Growth and yield components of sesame (*Sesamum indicum* L. landrace Matsai) in response t plant population and nitrogen rate, at Gwebi, Zimbabwe.

BY

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A dissertation submitted to the University of Zambia in partial fulfilment of the requirements f the degree of Master of Science in Agronomy.

CROP SCIENCE DEPARTMENT
THE UNIVERSITY OF ZAMBIA
LUSAKA

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DECLARATION

I, Ishmael Mashange Mujaya, hereby declare that this dissertation represents my own work and that it has never been submitted for a degree at this or any other university.

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APPROVAL

This dissertation of **Ishmael Mashange Mujaya** is approved as fulfilling part of the requirements for the award of the degree of Master of Science in Agronomy by the University of Zambia.

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ABSTRACT

The seed yield of sesame in Zimbabwe is low compared to other countries, yet the crop is gaining in economic significance. A trial was therefore conducted at Gwebi, Zimbabwe, to evaluate the effects of plant population and fertilizer nitrogen rate on the yield and yield components of sesame (*Sesamum indicum* L.) landrace Matsai. Plant population, intended were 100 000, 200 000, 300 000, and 400 000 plants ha^{-1}. Nitrogen was assessed at four levels of 0, 30, 60 and 90 kg N ha^{-1}. The experiment was arranged in a split plot design, with population as the main-plot factor and nitrogen rate as the sub-plot factor. The treatment combinations were replicated three times. Parameters derived or measured were plant nitrogen concentration, plant height, branch number/plant, capsule number/plant, seed number/capsule, seed weight/capsule, seed yield, and oil content.

Due to poor emergence and disease attack the actual plant populations achieved were 78 000, 105 000, 185 000 and 224 000 plants ha^{-1} instead of 100 000, 200 000, 300 000 and 400 000 plants ha^{-1} respectively. Neither plant population nor nitrogen level had any statistically significant effect on leaf nitrogen concentration, plant height, seed number/capsule, seed weight/capsule, seed yield, or oil content. Although analysis of variance showed that seed yield response to these factors was not significant, trend analysis showed that the linear effects of both factors were significant ($P \leq 0.05$). Seed yield was positively and significantly correlated with plant height ($r = 0.77^{**}$, $n = 48$) and plant population ($r = 0.70^{**}$, $n = 48$).

Nitrogen applications above 30 kg ha^{-1} significantly increased ($P \leq 0.05$) stem nitrogen concentration over the control only. Increasing population decreased combined leaf and stem nitrogen concentration from 0.151 g N/plant at 78 000 plants ha^{-1} to 0.124 g N/plant at 224 000 plants ha^{-1} but the decrease was not statistically significant. Combined stem and leaf nitrogen concentration significantly increased ($P \leq 0.05$) with increase in nitrogen rate from 0.110 g N/plant at 0 kg N ha^{-1} to 0.165 g N/plant at 60 kg N ha^{-1}.

Branch number/plant (BNP) significantly decreased ($P \leq 0.001$) from 15.36 at 78 000 plants ha^{-1} to 8.95 at 185 000 plants ha^{-1}. Branch number per plant at 185 000 plants ha^{-1} was not statistically different from the 7.87 recorded at 224 000 plants ha^{-1}. Increasing population from 78 000 to 105 000 plants ha^{-1} did not produce significant differences in BNP at 0, 30 and 60 kg N ha^{-1}, but had a significant interactive effect ($P \leq 0.05$) at 90 kg N ha^{-1}, whereby BNP decreased from 16.5 at 78 000 plants ha^{-1} to 10.2 at 105 000 plants ha^{-1}. Nitrogen level alone had no significant effect on BNP.

Capsule number/plant (CNP) significantly decreased ($P \leq 0.001$) with increase in population from 199.6 at 78 000 plants ha^{-1} to 103.1 at 224 000 plants ha^{-1}. The effect of nitrogen rate on CNP

was not significant. Capsule number per plant was positively and significantly correlated with BNP ($r = 0.92^{**}$, $n = 48$) but negatively and significantly correlated with population ($r = -0.74$, $n = 48$). The data obtained showed that on this site nitrogen applications up to 90 kg ha^{-1} and increasing plant population between 78 000 and 224 000 plants ha^{-1} had no influence on sesame yields.

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DEDICATION

To my daughters Linda and Caroline, and my mother, Jesina. I love you all.

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CHAPTER 1

INTRODUCTION

Sesame (*Sesamum indicum* L.), locally known as "runinga" in Shona, belongs to the family Pedaliaceae. Except for *Sesamum prostratum* (Retz) which is found in eastern India, all the other 19 wild species of sesame are found in Africa (Purseglove, 1977; Onwueme and Sinha, 1991). It is for this reason that Africa, probably Ethiopia, is considered to be the centre of origin of this plant (Onwueme and Sinha, 1991). Sesame is grown for its seed which is small, ovate in shape and can be white, yellow, grey, red, brown or black in colour (Purseglove, 1977; Jaiswal, 1980). The whole seed contains 45 to 55 percent edible, semi-drying oil, 19 to 25 percent protein, 11 percent carbohydrates and 3 percent minerals, notably calcium, phosphorus and iron (Purseglove, 1977; Onwueme and Sinha, 1991).The oil is of high quality, odourless and is not liable to become rancid. It is used as a salad dressing, and for cooking as well as in the manufacture of margarine. Poorer grades of the oil are used in the manufacture of paint and soap (Jaiswal, 1980 ; Purseglove, 1977; Onwueme and Sinha, 1991). The cake left - over after oil is expressed is an excellent high-protein (43 percent) feed for poultry, ruminants and pigs (Onwueme and Sinha, 1991).

The main commercial use of sesame in Zimbabwe is as garnish for bread, cakes and pastry. Current demand exceeds supply and the shortfall is met by imports from China

(C. Montgomery[1] and I. Prior[2] , personal communication). Available information shows that sesame has a good market value. The wholesale and retail prices in mid-1996 were Z$6.00/kg (US$0.61) and Z$10.00 (US$1.02) respectively (I. Prior, personal communication). Therefore sesame has potential for development as a cash crop since a good market already exists locally, with potential for export.

Sesame is grown to a small extent in the smallholder areas (mostly communal) of Zimbabwe in mixed - cropping with finger millet (*Eleusine coracana* L.). Average seed yields for Zimbabwe are not well established, but a yield range of 224 to 673 kg ha^{-1} has been reported by Mupawose (1971). Commercial seed yields of 2,240 kg ha^{-1} and more have been reported in the United States of America and Venezuela (Purseglove, 1977). There are no commercial varieties of sesame in Zimbabwe, and current production is based on local landraces. The yield potential, response to fertilizer and planting population of these landraces are not established. Currently, sesame is grown at very low populations as a mixed crop with finger millet. Matsai is a popular local landrace grown by smallholder farmers. Low yields obtained by farmers could in part be as a result of the low plant populations and the lack of any fertilizer input into the crop by smallholder farmers.

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[1]Managing director, Polyhandy (Pvt) Ltd, Harare, Zimbabwe.

[2]Managing director, Croplink (Pvt) Ltd, Harare, Zimbabwe.

Efforts to increase seed yields and national production are hampered by lack of research. There is therefore a need for local adaptive research to develop agronomic packages in order to increase production levels. Weiss (1983) observed that sesame responded well to the application of fertilizer, especially on poor soils. Most soils in the communal areas of Zimbabwe are granite-derived sands of low inherent fertility (Mashiringwani, 1983) and have been extensively cropped for many years with little or no addition of fertilizer. Hence they are largely deficient in nitrogen, phosphorus and sulphur (Mashiringwani, 1983). The low inherent fertility of communal area soils combined with the low or non-application of fertilizers probably contribute to the low yields reported. A knowledge of sesame response to nitrogen would enable communal farmers to use correct nitrogen rates necessary to achieve optimum yields.

