S2	D3R3S2
D1R3S3	D2R3S3	D3R3S3

D=Plant density

R=Row spacing

S=Sett size

Details of the exprimental layout is shown in appendix 3.

3.3 Plot size

The plot size measured 2.4x1.8m ($4.32m^2$) with a spacing of 0.6m between plots and 1.0m between blocks.

The total area of the experimental plot was $799.7m^2$ (27.2x29.4m).

3.4 Cultural practices

3.4.1 Land preparation and planting

The land was ploughed once and harrowed twice with a tractor to give a good soil tilth (to enhance the formation of well shaped rhizome" races" or" hands"; after which plot beds measuring 2.4x1.8m were raised with the aid of the hand hoe.

Whole mother rhizome "hands" of ginger were cut in the laboratory with the aid of a sharp cutting knife and weighed into the appropriate sett weights (7.5, 15.0 and 22.5gm) as per treatment.

The setts were planted on the 3rd and 4th of July, 1989, in holes 5 - 10cm deep and covered with a layer of soil.

3.4.2 Fertilizer application

Phosphorous and Potassium were applied as basal dressing at the time of bed preparation, at the rates of 80kg P_2O_5/ha and 50kg K_2O/ha respectively. The fertilizer used were single super phosphate (18.0%P_2O_5) for phosphorous and muriate of potash (60%K_2O) for potassium. Nitrogen at 200kg N/ha was applied in two equal split doses at 60 and 90 days after planting. Calcium ammonium nitrate (26%N) was used as the source of nitrogen (Musa, 1986).

3.4.3 Mulching

The seed bed were mulched with grass and leaves immediately after planting the rhizome setts. The mulch was applied to about 5cm thickness and soon after the crop had become established, the mulch was removed.

3.4.4 Weed, Pest and Disease control

Emerging weeds were controlled manually from the plot at 8, 12 and 16 weeks after planting (Olorukooba, 1987). However, weeds were additionally controlled when neccessary; by hand p ulling those weeds growing within the plot beds and hoeing those growing between plots.

At the time of planting, cut rhizome setts were treated with fanasan-D to protect against fungi and other soil borne disease and insect attack.

3.4.5 Harvesting

The crop was harvested on the 4th December, 1989 (20 WAP) after the leaves had turned yellow, dried up and lodged. The rhizomes were dug out by carefully lifting the soil clumps in the net plot area (1.2x0.6m) with the aid of a digging fork. The rhizomes were cleaned, devoid of adhering soil particles and gathered into labelled polythene bags after which they were taken to the laboratory for further analysis.

The net plot area incorporated the 6 centre rows in the 10cm row spacing; 3 centre rows in the 20cm row spacing and the 2 centre rows in the 30cm row spacing.

3.5 Data collection

3.5.1 Meteorological data

Data on the rainfall distribution, temperature, relative humidity and sunshine hours for the year, 1989, was obtained from the Institute for Agricultural Research Meteorological Station at Samaru - Zaria. Details are presented in appendix 1.

3.5.2 Soil analysis

Soil samples from the experimental location were taken at (0-15cm) and (15-30cm) depths before the commencement of the study. The sampled soils were ground into fine particles and thoroughly mixed and analysed for physico-chemical characteristics using the standard proceedure as described by Black (1965). The results of this analysis is presented in appendix 1.

The soil of the experimental location is classed as loamy. It is well drained , but characterised by a low P.H, low organic carbon, low cation exchange capacity (C.E.C), low nitrogen and high phosphorous.

3.5.3 Assessment of characters

The assessment of crop character started at 10 weeks after planting (WAP) with the percentage stand count. Subsequentlly, other growth para meters were assessed at fortnightly intervals. Four plant samples per plot were destructively sampled at random outside the net plot area (1.2x0.6m). The sampled plants were carefully lifted off the soil surface with the aid of the hand trowel; packed into labelled polythene bags and taken to the laboratory where they were carefully removed and washed clean of adhering soil particles. They were next seperated into their component parts (viz rhizomes, stems and leaves) using a sharp cutting knife and the following observations taken:

(ii) Number of offshoots (tillers)/plant

The total number of offshoots were counted from the four plants sampled per plot and the average per plant calculated.

(iii) Plant height

The height of the main shoots per plot were measured from the sample using ameasuring ruler. The height was taken from the ground level to the tip of the growing point and the average per plant was calculated.

(iv) Number of leaves/plant

The total number of green leaves were counted from the sampled plants per plot and the average per plant caculated.

(v) Leaves fresh and dry weight/plant

The fresh green leaves were removed from the sampled plants per plot and weighed in the laboratory. The average per plant was then calculated. The leaves were then oven dried at a temperature of 70 ^{o}C for 48 hours. The average dry weight per plant was then calculated.

(vi) Stem fresh and dry weight/plant

The cut fresh stems of the sample plants per plot were weighed in the laboratory and the average per plant calculated. These were then packed into a paper sampl ing bag and oven dried at a temperature of 70 ^{o}C for 48 hours. The average dry weight per plant was then calculated.

(vii) Rhizome fresh and dry weight/plant

Harvested ginger (fresh) rhizome weight of the sampled plants per plot were recorded in the laboratory. These were then packed into a paper sampling bag and oven dried at a temperature of 70 ^{o}C for 48 hours. And the average rhizome dry weight per plant was calculated.

(viii) Leaf area (LA)/plant (CM^2)

The leaf area of five representative leaves per treatment were determined by tracing them on square graph sheets and their area calculated as described by Evans (1972). After this, their fresh weights was taken in the laboratory. They were then oven dried at a temperature of $70^{o}C$ for 48 hours. The leaf area per plant was calculated using the leaf area — dry weight relationship.