The promotion of sesame production will lead to a diversification of the crops available to the Zimbabwean farmer, especially in the low rainfall, smallholder or communal areas. This is because the crop is drought tolerant and has been reported to produce good yields with 500 - 650 mm of rainfall per growing season in the Sudan (Weiss, 1983). This is particularly important when one considers that 91 percent of communal farming areas lie in agro-ecological regions III, IV and V (Natural Resources Board, Zimbabwe, 1987) which are marginal rainfall areas (Appendix 1). Emphasis in these regions should be placed on growing short season and drought tolerant crops (Vincent and Thomas, 1960).

The inclusion of sesame in a rotation offers another advantage because it improves soil structure.

This is due to the loosening effect of its dense root system on the soil (Purseglove, 1977; Onwueme and Sinha, 1991). This quality is particularly important in communal areas where the soils have a low organic matter content and are of poor structure. The removal of crop residues from lands to feed livestock in the dry season which reduces soil organic matter, and the non-application of lime on acid soils to correct acidity contribute to the deterioration of soil structure.

Sesame has a high nutritional value, having 19 to 25 percent protein, 1500 mg calcium, and 10 mg iron per 100 g edible portion (Harper *et al.*, 1984). It can therefore be used to improve the nutritional status of rural communities since the use of sesame butter as a substitute for peanut butter is already an established practice. With suitable intermediate technologies for oil expression, sesame can be used to produce cooking oil by rural communities and thus further helping to improve their nutritional status.

This study was conducted to evaluate the combined effects of plant population and nitrogen rates on the growth and yield components of sesame landrace Matsai in the Gwebi area.

CHAPTER 2

LITERATURE REVIEW

2.1 Botanical description

Sesame is an erect annual plant with square stems and the plant can reach a height of one to two metres . It has a strong tap root which grows to a depth of about 90 cm.. The lateral root system is dense, highly branching and spreads in the surface soil (Purseglove 1977; Onwueme and Sinha, 1991). Leaves are hairy and have ciliated margins. The lower leaves are opposite, while the upper leaves are alternately arranged. The petioles of the upper leaves are shorter than those of the lower leaves (Purseglove, 1977).

The flowers of sesame are borne either single or in two's or three's on short peduncles. The flowers are pubescent and may be white, pink or purplish with yellow, red or purplish blotches (Purseglove, 1977). Flowers are self pollinated, although five percent outcrossing has been reported (Purseglove, 1977). The fruit is a rectangular, deeply grooved capsule, up to 3 cm long with a short beak (Onwueme and Sinha, 1991). The capsule dehisces by two apical pores through which seed may be lost before or during harvest (Onwueme and Sinha, 1991).

2.2 Climatic requirements of sesame

Sesame is adapted to the hot tropical and subtropical regions. It is commonly distributed between latitudes 25° S and 25° N. However, it can be found growing as far as latitude 40° N in China, Russia and the United States of America, latitude 30° S in Australia and latitude 35° S in South America (Weiss, 1983). Sesame is grown from sea level up to altitudes of 1,500m above sea level (Onwueme and Sinha, 1991).

Germination, growth and fruiting of sesame are favoured by mean temperatures of around 27° C while temperatures below 20° C retard germination and growth. Very hot weather with temperatures greater than 41° C result in poor capsule set (Purseglove, 1977; Weiss, 1983).Sesame is sensitive to moisture deficiency during seedling establishment.If there is a drought occurrence at this stage it could result in a disastrous loss of crop stand (Mupawose, 1971). On the other hand, waterlogging during seedling establishment can lead to a serious loss of crop stand (Mupawose, 1971). Once established, sesame can tolerate short periods of drought and will do well with low rainfall (Onwueme and Sinha, 1991; Purseglove, 1977). Extended periods of rainfall and high humidity at later stages of crop growth will cause leaf spots (Onwueme and Sinha, 1991; Purseglove, 1977). However, good crops have been reported in areas of up to 1,000 mm of rainfall per growing season (Onwueme and Sinha, 1991; Weiss, 1983). In Ecuador and Venezuela, 800 mm rainfall per growing season is considered to be the upper limit for sesame production, as fungal diseases then become severe above that range (Weiss, 1983).

2.3 Cropping systems

Sesame is rarely grown as a sole crop in tropical Africa. It is usually intercropped with sorghum, millet, or maize (Onwueme and Sinha, 1991). In Zimbabwe it is intercropped with millets (Mupawose, 1971). Reports by Mupawose (1971), Purseglove (1977), and Torres-Osejo and Velasquez-Silva (1990) indicate that sesame yields and economic returns can be significantly increased when it is grown as a sole crop. Sesame is adapted to a wide range of soils, but it does better on deep, well drained, fertile sandy loam soils of neutral soil reaction (Onwueme and Sinha, 1991). These should be well ploughed and brought to a fine tilth (Mupawose, 1971).

2.4 Varietal characteristics of sesame

Sesame varieties are classified as either dehiscent (shattering) or indehiscent (non-shattering). The seed capsules of the shattering varieties open when they are mature and become dry. Those for non-shattering varieties remain closed, making them more suitable for combine harvesting (Martin and Leonard, 1964, as cited by Mupawose, 1971). Most local landraces are dehiscent.

Purseglove (1977) reported that the time between seedling emergence and crop maturity was between 80 and 180 days. This is influenced by variety and altitude. Most of the reported maturity periods are between 100 and 140 days after emergence. Mupawose (1971) working with three South African commercial varieties (Blanco, Margo and Renner 2) recorded a mean maturity period of 106 days from emergence, at an altitude of 1326 m in Zimbabwe. Based on this result he recommended that planting on the Zimbabwean highveld should be in the first week of December. Although there is no corresponding information on local landraces, a desirable period from crop emergence to maturity would be 96 to 150 days (Department of Agricultural Technical and Extension Services, 1987). This is in order for the crop to fit within the normal growing or rainy season in Zimbabwe.

2.5 Yields

Using the varieties Blanco, Renner 2 and Margo as sole crops Mupawose (1971) obtained mean sesame seed yields of 817, 943 and 1,020 kg ha^{-1} at Chibero College of Agriculture (Norton, Zimbabwe). The results are means for two seasons from early December plantings. The average world yield is 350 kg ha^{-1} (Onwueme and Sinha, 1991) but commercial yields of 2,240 kg ha^{-1} and greater have been reported in the United States of America and Venezuela, for sole crops (Purseglove, 1977).

2.6 Response of sesame to plant population

Weiss (1983) reported that there were no significant differences in number of branches per plant or plant height when the varieties Inamar and Morada were grown at nine plant populations from 36,630 to 200,000 plants ha^{-1}. Singh *et al.*(1990) working with four varieties found that the number of capsules per plant, number of seeds per capsule, and, seed weight per capsule significantly decreased when plant population was increased from 330,000 to 500,000 plants ha^{-1}.

Literature from various sources show varying response to population, indicating the possibility of varietal, site, moisture and residual fertility effects on seed yield.

Beltrao *et al.*(1989) reported that differences in seed yield due to spacing were not statistically significant at plant populations of 20,000 to 100,000 plants ha^{-1}. However, Torres-Osejo and Velasquez-Silva (1990) working with the variety China Roja in Nicaragua obtained seed yields of 1,900 and 3,129 kg ha^{-1} at populations of 50,000 (100cm x 20cm) and 100,000 (50cm x 20cm) plants ha^{-1}, respectively. The difference between the findings of Beltrao *et al.* (1989) and Torres-Osejo and Velasquez-Silva (1990) indicate the possibility of varietal or residual fertility effects on seed yield. Patel *et al.*(1990) working at three spacings obtained the highest yields of 887 and 754 kg ha^{-1} from the varieties G.Til-1 and Murug, respectively, at 222,222 plants ha^{-1} (30cm x 15cm). Crops grown at 148,148 (45cm x 15cm) and 111,111 (60cm x 15cm) plants ha^{-1} gave yields which were significantly lower. The observation by Patel *et al.*(1990) is similar to that by Arunachalam (1990) who also noted over three seasons in Coimbatore (India) that the highest seed yields were obtained with 200,000 plants ha^{-1} when sesame was grown at populations of 200,000 to 400,000 plants ha^{-1}.

Singh *et al.*(1988) reported that a density of 330,000 plants ha^{-1} was necessary to achieve good yields. They noted a 34 percent yield increase with 330,000 plants ha^{-1} over 220,000 plants ha^{-1} in branched varieties and 37 percent increase in single stemmed (non-branching) varieties. This indicated that yield increased when plant population was increased from 220,000 to 330,000 plants ha^{-1} irrespective of whether the variety was branching or single stemmed. In addition, work on branched varieties by Narayanan and Narayanan (1987) indicated that variety had an important influence on the optimum plant population required to attain the highest yields. They reported that varieties Gowri and Madhavi required 330,000 plants ha^{-1} to produce the highest seed yields while varieties NP-6, TMV-3 and T-12 required 660,000 plants ha^{-1} .

Kamel *et al.*(1984) working with a branched variety in Egypt at plant populations ranging from 41,000 to 485,000 plants ha^{-1} found that seed oil content (%) was highest with the highest population, but no reason was given for this observation. Weiss (1983) reported that when the branched varieties Inamar and Morada were grown at nine densities from 36,630 to 200,000 plants ha^{-1} there were no significant variations in seed oil content. The differences observed in response between the study by Kamel *et al.* (1984) and Weiss (1983) could be attributed to varietal influence on seed oil content.

2.7 Response of sesame to nitrogen

Subramanian *et al.*(1979) reported that with variety TMV-3, branch and capsule number per plant, and seed number per capsule increased with nitrogen applications up to 30 kg ha^{-1} when rates of 0 to 45 kg ha^{-1} were applied. Majumdar *et al.*(1990) also reported increases in plant height, number of capsules per plant and seed number per capsule with nitrogen applications of up to 60 kg ha^{-1}.

It can be assumed that the differences between the results of Subramanian *et al.* (1979) and Majumdar *et al.* (1990) were due to variations in the inherent soil nitrogen status at the test sites. The same upward trend was observed by Maiti *et al.*(1981) who reported increased seed yields due to increased number of capsules per plant and number of seeds per capsule when nitrogen was increased from 0 to 120 kg ha^{-1}.

Weiss (1983) noted that sesame responded well to the application of fertilizer, especially nitrogen, on low fertility soils. Kadam (1990) observed an increase in seed yield with an increase in nitrogen rates from 0 to 50 kg ha^{-1}. This was similar to observations by Daulay and Singh (1983) who reported an increase in yield with nitrogen application rates of 0 to 60 kg N ha^{-1}. Pineda and Velasquez-Silva (1990) working with the variety China Roja in Nicaragua found that at Polstega an increase in nitrogen from 32 to 65 kg ha^{-1} increased seed yields from 1,700 to 2,460 kg ha^{-1} in the absence of phosphate, again confirming the reports by Kadam (1990) and, Daulay and Singh (1983).

Deshmukh *et al.*(1991) reported a 58.3% seed yield increase from 547 to 866 kg ha^{-1} with increasing nitrogen rates from 0 to 120 kg ha^{-1}. The results are in agreement with observations reported by Maiti *et al.*(1981) and Puste and Maiti (1990) who obtained similar results over the same range of nitrogen application. However, Mehrotra *et al.*(1978) reported that seed yields were increased from 400 to 760 kg ha^{-1} with increases in rates of applied nitrogen from 0 to 30 kg ha^{-1} and that further increase in yield at 45 kg N ha^{-1} was not significant.

This finding is in agreement with Daulay and Singh (1982) who reported the most economic rate as 30 kg N ha^{-1}. The observations by Mehrotra *et al.*(1978) is in partial agreement with Singh *et al.*(1988) who, using the variety C-6, only noted a seed yield increase of 730 to 980 kg ha^{-1} with nitrogen rates of up to 40 kg ha^{-1} . Singh *et al.* (1988) also reported that further increases in nitrogen rates of up to 120 kg ha^{-1} had no effect on yield. The different responses to nitrogen cited above could be attributed to varietal responses to nitrogen, or differences in residual soil nitrogen levels at the test sites.

When Kadam (1990) applied 0 to 40 kg N ha^{-1} to two sesame varieties, he observed a decrease in seed oil content with increasing nitrogen supply. However, Singh *et al.*(1988) using variety C-6 noted an increase in seed oil content from 48.1 to 56.3 percent with increases in applied nitrogen up to 40 kg ha^{-1} . Further increases in nitrogen rate up to 120 kg N ha^{-1} had no effect on seed oil content. The contrasting responses may be due to differences in how varieties respond to nitrogen applications.

CHAPTER 3

MATERIALS AND METHODS

3.1 Site and site preparation

The experiment was conducted at Gwebi Variety Testing Centre in block MD 2 during the 1995/96 rainy season. The centre is located on latitude 17^0 41'S and longitude 30^0 52'E. It is 1448 m above sea level (Whingwiri *et al*., 1987). Gwebi is situated about 27km north-west of Harare along the Chirundu Road. It receives a mean annual rainfall of 805 mm which is representative of agroecological region IIa (Appendix 1), an intensive farming region.

The soil here is a moderately well drained, medium grained, fersiallitic sandy clay soil (Nyamapfene, 1991; Thompson and Purves, 1981). It is classified as a chromic luvisol (FAO) or rhodic paleustalf (USDA). The site which was under pearl millet (*Pennisetum typhoides*) during the season, prior to the trial was ploughed in mid-July, 1995. A single pass of the disc was made before taking soil samples.

A composite sample consisting of twelve sub-samples was taken soon after discing. The soil chemical characteristics are presented in Table 1. The soil pH ($CaCl_2$), at 5.7 was ideal for sesame growth without lime being applied according to the practice in the area.

Table 1. Soil analysis results for plot MD.2 at Gwebi Variety Testing Centre.

Parameter	Value	Rating	Remark
pH	5.7	slightly acid	highly satisfactory for most crops and no lime is required
Nitrogen (ppm)			
Initial	29	-	-
After incubation	31	medium	intensively managed cultivated lands
Organic matter (%)			
Available P_2O_5	10	deficient	yield increases by 1/3 to 2/3 with adequate dressings of P_2O_5 if other nutrients are not limiting
Exchangeable cations (m.e/100g soil)			
Potassium	0.17	marginal	some response lightly if other conditions are suitable
Calcium	6.24		
Magnesium	2.41		

Note:

1. pH determined in 0.01 M calcium chloride
2. Initial nitrogen = initial mineral nitrogen (NH_4^+ and NO_3^-)
3. After incubation nitrogen = mineral nitrogen after incubation (NH_4^+ and NO_3^-)
4. Available P_2O_5 = available phosphorus by resin extract method
5. ppm = parts per million
6. m.e/100g = milliequivalents per 100 grams soil
7. Ratings and remarks extracted from Oloya (1986) and "A guide to the meaning of soil analysis" No.36, Chemistry and Soil Research Institute, Department of Research and Specialist Services, Zimbabwe.

The soil was of medium fertility with respect to the test nutrient (31 ppm N = 62 kg N ha^{-1}), rich in calcium and magnesium, marginal for potassium and deficient in phosphorus.

The land was divided into three blocks, each 24 m long and 12 m wide ($288m^2$), with each serving as a replication. Each block was divided into main - plots, each 24m long and 3m wide ($72m^2$) which were further sub-divided into sub-plots 6m long and 3m wide ($18m^2$). Each sub- plot comprised 6 rows spaced 0.5 m apart. A border of 0.25 m was maintained at the edges of the plots to remove edge effects.

3.2 Experimental design

The experiment was arranged in a split plot design with three replications. Plant population was assigned to the main - plots and nitrogen rate to the sub - plots. Treatment combinations were randomly allocated to the plots.