(ix) Leaf area index (LAI)

The leaf area index (LAI) was calculated by dividing the leaf area per plant by the ground area occupied by the individual plant.

(x) Plant stand at harvest

The number of plants standing in the net plot area at harvest was recorded. This was expressed as a percentage.

(xi) Final yield (fresh)/ha

The yield per unit area (net plot area) was calculated after the fresh rhizomes had been dug out and weighed in the laboratory. This was recorded and subsequently converted to yield in tons per hectare.

3.6 Ginger quality analysis

In this study, the quality of ginger was characterised by the oil (oleoresin) and ash content.

(xii) Oil (oleoresin) content

The oil content of the ginger rhizomes was determined from the oven dried rhizome samples per plot. The rhizomes were ground using a pistil and mortar; after whcih a sample weight of 3 - 5gm was taken per plot for the oil content determination using a reflux apparatus to extract the oil in 90% alcohol as described by AOAC, (1965).

The oil content was calculated on a percentage basis using the formula:

$$\frac{\text{Initial sample weight} - \text{sample weight after oil extraction}}{\text{Initial sample weight}} \times 100$$

(xiii) Ash content

The ash content was determined from the dried rhizome samples per plot. The rhizomes were ground using a pistil and mortar; after which a sample weight 1.5 - 2.0gm per plot sample was taken for the ash content determination; using a muffle furnace in which the samples were burnt to ashes according to the standard proceedure described by AOAC (1965). The ash content was calculated on a percentage basis using the formular;

$$\frac{\text{Weight of Ash}}{\text{Weight of sample}} \times \frac{100}{1}$$

3.7 Analysis of Data

The collected data was compiled, tabulated and analysed statistically. The main treatment effect of plant density, row spacing and rhizome sett size and their interactions were of major importance. In the analysis of variance, as described by Snedecor and Cochran (1969), where the "F" test was significant, the means were compared using the LSD (Least significance difference) test.

Chapter 4

RESULTS

4.1 Number of offshoots\plant

The effect of plant density, row spacing and sett size on the number of offshoots per plant at 10, 12, 14 and 16 weeks after planting (WAP) is presented in table 1.

The number of offshoots per plant increased with increasing plant density throughout the sampling period. However, differences between densities were significant only at 12, 14 and 16 WAP. At 12 WAP, there was no significant increase in the number of offshoots when the population was increased from 166,666 to 333,333 plants/ha. However, a further increase in population to 500,000 plants/ha increased the number of offshoots per plant significantly. At 14 and 16 WAP, the number of offshoots was significantly lower at 166,666 plants/ha compared with either 333,333 or 500,000 plants/ha.

Row spacing had a significant influence on the number of offshoots per plant at 14WAP only (Table 1). A row spacing of 20cm significantly produced higher number of offshoots per plant than both 10 and 30cm row spacings which did not statistically differ from each other.

Number of offshoots per plant was not significantly affected by sett size. Neither was there a significant interaction between the treatments on the

Table 1 Effects of plant density, row spacing and sett size on the number of offshoots/plant of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
Plant population(/ha)				
166,666	3.2	4.4	5.4	5.4
333,333	3.7	5.9	6.4	6.5
500,000	3.8	7.5	6.9	6.8
LSD(5%)	N.S	1.87	0.99	1.07
Row spacing (cm)				
10	3.4	6.7	5.8	6.5
20	3.6	5.3	7.2	6.1
30	3.7	5.8	5.7	6.2
LSD(5%)	N.S	N.S	0.99	N.S
Sett size (gm)				
7.5	3.5	6.0	6.0	6.7
15.0	3.8	5.5	6.3	6.3
22.5	3.6	6.2	6.3	5.8
LSD(5%)	N.S	N.S	N,S	N.S
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S = Not Significant.

number of offshoots per plant (Table 1).

4.2 Number of leaves/plant

Table 2 presents the effect of plant density, row spacing and sett size on the number of leaves per plant at 10, 12, 14 and 16 weeks after planting (WAP).

Plant density had a significant effect on the number of leaves per plant which increased with increasing plant density. At 10 and 14 WAP, the number of leaves at 166,666 plants/ha was significantly lower than the number of leaves at the two higher densities. However, at 12 and 16 WAP, leaf number per plant at 500,000 plants/ha was significantly higher than at 166,666 and 333,333 plants/ha which were statistically at par.

Row spacing had a sigificant effect on the number of leaves per plant at 14WAP only (Table 2) plants spaced 20cm apart significantly produced higher number of leaves per plant than those spaced 10 and 30cm apart which did not statistically differ from each other.

Sett size had no influece on the number of leaves per plant throughout the sampling period.

None of the interactions was significant on the number of leaves per plant (Table 2).

Table 2 Effects of plant density, row spacing and sett size on the number of leaves/plant of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
Plant poplutation(/ha)				
166,666	17.3	34.6	48.7	48.3
333,333	21.7	44.6	58.8	56.9
500,000	23.7	57.8	63.1	66.5
LSD(5%)	3.81	11.79	6.12	8.93
Row spacing (cm)				
10	20.2	51.1	52.5	58.3
20	20.3	42.8	64.4	58.5
30	22.3	43.1	53.8	54.9
LSD(5%)	N.S	N.S	6.12	N.S
Sett size(gm)				
7.5	21.0	46.1	55.4	60.8
15.0	20.5	44.1	53.9	54.6
22.5	21.2	46.8	61.4	56.3
LSD(5%)	N.S	N.S	N.S	N.S
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S= Not Signific

4.3 Plant height

Table 3 shows the effect of plant density, row spacing and sett size on plant height at 10, 12 14 and 16 weeks after planting (WAP).

Plant density had a significant influence on plant height throughout the period. Plant height increased with increasing plant density.

Row spacing had no signifcant effect on the height of the plants.

Sett size significantly influenced plant height at 14 and 16 WAP. The general trend showed that the largest sett weight (22.5gm) produced taller plants than the other two smaller sett weights. The difference in the height of plants produced from the 7.5 and 15.0gm sett weights was not significant.

There was no significant interaction of the treatments on plant hight (Table 3).

4.4 Stem dry weight/plant

The effects of plant density, row spacing and sett size on the stem dry weight per plant at 10, 12, 14 and 16 weeks after planting (WAP) is presented on table 4.

Stem dry weight per plant increased with increasing plant density throughout the sampling period.

Row spacing and sett size had no significant effect on stem dry weight per plant (Table 4).

Table 3   Effect of plant density, row spacing and sett size on plant height(cm) of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
plant population(/ha)				
166,666	19.7	22.4	26.1	25.3
333,333	25.9	29.3	30.3	30.7
500,000	28.4	34.7	35.9	35.4
LSD(5%)	2.55	1.77	2.29	2.94
Row spacing(cm)				
10	25.3	29.1	29.4	29.0
20	24.4	27.9	31.5	31.7
30	24.3	29.5	31.3	30.7
LSD(5%)	N.S	N.S	N.S	N.S
Sett size (gm)				
7.5	24.7	28.3	30.0	29.6
15.0	24.4	28.0	29.5	28.8
22.5	24.9	30.2	32.7	33.0
LSD(5%)	N.S	N.S	2.39	2.62
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S = Not Significant
30.S = Not Significant
30.S = Not Significant
33

Table 4 Effect of plant density, row spacing and sett size on the stem dry weight (gm)/ plant of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
lant population(/ha)				
166,666	0.9	1.3	2.1	2.4
333,333	1.5	2.4	2.9	3.1
500,000	1.8	3.8	4.2	4.1
LSD(5%)	0.26	0.64	0.47	0.66
Row spacing(cm)				
10	1.5	3.0	2.9	3.4
20	1.4	2.2	3.4	3.3
30	1.4	2.4	2.9	2.9
LSD(5%)	N.S	N.S	N.S	N.S
Sett size(gm)				
7.5	1.4	2.5	2.9	3.1
15.0	1.3	2.3	2.8	3.1
22.5	1.4	2.8	3.4	3.4
LSD(5%)	N.S	N.S	N.S	N.S
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S = Not Signifiacnt.

None of the interactions of the treatments was significant on stem dry weight per plant (Table 4).

4.5 Rhizome dry weight/plant

Table 5 presents the effect of plant density, row spacing and sett size on rhizome dry weight per plant at 10, 12, 14 and 16 weeks after planting (WAP).

The influence of plant density on rhizome dry weight per plant was significant throughout the period. Generally, rhizome dry weight increased with increasing plant density.

Rhizome dry weight was significantly influenced by row spacing at 12 WAP only. The rhizome dry weight obtained at 10cm, was significantly higher than that recorded at 20cm but was statistically at par with the dry weight at 30cm row spacing.

Sett size similarly had a significant effect on rhizome dry weight per plant at 12 WAP only. The largest sett weight (22.5gm) produced significanlty higher rhizome dry weights than the 15.0gm setts; but the difference in rhizome weight between the 22.5 and 7.5gm sett weights was not significant.

The interaction between the treatments on rhizome dry weight was not significant (Table 5).

4.6 Leaf dry weight/plant

Table 6 presents the effect of plant density, row spacing and sett size on the leaf dry weight per plant

Table 5 Effect of plant density, row spacing and sett size on rhizome dry weight (gm)/plant of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
Plant population(/ha)				
166,666	1.0	1.3	3.2	3.7
333,333	1.6	2.7	5.1	4.8
500,000	1.9	4.4	7.6	7.0
LSD(5%)	0.34	0.63	1.06	1.43
Row spacing				
10	1.6	3.2	4.7	5.1
20	1.5	2.3	5.8	5.4
30	1.4	2.9	5.5	5.0
LSD(5%)	N.S	0.63	N.S	N.S
Sett size(gm)				
7.5	1.5	2.9	5.2	4.9
15.0	1.5	2.4	4.9	4.7
22.5	1.5	3.2	5.9	5.9
LSD(5%)	N.S	0.56	N.S	N.S
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S = Not Signifcant.

Table 6 Effect of plant density, row spacing and sett size on leaf dry weight(gm)/plant of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
Plant population(/ha)				
166,666	1.4	1.7	3.0	3.2
333,333	2.1	3.1	4.1	4.1
500,000	2.5	4.5	5.9	5.6
LSD(5%)	0.34	0.80	0.64	0.85
Row spacing (cm)				
10	2.1	3.6	4.1	4.6
20	2.0	2.7	4.8	4.4
30	1.9	3.0	4.2	4.0
LSD(5%)	N.S	N.S	N.S	N.S
Sett size(gm)				
7.5	2.1	3.1	4.2	4.2
15.0	1.9	2.8	4.0	4.1
22.5	2.0	3.3	4.9	4.6
LSD(5%)	N.S	N.S	N.S	N.S
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S = Not Significant.

at 10, 12, 14 and 16 weeks after planting (WAP).

Plant density had a significant influence on leaf dry weight per plant throughout the period. Leaf dry weight increased with increasing plant density.

Row spacing and sett size did not significantly influence leaf dry weight throughout the period.

There was no significant interaction of the treatments on leaf dry weight per plant (Table 6).

4.7 Leaf area/plant

Plant density had a significant effect on the leaf area per plant throughout the sampling period (Table 7). There were significant increases in the leaf area with increasing plant density except at 16 weeks after planting (WAP) when the leaf area at 166,666 plants/ha did not differ statistically from that at 333,333 plants/ha.