3.3 Planting and plant populations

The study set out to evaluate plant population at four levels of 100,000 ; 200,000 ; 300,000 and 400,000 plants ha^{-1}. The same inter-row spacing of 50 cm was maintained, but the intra-row spacing was varied to achieve the desired populations. These were 20cm , 15cm , 6.7cm and 5 cm for 100,000 ; 200,000 ; 300,000 and 400,000 plants ha^{-1} respectively. The crop was thinned to the required intra-row spacings two weeks after emergence.

Sesame landrace Matsai, which is free-branching, dehiscent and of mixed seed colour was used for the experiment. Planting was done on 5th December, 1995. Seeds were planted by hand at a seeding rate of 4kg ha^{-1}. The seeds were mixed with dry river sand at the rate of one part seed : three parts sand by volume in order to achieve thin and even seed distribution. The seed/sand mixture was then applied continuously in planting furrows and covered with soil to a depth of about 2 cm.

3.4 Nitrogen levels

Nitrogen was applied at four rates of 0 , 30 , 60 and 90 kg N ha^{-1} as ammonium nitrate. There were a total of 16 treatment combinations comprising four plant populations and four nitrogen rates. Treatments which were to receive nitrogen were supplied with one-third of the rate as a basal application of ammonium nitrate. The balance of the nitrogen was applied as a side dressing 5-8 cm away from the plants six weeks after emergence.

3.5 Management of non-experimental variables

All treatments received a uniform basal fertilizer application of 27.5kg ha^{-1} of P applied as double super phosphate and 29.2kg ha^{-1} of K applied as muriate of potash. These fertilizers were applied in the planting furrows by hand and then covered with soil before planting to avoid fertilizer and seed contact. Plots were kept weed free as much as possible by use of a hand hoe. The first weeding coincided with the time of thinning. Supplementary irrigation was given during the short dry spells experienced to ensure adequate soil moisture availability throughout the growing season (Appendix 2).

Lamdacyhalothrin (karate), a synthetic pyrethroid, was used as a full cover spray for the control of cutworm *(Agrotis segetum* and *Agrotis ipsilon*) at 200 ml ha^{-1}, 25 days after emergence (Mc Clymont and Muchenje, 1990). The same treatment was used for the control of stichworms *(Marasmia trapezalis*) at 63 and 72 days after emergence.

Dimethoate 40ec at 400 ml ha^{-1} was used as a full cover spray for the control of aphids (*Aphis gossypii*) and whiteflies (*Bemisia tabaci*) at 32, 43 and 63 days after emergence.

3.6 Harvesting

Harvesting was done 140 days after emergence at the first sign of opening of the bottom capsules, which was when leaves started to drop off and capsules had turned yellow (Plate I). Harvesting consisted of cutting the plants at ground level. The cut plants were tied into bundles and stacked in the field for two weeks to dry and have the capsules open (Plates II, III and IV). Seeds were collected by turning each bundle upside down over a polythene sheet on a calm day to avoid wind blowing away the seed. The bundle was beaten with a stick , with the seed falling on the polythene sheet (Plate V). The bundles were restacked and the process repeated after one week to ensure that all the seed was recovered. The seeds were then cleaned using traditional winnowing trays. Seed weight was determined using an EP-12KA AND Electronic Balance (A and D Company, Tokyo).

3.7 Data collection

3.7.1 Rainfall and irrigation

Rainfall and irrigation data for the 1995/96 season were recorded and are shown in Appendix 2.

3.7.2 Nitrogen concentration and uptake at flowering

Ten whole plants from outside the harvest (net plot) area were randomly selected for plant analysis to determine nitrogen concentration (mg N g^{-1}) in stems and leaves. Samples were taken at 50 percent flowering which was 72 days after crop emergence. Nitrogen was determined by the Kjeldahl method (Bremner and Mulvaney, 1982).

3.7.3 Plant height

Four days before harvesting, 10 plants were randomly selected from the harvest area and their heights measured. Height was taken to be the distance from the soil surface to the tip of the growing point. The mean value was taken as the plant height for that plot.

3.7.4 Number of branches per plant

Data for this parameter were collected at the same time as that for plant height and on the same plants. Branch number was taken as the sum of any secondary branch from the main stem and the mean of the 10 plants was recorded as the branch number for that plot.

3.7.5 Number of capsules per plant

The number of capsules were counted on 10 plants randomly selected in the harvest area two days before harvesting. All the capsules on each plant, which included those from the main stem and from branches were counted and recorded. The mean of 10 plants was taken to be the number of capsules per plant.

3.7.6 Number of seeds per capsule

This was determined by counting the number of seeds in 10 capsules per plant. The capsules were harvested from different positions of five randomly selected plants from the net plot area giving a total of 50 capsules per plot. This operation was conducted two days before harvesting.

3.7.7 Seed weight per capsule

Two days before harvesting, 10 capsules per plant were harvested from five randomly selected plants in a plot to obtain the mean seed weight per capsule and this was expressed in grams/capsule. This was achieved by dividing the total weight of seed from 50 capsules by the number of capsules.

3.7.8 Seed yield per ha

Seed for each plot was harvested from a net plot area measuring 5 m long by 2 m wide (10 m^2). The seed weight per plot was thereafter converted to seed yield in kg ha^{-1} calculated at 10% moisture content.

3.7.9 Oil content (Ether extract)

Oil content was determined by solvent extraction according to the Official and Tentative Methods of the American Oil Chemists Society (1974) and measured on an atomic absorption spectrophotometer. The oil content was expressed as a percentage using the following equation:

$$Ether\ extract\,(\%) = \frac{Weight\ of\ oil}{Weight\ of\ seed\ sample}\ X\ 100$$

3.8 Data analysis

The statistical fixed linear model was:

$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + T_k + (\beta T)_{jk} + (\alpha\beta T)_{ijk.}$

for $i = 1, 2, 3, ... r$

$j = 1, 2, 3, 4, ... b$

$k = 1, 2, 3, 4, ...a$

where

Y_{ijk} = the observation of the k^{th} subplot treatment and the j^{th} main plot in the i^{th} block.

μ = overall mean.

α_i = effect of the i^{th} block.

β_j = fixed effect of the j^{th} treatment in the main plot.

$(\alpha\beta)_{ij}$ = main plot error.

T_k = fixed effect of the k^{th} subplot treatment.

$(\beta T)_{jk}$ = interaction between the k^{th} subplot treatment and the j^{th} main plot treatment.

$(\alpha BT)_{ijk}$= subplot error assumed to be ~N (0, σ^2).

Analyses of variance (ANOVA's) were performed to detect the effects of plant population and nitrogen rate on growth parameters, yield components and oil content by use of the MSTATC statistical computer programme. The Genstat 5 Release 2.2 statistical computer programme was used to analyse data for seed yield ha^{-1}. Using the Genstat programme, analyses of variance were performed to determine the effects of population and nitrogen rates on seed yield. Trend analysis was done to obtain linear and quadratic effects of population and nitrogen rate on seed yield. Regression analysis was also performed. Correlation analysis was performed using the Minitab statistical computer programme to determine the degree of association between parameters.

Plate 1: Sesame ready for harvesting. Note yellowing of the capsules.

Plate II: Cut sesame plants being put into heaps big enough to make a bundle.

Plate III: Tying Sesame into bundles using string

Plate IV: Staking sesame bundles for drying

Plate V: Collecting seed from dry sesame bundles

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Background aspects

Intended planting populations were not achieved (Table 2) due to poor emergence and disease (Plates VI - IX). In the latter case infected plants were rogued to prevent further spread of the diseases. The achieved planting populations have been used in the presentation of the results and subsequent discussion.

Table 2 Intended and achieved plant populations for sesame grown at Gwebi Variety Testing Centre.