Row spacing and sett size had no significant effect on the leaf area per plant.

There was also no significant interaction of the treatments on leaf area per plant (Table 7).

4.8 Leaf area index

Table 8 shows the effect of plant density, row spacing and sett size on the leaf area index (LAI) at 10, 12, 14 and 16 weeks after planting (WAP).

Plant density had a significant influence on leaf area index throughout the period of sampling. Leaf area

Table 7 Effect of plant density, row spacing and sett size on leaf area(cm^2)/plant of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
Plant population(/ha)				
166,666	169.8	245.1	414.8	451.1
333,333	248.3	448.4	570.5	567.7
500,000	307.0	667.8	813.6	783.5
LSD(5%)	42.41	116.36	88.18	117.84
Row spacing(cm)				
10	250.4	528.5	558.5	634.2
20	240.0	390.8	662.0	615.8
30	234.7	442.0	578.5	552.4
LSD(5%)	N.S	N.S	N.S	N.S
Sett size(gm)				
7.5	249.8	461.8	583.8	588.1
15.0	232.0	406.7	547.3	567.3
22.5	243.4	492.8	667.9	646.9
LSD(5%)	N.S	N.S	N.S	N.S
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S = Not Significant.

index increased with increasing plant density.

Row spacing similarly influenced leaf area index throughout the period. Leaf area index increased with increasing row spacing. Sett size did not significantly influence leaf area index.

There was no significant interaction of the treatments on leaf area index (Table 7).

4.9 Rhizome yield

Rhizome yield increased linearly and significantly with increasing plant population up to 500,000 plants/ha (Table 9).

Rhizome yield also increased with increasing row spacing. However, only the yield at 30cm row spacing was significantly superior to that at either 10 or 20cm.

Sett size did not have a significant influence on yield though, the largest rhizome weight (22.5gm) produced higher rhizome yield than other smaller sett sizes.

The plant density X sett size and row spacing X sett size interactions were significant (Table 9).

Table 10 presents the interaction between plant density and sett size on yield. At plant populations of 166,666 and 333,333 plants/ha, sett size had no significant influence on yield. However, at a plant population of 500,000 plants/ha, the yield recorded with a 7.5gm sett weight was significantly higher than the

Table 8 Effect of plant density, row spacing and sett size on leaf area index of ginger in 1989.

Treatment	Weeks after planting 10	12	14	16
Plant population(/ha)				
166,666	0.6	0.8	1.4	1.4
333,333	0.8	1.5	2.0	1.9
500,000	1.0	2.1	2.7	2.6
LSD(5%)	0.12	0.40	0.36	0.45
Row spacing(cm)				
10	0.4	0.9	0.9	1.1
20	0.8	1.3	2.2	2.1
30	1.2	2.2	2.9	2.8
LSD(5%)	0.12	0.40	0.36	0.45
Sett size(gm)				
7.5	0.8	1.6	1.9	1.9
15.0	0.8	1.3	1.9	1.9
22.5	0.8	1.6	2.2	2.1
LSD(5%)	N.S	N.S	N.S	N.S
Interactions				
RXD	N.S	N.S	N.S	N.S
RXS	N.S	N.S	N.S	N.S
DXS	N.S	N.S	N.S	N.S
RXDXS	N.S	N.S	N.S	N.S

N.S =Not Significant.

yield obtained with either 15.0 or 22.5gm sett weights.

The interaction between row spacing and plant density on yield is presented in table 11. At 10cm row spacing, yield was significantly higher at 166,666 plants/ha compared with the yield at either 333,333 or 500,000 plants/ha which were statistically at par. At 20cm row spacing, plant density had no significant influence on yield. However, at 30cm, a significantly higher yield was obtained at 500,000 plants/ha compared with either yields at 166,666 or 333,333 plants/ha which did not differ statistically.

4.10 Correlation

Table 14 shows the matrix of coefficients of correlations between all the yield components and rhizome yield. Leaf area index (LAI) was observed to be positively and significantly correlated with rhizome yield (r=0.475*). Other yield components were positively correlated with yield, but the relationships were not significant. Rhizome dry weight which is an index of rhizome yield was, however, positively and significantly correlated with stem dry weight (r=0.893**), plant height (r=0.783**), number of leaves (r=587**), and number of offshoots (r=574**).

1.11 Percentage oil (oleoresin) and ash content

Table 12 presents the effect of plant density, row spacing and sett size on the quality, characterised by

Table 9 Effect of pland density, row spacing and sett size on the yield (t/ha) of ginger at 20WAP in 1989.

Treatment	Fresh yield (t/ha)
Plant population(t/ha)	
166,666	3.3
333,333	6.5
500,000	9.0
LSD(5%)	1.95
Row spacing(cm)	
10	4.5
20	5.4
30	8.8
LSD(5%)	1.95
Sett size(gm)	
7.5	6.5
15.0	5.8
22.5	6.6
LSD(5%)	N.S
Interactions	
RXD	**
RXS	N.S
DXS	**
RXDXS	N.S

N.S = Not Significant.
** = Significant at 0.01% level of probability

Table 10 The interaction of plant density and sett size on the yield (t/ha) of ginger in 1989.

Sett size (gm)	Plant population(/ha) 166,666	333,333	500,000
7.5	2.9	5.1	11.4
15.0	2.6	7.7	7.3
22.5	4.4	6.7	8.2
LSD(5%)		2.58	

Table 11 The interaction of row spacing and plant density on yield (t/ha) of ginger in 1989.

Plant population (/ha)	Row spacing (cm) 10	20	30
166,666	7.6	4.0	7.8
333,333	3.0	6.8	7.8
500,000	2.9	5.4	10.9
LSD(5%)		2.58	

the oil and ash content of ginger.

Plant density had a significant influence on the oil content of ginger only. The oil content increased with increased plant population from 166,666 to 333,333 plants/ha. A further increase in plant population to 500,000 plants/ha resulted in a significant decrease in the oil content.

Row spacing had no significant influence on both the oil and ash content of ginger.

Sett size had no significant influence on ash content but the oil content decreased with increasing sett size; the difference between the oil content at 7.5 and 22.5gm sett weights being significant.

Table 13 presents the interaction between row spacing and sett size on the ash content of ginger. At 10cm, increasing sett size from 7.5 to 15.0gm did not affect ash content while a further increase in sett size to 22.5gm significantly increased the ash content. At 20cm, increasing sett size from 7.5 to 15.0gm similarly did not influence the ash content; but a further increase in sett size to 22.5gm significantly decreased the ash content. Sett size had no significant effect on the ash content at 30cm row spacing.

Table 12 Effect of plant density, row spacing and sett size on the percentage oil (oleocesin) and ash content of ginger at 20WAP in 1989.

Treatment	Ash content (%)	Oil content (%)
Plant population(/ha)		
166,666	5.0	5.9
333,333	5.7	7.1
500,000	4.4	5.8
LSD(%)	N.S	1.07
Row spacing(cm)		
10	5.7	6.1
20	4.7	6.4
30	4.7	6.3
LSD(%)	N.S	N.S
Sett size(gm)		
7.5	5.0	6.9
15.0	5.2	6.3
22.5	5.0	5.6
LSD(%)	N.S	1.01
Interactions		
RXD	N.S	N.S
RXS	**	N.S
DXS	N.S	N.S
RXDXS	N.S	N.S

N.S = Not Significant.
* * = Significant at 0.01% level of probability.

Table 13 Ash content of ginger at 20 WAP as influenced by row spacing and sett size interactions in 1989.

Sett size (gm)	Row spacing (cm) 10	20	30
7.5	4.6	5.0	5.3
15.0	5.0	6.2	4.5
22.5	7.4	3.0	4.5
LSD(%)		1.61	

Table 14: Correlation(r) between rhizome(fresh) yield of ginger and other growth components.

	Variables	1	2	3	4	5	6	7	8	9	10
1	Rhizome yield(fresh)	1									
2	Number of offshoots	0.147	1								
3	Number of leaves	0.213	0.762**	1							
4	Plant height	0.367	0.357	0.512**	1						
5	Stem dry weight	0.368	0.639**	0.708**	0.816**	1					
6	Rhizome dry weight	0.349	0.574**	0.587**	0.783**	0.893**	1				
7	Leaf dry weight	0.372	0.668**	0.740**	0.788**	0.970**	0.899*	1			
8	Leaf area	0.372	0.667**	0.739**	0.789**	0.970**	0.900**	0.999**	1		
9	Leaf area index	0.475*	0.495**	0.552**	0.601**	0.714**	0.704**	0.744**	0.745**	1	
10	Plant stand at harvest	0.229	0.145	0.224	0.464*	0.437*	0.415*	0.407*	0.409*	0.176	1

* = Significant at 0.05% level of probability.

** = Significant at 0.01% level of probability.

Chapter 5

DISCUSSION

5.1 General

Among the various growth factors, climate plays a strong modifying role on the growth and productivity of field and vegetable crop plants. Ginger is well adapted to the agro ecological conditions of the southern guinea savanna, where its productivity is directly dependent on the length of the growing season, and the amount and distribution of rainfall. In the present study, ginger was planted on the 3rd July and harvested on 4th December, 1989; but the rain ceased on 16th October, 1989. Thus the active growing season was about 154 days including the last 48 days during which no rainfall was recorded. This is considerably less than the ideal growing period of 180 - 240 days. Even though, the seasonal rainfall was well distributed, it was about 33% lower than the normal rainfall required for ginger production (Anon., 1987). As such, the average yield in this experiment (3.3 - 9.0 t/ha) may be said to be low compared with the 20 - 30 t/ha reported under ideal condition elsewhere (Purseglove, 1972). Moreover, the soil of the experimental location was loamy, characterised by a low PH 3.9 value, low nitrogen and low organic carbon content. These, coupled with the high day temperatures recorded during the period, inadequate precipitation and mulching; lack of organic matter application coupled with incidences of termite attack, fungal and disease infestation of setts, probably contributed in adversely affecting the overall field performance of the crop. As such, the yield levels recorded in this experiment are representive of the northern guinea savanna agro ecological conditions of Nigeria.

5.2 Plant density

Ginger rhizome yield responded positively and significantly to increasing population levels. The medium population (333,333 plants/ha) outyielded the 166,666 plants/ha by about 49% while yield at 500,000 plants/ha was 63% higher than that at 166,666 plants/ha. Thus it appears that ginger yield can be further increased by increasing plant population beyond the 500,000 plants/ha tried in this study; provided other conditions especially moisture, soil and management practices are conducive.

The favourable response of ginger to high density was manifested in a number of yield contributing characters namely, the number of offshoots, number of leaves, stem dry weight, rhizome dry weight, leaf dry weight, leaf area and leaf area index. Of most significance however, was the observed increase in the number of shoots with increasing plant density. The importance of the number of offshoots as a major contributor to the photosynthetic activity of crop plants had been emphasized (Tetio-Kagho and Gardner, 1988). In the present study, the number of shoots was positively and significantly correlated with the number of leaves (r = 0.762**), stem dry weight (r = 0.639**), rhizome dry weight(r = 0.667**), and leaf area index (r = 0.495**). The production of more shoots under such high population pressure could probably be associated with genetic or physiological factors. Further research works should therefore take into account the effects of these factors on the response of ginger to plant density.