Population (plants ha^{-1})		**Spacing (cm)**	
Intended	**Achieved**	**Inter-row**	**Intra-row (Intended)**
100 000	78 000	50	20
200 000	105 000	50	15
300 000	185 000	50	6.7
400 000	224 000	50	5

Plate VI: Fusarium wilt (*Fusarium oxysporium)* showing leaf yellowing and wilting: Note the brown stem discolouration indicated by arrow.

Plate VII: Fusarium wilt showing advanced wilting and drying of leaves.

Plate VIII: Leaf curl infected plant in the foreground indicated by arrow.

Plate IX: A normal, healthy growing crop of sesame.

4.2 Leaf nitrogen concentration

Neither plant population nor nitrogen application significantly affected the leaf nitrogen concentration at flowering. The leaf nitrogen concentrations were 35.57; 35.13; 35.65 and 35.33 mg N g^{-1} at 78 000; 105 000; 185 000 and 224 000 plants ha^{-1}, respectively. For nitrogen rate the concentrations were 32.88; 35.97; 37.82 and 35.02 mg N g^{-1} at 0; 30; 60 and 90 kg N ha^{-1} respectively. The mean leaf nitrogen concentration was 35.4 mg N g^{-1} (S.E ± 0.13). It would have been expected that leaf nitrogen concentration would decrease with an increase in plant population. This is because the combined sink capacity for nitrogen should be greater with increasing plant population. Assuming that nitrogen requirements increase with plant population, when the former is held constant, plants in higher population plots may assimilate lower amounts of nitrogen individually. Allison (1984), working with maize in Zimbabwe reported an increase in leaf nitrogen with a decrease in plant population, thus supporting the above assertion. The reason given for increased leaf nitrogen concentration with a decrease in plant population is that the same amount of nitrogen is shared between fewer individuals. It could be argued that the similarity in nitrogen concentration among the population treatments was due to a high residual soil nitrogen level at the population levels achieved in the experiment. No significant interaction between the factors was detected (Appendix 3).

4.3 Stem nitrogen concentration

Stem nitrogen concentration decreased from 21.35 mg N g^{-1} at 78 000 plants ha^{-1} to 20.55 mg N g^{-1} at 105 000 plants ha^{-1}, 20.12 mg N g^{-1} at 185 000 plants ha^{-1} and 19.50 mg N g^{-1} at 224 000 plants ha^{-1}, but the decreases were in all cases small and not statistically significant (Table 3). Nitrogen applications above 30 kg N ha^{-1} significantly increased ($P \leq 0.05$) stem nitrogen concentration over the control only (Table 3). There were no significant differences in this parameter among the applied rates of nitrogen. No significant interaction for stem nitrogen was observed between the factors (Appendix 4), suggesting that the two factors were affecting the stem nitrogen concentration independently of each other.

Table 3 The combined effects of plant population and nitrogen rate on stem nitrogen concentration at flowering

Population	**Nitrogen rate (kg ha^{-1})**				**Population**
(plants ha^{-1})	**0**	**30**	**60**	**90**	**Mean**
78 000	1.97	2.07	2.17	2.33	**2.14**
105 000	1.86	2.12	2.05	2.19	**2.06**
185 000	1.85	2.11	2.15	1.93	**2.01**
224 000	1.84	1.80	2.07	2.09	**1.95**
Nitrogen rate mean	**1.88**	**2.03**	**2.11**	**2.14**	

$LSD_{0.05}$ Population = 0.24

$LSD_{0.05}$ Nitrogen = 0.15

$LSD_{0.05}$ Population x nitrogen = 0.29

CV(population) = 8% **CV(nitrogen) = 9.8%**

4.4 Combined stem and leaf nitrogen content

4.4.1 Effect of population on combined stem and leaf nitrogen content

There was a general decrease in nitrogen content per plant with increase in population. The values obtained were 0.151 g N $plant^{-1}$ (78 000 plants ha^{-1}), 0.137 g N $plant^{-1}$ (105 000 plants ha^{-1}), 0.140 g N $plant^{-1}$ (185 000 plants ha^{-1}), and 0.124 g N $plant^{-1}$ (224 000 plants ha^{-1}). However, the differences in nitrogen yield per plant among population levels were not statistically significant (Appendix 5). The mean combined stem and leaf nitrogen concentration was 0.138 g N $plant^{-1}$ (S.E ± 0.011). There was no significant interaction detected between factors in the experiment (Appendix 5). The trend of decreasing nitrogen content with increasing population seems normal since the same amount of nitrogen is being shared by an increasing number of plants. The response was not significant possibly due to the high nitrogen status of the soil which was at or above the crop's requirements over the population range achieved in the experiment.

4.4.2 Effect of nitrogen rate on combined stem and leaf nitrogen content.

The amount of applied nitrogen significantly ($P \leq 0.05$) affected combined stem and leaf nitrogen content (Table 4). The mean plant nitrogen uptake at 30 kg ha^{-1} (0.138 g N $plant^{-1}$) was not significantly greater than that at 0 kg N ha^{-1} (0.11 g N $plant^{-1}$). However, the mean nitrogen uptake at 60 kg N ha^{-1} (0.165 g N $plant^{-1}$) was significantly higher ($P \leq 0.05$) than that at 0 kg N ha^{-1} (50.4% increase), but was not statistically different from that at 90 kg N ha^{-1} (0.14 g N $plant^{-1}$). The response at 60 kg N ha^{-1} appears to be a chance occurrence when one considers that it is the only odd result among the nitrogen receiving treatments.

Table 4 Effect of applied nitrogen on combined stem and leaf nitrogen content at flowering.

Nitrogen rate (kg ha^{-1})	**Total nitrogen uptake (g N $plant^{-1}$)**
0	0.110
30	0.138
60	0.165
90	0.140
Mean	0.138
LSD ($P \leq 0.05$)	0.033
CV (%)	27.9

4.5 Plant height

Plant population and nitrogen application rate did not significantly affect plant height (Appendix 6). The plant height means for population were 130.77 cm (78 000 plant ha^{-1}), 138.02 cm (105 000 plants ha^{-1}), 141.76 cm (185 000 plants ha^{-1}), and 140.03 cm (224 000 plants ha^{-1}). The plant height means for nitrogen rate were 132.84 (0 kg N ha^{-1}), 139.65 cm (30 kg N ha^{-1}), 137.41 cm (60 kg N ha^{-1}) and 140.68 cm (90 kg N ha^{-1}). Each factor had a mean plant height of 137.65 cm (S.E ± 2.71). Although differences in height were statistically not significant means of plant height generally increased with both population and nitrogen rate. Plant height was positively and significantly correlated ($r = 0.62^{**}$; n = 48) with plant population (Appendix 15) but not with nitrogen rate. It is possible that a phototropic response was induced at higher plant population levels which resulted in increased plant height at the higher plant populations. No significant interactions between the two factors were detected in the experiment.

The above results are in agreement with those of Weiss (1983) who reported no significant differences in plant height when varieties Inamar and Morada were grown at populations of 36 630 to 200 000 plants ha^{-1}. The response to increased rates of applied nitrogen is contrary to the findings of Majumdar *et al.* (1990) who obtained significant increases in plant height with nitrogen rates of up to 60 kg ha^{-1}.

4.6 Branch number per plant

Branch number/plant (BNP) significantly decreased ($P \leq 0.001$) with increase in plant population up to 185 000 plants ha^{-1} (Table 5). This result was also reflected in the significantly negative correlation ($r = - 0.74^{**}$; $n = 48$) between BNP and plant population (Appendix 15). Branch number per plant at 185 000 plant ha^{-1} was not significantly different from that at 224 000 plants ha^{-1}. The results are not consistent with those of Weiss (1983) who reported that there were no significant differences in BNP when varieties Inamar and Morada were grown at plant populations ranging from 36 630 to 200 000 plants ha^{-1}. The differences in response could be due to varietal differences.