The leaf area index (LAI) increased linearly and significatly from a low value of 1.4 at plant populations of 166,666 plants/ha to a maximum of 2.6 with 500,000 plants/ha. It is noteworthy that LAI was positively and significantly correlated with rhizome yield (r =0.475*). It has been established that for most crops, the optimum LAI for maximum yield is in the range 3.0 - 5.0 (Brougham, 1960; Buttery, 1969; Eddowes,,1969; Enyil, 1973; Wall and Kanemasu, 1990). When the values of LAI are below the optimum for full utilization of incoming light energy, maximum growth cannot be achieved (Mandel and Sahu, 1997; Harshem and Gill, 1987). In this regard, for most crops total dry matter production and yield per unit area has been found to be related to plant density (Williams and Joseph, 1976; Katung, 1987; Chiezey, 1989; Lamido, 1990). Similarly, yield in ginger has been reported to have been increased with increasing plant density (Whiley, 1981; Menta, 1987; Orkwor et al, 1988).

Linear increases in yields with increasing plant population were reported for ginger (Quinn, 1973) and soyabean (Woods, 1974). Woods (1974) observed that even if there was shading of leaves at high densities, dry matter production was not adversely affected. This means that the lower leaves were not parasitic on the plants and therefore high population presssures might be required to achieve optimum yields (Shibles and Weber, 1965).

5.3 Inter-row spacing

Rhizome yield per hectare at 30cm was higher than the yields at 10 and 20cm row spacings by 47% and 39% respectively. The higher yield recorded at 30cm could by attributed to the relatively high LAI recorded at 30cm row spacing throughout the period. The significant contribution of the leaf area index - LAI (r =0.475*) as supported by the index of correlation ensured adequate coverage of the soil surface resulting in efficient interception of the incoming sunlight for dry matter production. It is significant that during the period, values of leaf area index-LAI (above 1) were attained earlier at 30cm row spacing compared with the other row spacings (10 and 20cm). It is known that the low efficiency of the overall utilization of incoming solar radiation by crop plants resulted in part from the long period between planting and the attainment of optimum LAI; and thus much of the light fall on bare soil surface. Therefore when values of LAI are below the optimum for full utilization of incoming light energy, maximum growth cannot be achieved. Thus factors such as plant spacing by influencing the LAI affect considerably, the course of dry matter production and yield.

The observed response of ginger to row spacing could be attributed to its morpholoy; and of probable importance is its canopy architecture, leaf shape and size. The ginger plant is characterised by narrow, smooth, pinnate and alternately arranged leaves on both sides of the stem. The leaves are displayed at near horizontal levels (Rodriguez, 1971; Purseglove, 1972; Anon., 1987). Thus the most suitable arrangement favouring a larger display of the photosynthetic surfaces to incoming radiation will enhance higher photosynthetic productivity. Since mature ginger leaves measure about 15 - 35 cm or more in length, (Rodriguez,1971), wider plant spacings could favour better display of leaves to incoming solar radiation and therefore enhance crop productivity.

Most of the reported work on ginger maintained constant inter-row spacing while varying the intra row spacings only (Quinn, 1973; Whiley,1981; Menta, 1987; Orkwor et al, 1988). However, from the results of the present study, it seems that the inter-row spacing is an important determinant of ginger yield. Further work is therefore needed on ascertaining the response of ginger to increasing inter-row spacings and the optimum row spacing under the condition of the northern guinea savanna ecological zone.

5.4 Rhizome sett size

Only a small and insignifcant increase in rhizome yield (final) was recorded using the largest sett weight (22.5gm).

It is significant to note that though the exact growth pattern of the crop at the earlier stages of growth cannot be ascertained since plant sampling began at 10 WAP; generally the growth of the plant produced from the largest setts was more vigorous than those from the smaller setts; especially at the period preceeding harvest as shown by the increased plant height.

In bulbs, root and tuber crops, the advantage of using larger setts size for better plant growth and yield have been established (Nelson, 1970; Izzitani et al, 1972; Onwueme, 1978; Bleasdale, 1979; El-Emery, 1985; Musa, 1990). However, ginger is a long duration, small rhizome crop. Planting setts of ginger are obtained from "mother" sett cuttings only. Work on the effect of planting cuttings from whole "mother" bulbs of onions has shown that generally, this could be detrimental to bulb yield (Adjei - Twum, 1980). This may in part explain why rhizome sett size had no effect on rhizome yield in the present study. Thus future research efforts should look into the effect of planting whole rhizome setts and cuttings.

On the whole, the yield advantage of using larger rhizome sett weights of ginger did not justify the expenses incurred in planting large setts. This is similar with the findings of Whiley (1981) in Queensland, Australia and Orkwor et al (1988) in the sourthern guinea savanna and rainforest zones of Nigeria. Thus, the sett size of ginger may not be a major determinant of final yield.

5.5 Interactions

The row spacing X plant density interaction on final yield showed that at 10cm row spacing, the highest yield was obtained at a low population of 166,666 plants/ha; whereas, at 30cm row spacing the maximum yield was recorded using a high population of 500,000 plants/ha (i.e 6.7 x 30 cm). It is worthy to note that the yield at 30cm row spacing and 500,000 plants/ha was significantly higher than that recorded at 10cm row spacing and 166,666 plants/ha. This is indicative of the fact that the yield of ginger (a crop characterised by short vertical growths and horizontal spreads) could be increased by increasing the number of plants per unit area. This could be achieved by further decreasing the intra row spacings while maintaining an appropriate inter row spacing (30cm) as shown in the study. Moreover, the yield of ginger was significantly higher at 500,000 plants/ha using the smallest rhizome sett weights (7.5gm) as shown by the density X sett size interaction. This supports the suggestion that yield could be significantly increased by planting at 500,000 plants/ha and at 30cm row spacings. In order to attain this high density, there must be availability of space for setts. This is made possible by using small rhizome setts (7.5gm).

The interaction between row spacing and sett size on the ash content of ginger showed that at 10cm row spacing, ash content decreased with decreasing sett size, while at 30cm, ash content decreased with increasing sett weight. It is important to note that at 10cm, the ash content obtained with the largest sett (22.5gm) was significantly higher than the ash content at 30cm with the smallest sett (7.5gm); which was within the range acceptable by international quality standards (Rodriguez, 1971). This again supports the fact that both yield as well as a good quality crop of ginger could be obtained by planting at wider row spacings (30cm) and using the smallest (7.5gm) rhizome sett weights.

5.6 Ginger quality

Planting ginger at the medium plant population (333,333 plants/ha) increased the oil content while an increase in population to 500,000 plants/ha reduced the total ash content. This shows that planting ginger at plant populations of 333,333 to 500,000 plants/ha improved quality. Moreover, at 30cm row spacing, lower ash content and high oil contents were obtained; while the smallest rhizome setts similarly recorded low ash values and high oil contents. This shows that planting ginger at high populations of 333,333 to 500,000 plants/ha and at the widest row spacing of 30cm, using the smallest rhizome sett weight (7.5gm) improved both yield and quality. Joachim and Pieris (1934) had earlier observed and reported that if ginger curring is the objective of production, then planting **Small** setts would be better than planting large setts.

In general, ginger variety "Tafin Giwa" characterised in the present study by its oil and ash contents, met the international standards of quality. The results further agree with Faulkner and Mackies (1933) that the quality of the Nigerian ginger compares favourably well with those of other countries in the world market or in international trade. However, more work on this and other aspects of the quality characteristics of the Nigerian ginger are still needed.

5.7 Correlation

Rhizome yield was positively correlated with all yield contributing components considered in this study. Though the correlations were not significant except for LAI, they nonetheless are indicative of the fact that the rapid establishment and growth of the crop soon after germination is important to dry matter production. Watson (1971) had pointed out in this regard that although economic yield is correlated with total dry matter yield, it does not neccessarily continue to increase proportionately with increase in total dry wieght. What happens could depend on the source - sink relationships.

Leaf area index (LAI) was positively and significantly correlated with rhizome yield (r = 0.475*). A such LAI could be said to have been the major critical determinant of the rate of dry matter production and final yield.

Essentially, the various growth processes that proceed simultaneously in the crop plant, as observed in the present study, are not independent of one another, but are closely linked or inter related with one another (Wareing and Phillips, 1977).

Chapter 6

SUMMARY AND CONCLUSIONS

Ginger variety "Tafin Giwa" was planted at three plant populations (166,666; 333,333; and 500,000 plants/ha); three inter - row spacings (10, 20 and 30cm); and three sett piece weights (7.5, 15.0 and 22.5gm). The design was a split plot with density and row spacing in the main plot while sett size was the sub plot treatment.

All aspects of crop growth and development considered in this study were significantly influenced by increasing plant density. Yield increased linearly with increasing density up to the highest (500,000 plants/ha) tested in this experiment.

Row spacing significantly influenced the number of offshoots and number of leaves at 14 WAP and rhizome dry weight at 12 WAP. Better crop growth was observed at 20cm compared with thr 10 and 30cm row spacing. However, rhizome dry weight was not consistently affected by row spacing. Leaf area index (LAI) and rhizome yield (8.8t/ha) were significantly higher at the widest row spacing (30cm) compared with that at 10 and 20cm. The interaction between row spacing and plant density showed that significantly higher yields were obtained at a row spacing of 30cm and at 500,000 plants/ha (i.e 6.7 x 30cm) compared with that at 10cm and 500,000 plants/ha.

Though, the effect of sett size was inconsistent, better crop growth and yield were obtained with the largest rhizome setts (22.5gm). However, the differences in final yield were small and insignificant. The sett size X density interaction showed that yield could be significantly increased by using the smallest setts (7.5gm) at the highest population (500,000 plants/ha). Therefore based on the findings of the present study, it is better to use smaller planting setts at high plant densities to enhance yield.

The results also suggests that a good yield and quality crop of ginger (variety "Tafin Giwa") could be obtained using small setts (7.5gm) and high populations (333,333 to 500,000 plants/ha) under the conditions of the northern guinea savanna agro-ecological zone of Nigeria.

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Appendix I. Total monthly rainfall, mean temperature, relative humidity and sunshine hours during 1997.

Month	Total rainfall (mm)	Mean temperature (°C) max.	min.	Relative humidity (%) a.m	p.m	Sunshine (hours)
Jan.	0.0	24.5	12.8	25.6	17.7	10.1
Feb.	0.0	27.7	14.2	17.5	14.9	6.2
Mar.	0.0	33.9	17.2	15.0	12.4	8.7
Apr.	15.0	35.9	19.9	37.0	20.0	9.2
May	112.0	33.1	43.8	61.7	43.8	7.7
June	124.4	30.4	20.0	73.1	58.0	7.5
July	159.7	29.4	19.7	8.8	63.0	6.9
Aug.	169.5	28.0	19.3	81.7	71.1	5.8
Sept	118.3	29.8	19.2	78.4	66.9	6.4
Oct.	52.9	30.6	16.6	52.9	43.0	8.4
Nov.	0.0	31.1	12.8	19.3	18.5	9.3
Dec.	0.0	28.6	12.9	19.3	17.4	8.0