The effect of nitrogen rate on BNP was not significant (Table 5). Subramanian *et al.* (1979) reported that when nitrogen was applied at rates of up to 45 kg ha^{-1}, the highest BNP was attained at 30 kg N ha^{-1}. In this study the parameter was not influenced by nitrogen rate due to high residual nitrogen in the soil (Table 1).

The effect of population was confounded within the population x nitrogen rate interaction. Therefore the effect of population was dependent on the level of applied nitrogen. Branch number per plant was significantly decreased at nitrogen rates of 0, 30 and 60 kg ha^{-1} when the plant population was above 105 000 plants ha^{-1} (Table 5).

However, at nitrogen level of 90 kg ha^{-1}, BNP decreased when plant population was greater than 78 000 plants ha^{-1}. Therefore tendency for BNP to decrease with each increase in plant population was greater at higher than lower nitrogen levels.

Table 5 Effects of plant population and nitrogen rate interaction on branch number per plant

Population	**Nitrogen rate (kg ha^{-1})**				**Population**
(plants ha^{-1})	**0**	**30**	**60**	**90**	**Mean**
78 000	15.60	15.90	13.47	16.47	**15.36**
105 000	13.23	14.57	13.87	10.20	**12.97**
185 000	9.00	8.57	9.30	8.93	**8.95**
224 000	7.88	8.03	8.00	7.56	**7.87**
Nitrogen mean	**11.43**	**11.77**	**11.16**	**10.79**	

$LSD_{0.05}$ Population = 2.50

$LSD_{0.05}$ Nitrogen = 1.05

$LSD_{0.05}$ Population x nitrogen = 1.76

CV (population) =7.8% **CV (nitrogen) = 11.1%**

4.7 Capsule number per plant

Capsule number/plant (CNP) significantly decreased ($P \leq 0.001$) with increase in population at all nitrogen rates (Table 6). This response by CNP to population was consistent with findings by Singh *et al.* (1990) who obtained a significant decrease in CNP with increase in population from 330 000 to 500 000 plant ha^{-1}. Capsule number per plant was negatively and significantly correlated with population ($r = -0.74^{**}$; n = 48) but positively and significantly correlated with BNP ($r = 0.92^{**}$; n = 48). The decrease in CNP with increase in population was due to the decreased number of branches per plant as plant population increased, leading to less fruiting points per plant.

The effect of nitrogen rate on CNP was not significant (Table 6). Subramanian *et al.* (1979) obtained the highest capsule number at 30 kg N ha^{-1} when nitrogen was applied at rates of up to 45 kg ha^{-1}. Significant increases in CNP with increase in nitrogen rate were also reported by Majumdar *et al.* (1990) who obtained increased CNP with nitrogen rates of up to 60 kg ha^{-1}. The result in this study was probably due to high residual nitrogen levels on the test site.

The effect of population was confounded within the population x nitrogen rate interaction (Table 6). Therefore, the effect of population was dependent on the level of applied nitrogen. Capsule number per plant was significantly reduced at 0, 30 and

90 kg N ha^{-1} when plant population was increased from 78 000 to 105 000 plants ha^{-1}. However, there was no effect on CNP at 60 kg N ha^{-1}. Capsule number per plant was significantly reduced at 0, 30 and 60 kg N ha^{-1} when plant population was increased from 105 000 to 185 000 plants ha^{-1}, but had no effect at 90 kg N ha^{-1}. Further increase in population from 185 000 to 224 000 plant ha^{-1} significantly decreased CNP at 0, 60, and 90 kg N ha^{-1} but had no effect at 30 kg N ha^{-1}. The 3 CNP trend anomalies described above could possibly be due to chance occurrence for there is no definite trend in the anomalies.

Table 6 Effects of plant population and nitrogen rate interaction on capsule number/plant

Population (plants ha-1)	Nitrogen rate (kg ha^{-1}) 0	30	60	90	Population Mean
78 000	208.23	200.83	175.77	213.63	**199.62**
105 000	158.83	174.47	162.27	154.87	**162.61**
185 000	117.83	133.83	138.97	134.97	**131.40**
224 000	90.22	113.73	112.33	98.57	**103.71**
Nitrogen mean	**143.78**	**155.72**	**147.34**	**150.51**	

$LSD_{0.05}$ Population = 23.10

$LSD_{0.05}$ Nitrogen = 20.99

$LSD_{0.05}$ Population x nitrogen = 11.79

CV (population) = 4% **CV (nitrogen) = 8.3%**

4.8 Seed number per capsule

Increasing the plant population from 78 000 to 224 000 plants ha^{-1} did not have significant effects on seed number/capsule (SNC) (Table 7). The seed numbers/capsule were 60.12 , 62.72 , 61.46 and 62.48 at 78 000; 105 000; 185 000 and 224 000 plants ha^{-1}, respectively.

The mean seed number/capsule was 61.7 (S.E ±1.83). When Singh *et al.* (1990) used higher plant populations, 300 000 to 500 000 plants ha^{-1}, they observed a significant increase in seed number/capsule as plant population increased. Possible reasons for the observations in this current study could be that either the population range used in this experiment was not high enough to influence this parameter, or that the landrace Matsai does not respond in this respect within the plant population range which was used in the present experiment.

Table 7 Combined effects of plant population and nitrogen rate on seed number per capsule

Population	**Nitrogen rate (kg ha^{-1})**				**Population**
(plants ha^{-1})	**0**	**30**	**60**	**90**	**Mean**
78 000	56.49	59.52	61.95	62.51	**60.12**
105 000	63.20	62.03	58.48	67.16	**62.72**
185 000	63.49	61.71	59.49	61.14	**61.46**
224 000	64.41	60.37	62.38	62.77	**62.48**
Nitrogen rate mean	**61.90**	**60.91**	**60.58**	**63.40**	

$LSD_{0.05}$ Population = 4.57

$LSD_{0.05}$ Nitrogen = 3.07

$LSD_{0.05}$ Population x nitrogen = 6.14

CV(population) = 5.1% **CV (nitrogen) = 6.9%**

Similarly, SNC did not significantly change with nitrogen applications within the range 0 to 90 kg ha^{-1} . (Table 7). The seed numbers/capsule were 61.90 , 60.91 , 60.58 and 63.39 at 0, 30, 60, and 90 kg N ha^{-1}, respectively.

The mean seed number/capsule for nitrogen was 61.7 (S.E ±1.23). This result is at variance with the findings of other researchers. For example, Subramanian *et al.* (1979) obtained the highest seed number/capsule at 30 kg N ha^{-1} when nitrogen was applied at 0 to 45 kg ha^{-1}, while Majumdar *et al.* (1990) recorded significant increases in seed number/capsule with nitrogen rates of up to 60 kg ha^{-1}. This was probably due to the high soil nitrogen status (62 kg ha^{-1}) at the site, sesame appears to respond only at lower nitrogen levels as reported by Subramanian *et al.* (1979) and Majumdar *et al.* (1990). No significant interaction effect between the factors was observed on seed number/capsule.

4.9 Seed weight/capsule

Both population and nitrogen rate did not significantly influence seed weight/capsule (Table 8). The seed weights/capsule in respect to population were 0.177, 0.181, 0.173, and 0.179 g at 78 000, 105 000, 185 000, and 224 000 plants ha^{-1}, respectively. The mean seed weight/capsule for population was 0.178 g (S.E ± 0.007). For nitrogen rate seed weights were 0.178 , 0.179 , 0.171 and 0.183 g/capsule at 78 000, 105 000, 185 000, and 224 000 plants ha^{-1}, respectively (mean = 0.178 g S.E ± 0.005). Seed weight/capsule was positively and significantly correlated with seed number/capsule ($r = 0.89^{**}$; n = 48). Assuming that individual seed weight does not change, seed weight per capsule should increase as seed number per capsule increases. There was no significant interaction between population and nitrogen rate on seed weight/capsule (Table 8).