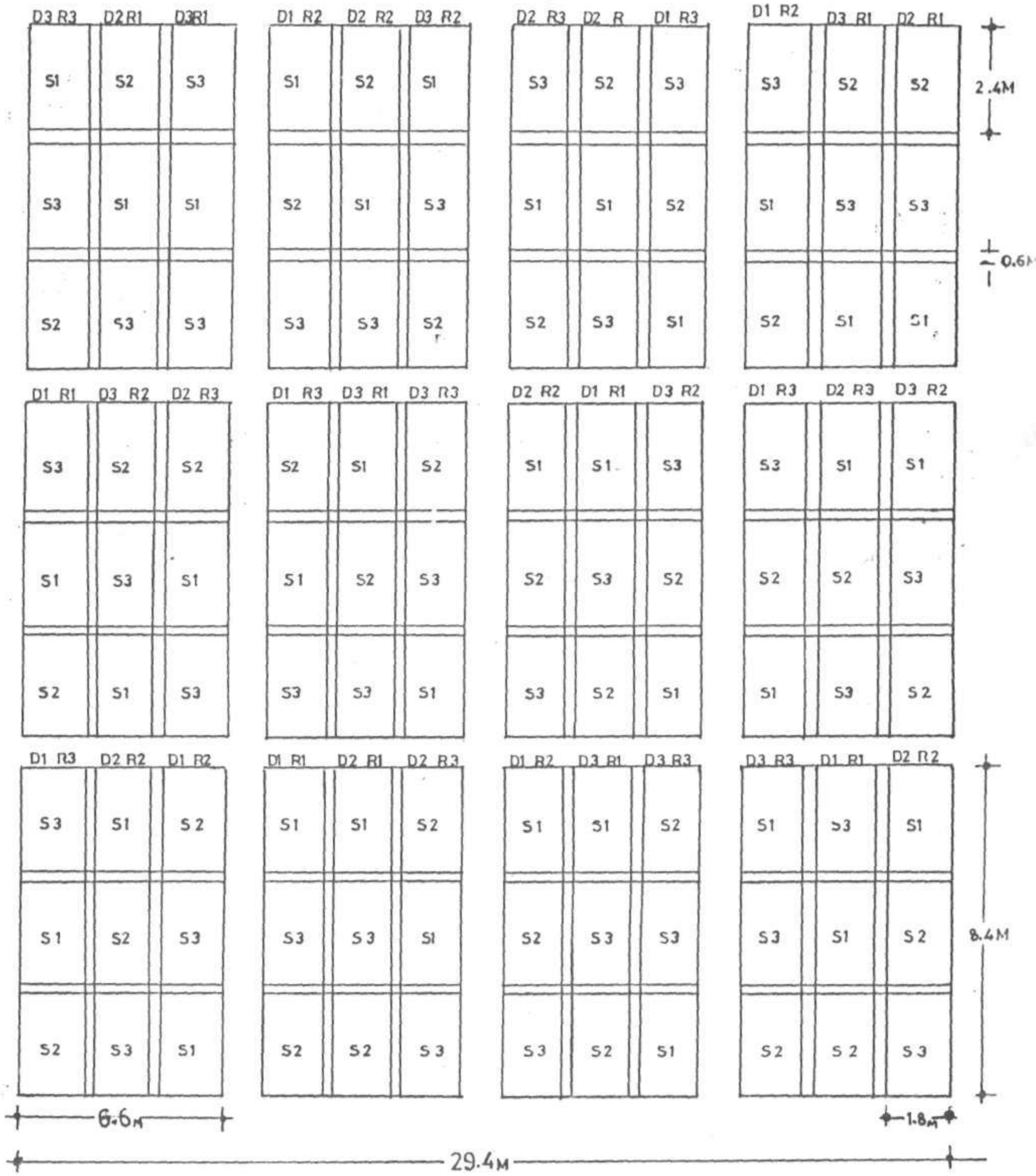
Source: Meteorological Unit,
Institute for Agricultural Research,
Samaru, Zaria - Nigeria.

Appendix 2. Physico-chemical properties of the soil of the experimental site in. 1989.

Soil property	Soil depth)cm) 0 - 15	15 - 30
PH 1:25		
- Water	4.50	4.40
- 0.01m $cacl_2$	3.90	3.90
Organic carbon(%)	0.60	0.38
C.E.C. (Meg/100g soil)	3.80	4.60
Available phosphorous (PPm)	35.84	12.00
Total Nitrogen (%)	0.06	0.04
Exchangeable bases (Neg/100g soil)		
Ca	1.09	1.32
Mg	0.40	0.43
K	0.33	0.19
Na	0.11	0.12
H + Al	0.10	0.30
Physical classsification		
Clay (%)	16	22
Silt (%)	42	38
Sand (%)	42	40
Textural class	Loamy	Laomy.

Appendix 3 SPLIT PLOT DESIGN

FIELD LAYOUT.



KEY

D = DENSITY

R = RAW SPACING

S = SEED SETT SIZE

AREA OF ONE PLOT = 2.4x1.8 = 4.32M^2

AREA OF ONE BLOCK = 8.4x6.6 = 55.44M^2

TOTAL AREA OF PLOT = 27.2 x 29.4 = 799.68 ≃ 0.079968ha

D1 = 166.666	R1 = 10	S1 = 7.5
D2 = 333.333	R2 = 20	S2 = 15.0
D3 = 500 000	R3 = 30	S3 = 22.5

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-College of Advance Studies, Zaria - Nigeria.	1982/83	1984	I.J.M.B"A" Level.
-Ahmadu Bello University.	1984/85	1987	B.Sc.(Botany) Second Class Lower Degr.

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Organisation	From	To	Position
-Command Day Sec.Sch., Ikpoba Hill, Benin, Bendel State,Nigeria (N.Y.S.C).	1978	1988	Maths.Teacher/ Games-Master.
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