Table 8 The combined effects of plant population and nitrogen rate on seed weight per capsule

Population (plants ha^{-1})	Nitrogen rate (kg ha^{-1}) 0	30	60	90	Population Mean
78 000	0.168	0.177	0.175	0.187	**0.177**
105 000	0.183	0.187	0.160	0.193	**0.181**
185 000	0.183	0.173	0.171	0.167	**0.174**
224 000	0.177	0.179	0.175	0.184	**0.179**
Nitrogen rate mean	**0.178**	**0.179**	**0.170**	**0.183**	

$LSD_{0.05}$ Population = 0.018

$LSD_{0.05}$ Nitrogen = 0.012

$LSD_{0.05}$ Population x nitrogen = 0.024

CV(population) = 6.8% **CV (nitrogen) = 6.3%**

Singh *et al.* (1990) obtained a significant decrease in seed weight/capsule with increase in population from 300 000 to 500 000 plants ha^{-1} which was a higher population range than the one attained in this experiment. The results could be attributed to varietal, site or seasonal effects on the yield seed weight /capsule.

The nature of response to nitrogen could be normal for sesame as a crop, or normal for landrace Matsai, meaning varietal effect. Alternatively, it can be attributed to the high soil nitrogen status of the site which masked the response at low nitrogen levels. The result is in contrast to the results of Majumdar *et al.* (1990) who reported increased seed weight/capsule up to 60 kg N ha^{-1}.

4.10 Seed yield/ha

Appendix 13 shows the analysis of variance for seed yield. The effects of plant population and nitrogen rate on seed yield were not statistically significant. The interaction between plant population and nitrogen rate was also not statistically significant.

4.10.1 Effect of population on sesame seed yield

Although analysis of variance showed that population did not significantly affect seed yield, trend analysis (Appendix 13) shows that the linear effect of population was significant ($P \leq 0.05$), which indicated a general increase in seed yield with increases in plant population. The quadratic effects were not significant.

The seed yields were 1076 kg ha^{-1} (78 000 plants ha^{-1}), 1237 kg ha^{-1} (105 000 plants ha^{-1}), 1481 kg ha^{-1} (185 000 plants ha^{-1}) and 1384 kg ha^{-1} at 224 000 plants ha^{-1} (Table 9). The mean seed yield was 1294.5 kg ha^{-1} (S.E ±51).

Table 9 The combined effects of plant population and nitrogen rate on seed yield ha^{-1}

Population (plants ha^{-1})	**Nitrogen rate (kg ha^{-1})**				**Population Mean**
	0	**30**	**60**	**90**	
78 000	711	1085	1343	1166	**1076**
105 000	1305	1069	965	1611	**1237**
185 000	1253	1514	1542	1616	**1481**
224 000	1159	1667	1207	1505	**1384**
Nitrogen mean	**1107**	**1334**	**1264**	**1475**	

$LSD_{0.05}$ Population = 339.75

$LSD_{0.05}$ Nitrogen = 369.75

$LSD_{0.05}$ Population x nitrogen = 725.00

CV(population) = 12.9% CV (nitrogen) = 28%

The regression of seed yield on population (Fig.1) was significant ($P \leq 0.001$) and explained 48.3% of the variation. Seed yield was positively and significantly correlated with plant population ($r = 0.70^{**}$; $n = 48$). The results show that seed yield response to plant population was linear over the population range used in this study. There is the indication that a linear response would be maintained beyond the population used here (Fig. 1). Therefore higher plant populations may be required in order to obtain the optimum yield for landrace Matsai.

Although CNP, another important yield component, significantly decreased ($P \leq 0.001$) with increase in population, its effects on seed yield was balanced out at higher plant populations by the fact that the higher number of plants compensated for loss in productivity per plant.

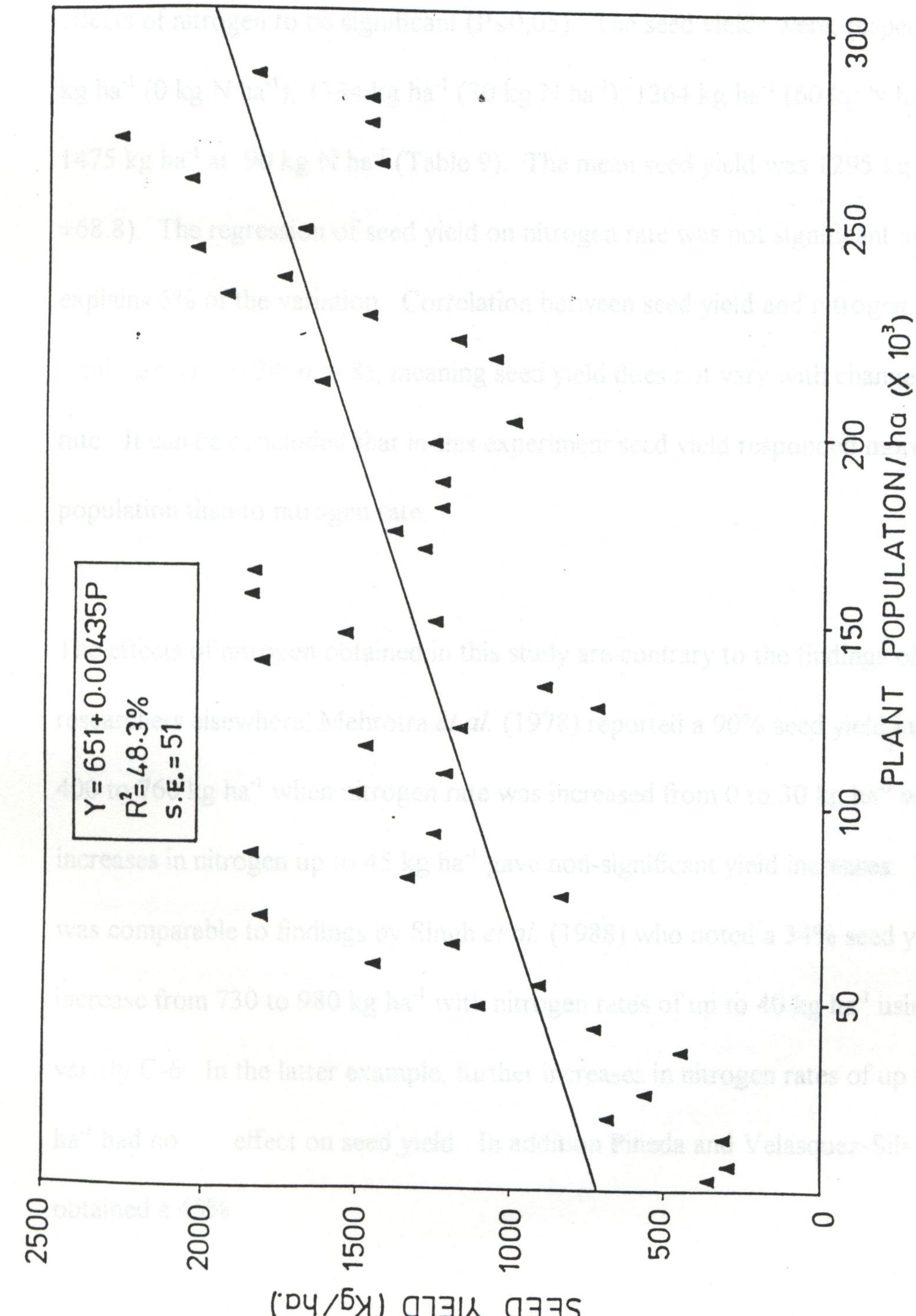

Fig 1. Regression of seed yield on population.

4.10.2 Effect of nitrogen rate on sesame seed yield

Analysis of variance (Appendix 13) shows that there was had no significant effect of nitrogen rate on seed yield. However, trend analysis (Appendix 13) shows linear effects of nitrogen to be significant ($P \leq 0.05$). The seed yields were, respectively, 1107 kg ha^{-1} (0 kg N ha^{-1}), 1334 kg ha^{-1} (30 kg N ha^{-1}), 1264 kg ha^{-1} (60 kg N ha^{-1}) and 1475 kg ha^{-1} at 90 kg N ha^{-1} (Table 9). The mean seed yield was 1295 kg ha^{-1} (S.E ±68.8). The regression of seed yield on nitrogen rate was not significant and only explains 6% of the variation. Correlation between seed yield and nitrogen rate was not significant ($r = 0.24$; $n = 48$), meaning seed yield does not vary with changes in nitrogen rate. It can be concluded that in this experiment seed yield responded more to population than to nitrogen rate.

The effects of nitrogen obtained in this study are contrary to the findings of other researchers elsewhere. Mehrotra *et al.* (1978) reported a 90% seed yield increase from 400 to 760 kg ha^{-1} when nitrogen rate was increased from 0 to 30 kg ha^{-1} while further increases in nitrogen up to 45 kg ha^{-1} gave non-significant yield increases. This result was comparable to findings by Singh *et al.* (1988) who noted a 34% seed yield increase from 730 to 980 kg ha^{-1} with nitrogen rates of up to 40 kg ha^{-1} using the variety C-6. In the latter example, further increases in nitrogen rates of up to 120 kg ha^{-1} had no effect on seed yield In addition Pineda and Velasquez-Silva (1990) obtained a 45%

seed yield increase from 1700 to 2460kg ha^{-1} with increase in nitrogen rates from 32 to 65 kg ha^{-1} using the variety China Roja. The lack of significant response by nitrogen rate on seed yield is also reflected in the response by the other yield components to this treatment. The yield components referred to being capsule number/plant, seed number/capsule and seed weight/capsule. It is possible that soil nitrogen levels in this experiment were already at or close to the yield response plateau or that landrace Matsai is adapted to low levels of available nitrogen. It is also possible that soils used by Mehrotra *et al.* (1978) and Singh *et al.*(1988) had relatively low nitrogen levels which enabled detection of significant yield increases with nitrogen rates of up to 30 and 40 kg ha^{-1}, respectively.

Since other literature indicate that sesame seed yield responds positively to increases in nitrogen rate, there is need to repeat the present experiment on a soil with low nitrogen levels in order to establish whether the lack of significant response to nitrogen at the site used in this study was due to the high soil nitrogen reserves or it is a varietal characteristic of landrace Matsai.

4.11 Seed oil content

Seed oil content generally increased with increase in population, although the treatment differences were not statistically significant (Table 10). The oil contents were 42.47% (78 000 plants ha^{-1}), 42.45% (105 000 plants ha^{1}), 42.91% (185 000 plants ha^{-1}), and 43.23% (224 000 plants ha^{-1}).

The mean oil content for population was 42.8% (S.E ± 1.1). These results are in agreement with findings by Weiss (1983) who reported no significant variation in oil content when varieties Inamar and Morada were grown at plant populations ranging from 36 630 to 200 000 plants ha^{-1}.

Table 10 The combined effects of plant population and nitrogen rate on sesame seed oil content

Population (plants ha^{-1})	**Nitrogen rate (kg ha^{-1})** 0	30	60	90	**Population Mean**
78 000	44.34	40.20	43.36	41.99	**42.47**
105 000	39.96	43.52	43.43	42.88	**42.45**
185 000	44.37	42.13	41.99	43.16	**42.91**
224 000	44.51	44.65	40.25	43.52	**43.23**
Nitrogen rate mean	**43.30**	**42.63**	**42.26**	**42.89**	

$LSD_{0.05}$ Population = 2.75

$LSD_{0.05}$ Nitrogen = 1.79

$LSD_{0.05}$ Population x nitrogen = 3.58

CV(population) = 4.5% **CV (nitrogen) = 5.8%**

Nitrogen rate had no significant effect on seed oil content (Table 14). The oil content values were 43.30% (0 kg N ha^{-1}), 42.62% (30 kg N ha^{-1}), 42.26% (60 kg N ha^{-1}), and 42.89% (90 kg N ha^{-1}). The mean oil content for nitrogen was 42.8%. (S.E ± 0.72). These results are similar to the findings of Mitchell *et al.* (1974) who observed that fertilizer, nitrogen included, had no significant effect on oil content except at much higher rates than are economically justified. However, the results are in contrast to the findings of Singh *et al.* (1988) who obtained an increase in oil content from 48.1 to 56.3% with increase in nitrogen from 0 to 40 ha^{-1} and Kadam (1990) who reported a decrease in oil content over the same range of nitrogen application. The contrasting responses are probably mainly due to differential varietal responses to nitrogen. Alternatively, the lack of significant response to nitrogen rate could be due to the high nitrogen status at the test site which was above the response limit of landrace Matsai. However, the authenticity of this assertion has to be established by repeating the experiment on a soil with a poor nitrogen status. No significant interaction between population and nitrogen rate on oil content was observed (Table 10).

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 CONCLUSIONS

The following conclusions can be drawn about sesame landrace Matsai grown at 78,000 to 224,000 plants ha^{-1} and at four nitrogen rates (0, 30, 60 and 90 kg N ha^{-1}) grown in the 1995/96 season under Gwebi Variety Testing Centre conditions.

5.1.1 The effect of population and nitrogen rate on yield components, seed yield and oil content were variable:

a) Branch and capsule number per plant significantly decreased ($P \leq 0.001$) with increase in population. Plant population had no significant effect on leaf nitrogen concentration, stem nitrogen concentration, combined stem and leaf nitrogen concentration, plant height, seed number per capsule and seed weight per capsule.

b) Increase in nitrogen application rate resulted in significant increases ($P \leq 0.05$) in stem nitrogen concentration and in combined stem and leaf nitrogen concentration with the highest concentrations being attained at 60 kg N ha^{-1} in both cases. However, nitrogen rate had no significant effect on leaf nitrogen concentration, plant height, branch number per plant, capsule number per plant, seed number per capsule and seed weight per capsule.

5.1.2 Seed yield of landrace Matsai is not significantly affected by changes in plant population and nitrogen rate. Although, the response of seed yield to plant population was not statistically significant, there was an increase in seed yield of 405 kg ha^{-1} (37.6%) when plant population was increased from 78 000 to 185 000 plants ha^{-1}. This represents a substantial increase in gross income of $2 430,00 ha^{-1}. The lack of significant response to nitrogen rate could be attributed to varietal effect or high residual nitrogen levels at the test site.

5.1.3 Seed oil content of landrace Matsai is not significantly affected by changes in population and nitrogen rate.

However, the results of this study represent only one season's data and was conducted at an inappropriate site and therefore are of limited value. The experiment needs to be repeated over two to three seasons on appropriate sites in order to draw more reliable conclusions.

5.2 RECOMMENDATIONS

Since seed yield response was still in the linear phase no optimum plant population could be established in this experiment Based on these preliminary findings one can in the short term recommend a plant population of 185 000 plants ha^{-1}. However, a need to repeat the experiment at higher populations than those achieved in the experiment has been recognised. In addition, a site or sites with low inherent nitrogen levels need to be used in order to realistically evaluate the response by sesame to nitrogen levels. The relatively high soil nitrogen reserves (62 kg ha^{-1}) at the test site may have masked or compounded the effects of applied nitrogen.

For the purpose of comparing experimental results, there is need to express response to nitrogen on the basis of total available nitrogen (soil nitrogen reserves and applied nitrogen) rather than applied nitrogen alone. This is because soils used by different researchers cited in the literature have different levels of nitrogen reserves. This, therefore, tends to distort comparisons with results obtained by other researchers who have worked on soils with different nitrogen levels. Using this concept the optimum total available nitrogen level necessary to achieve high yields can be established. In this context soil nitrogen reserves would need to be established by soil analysis and applied nitrogen fertilizer programmes then aim at supplying the balance of the nitrogen.

CHAPTER 6

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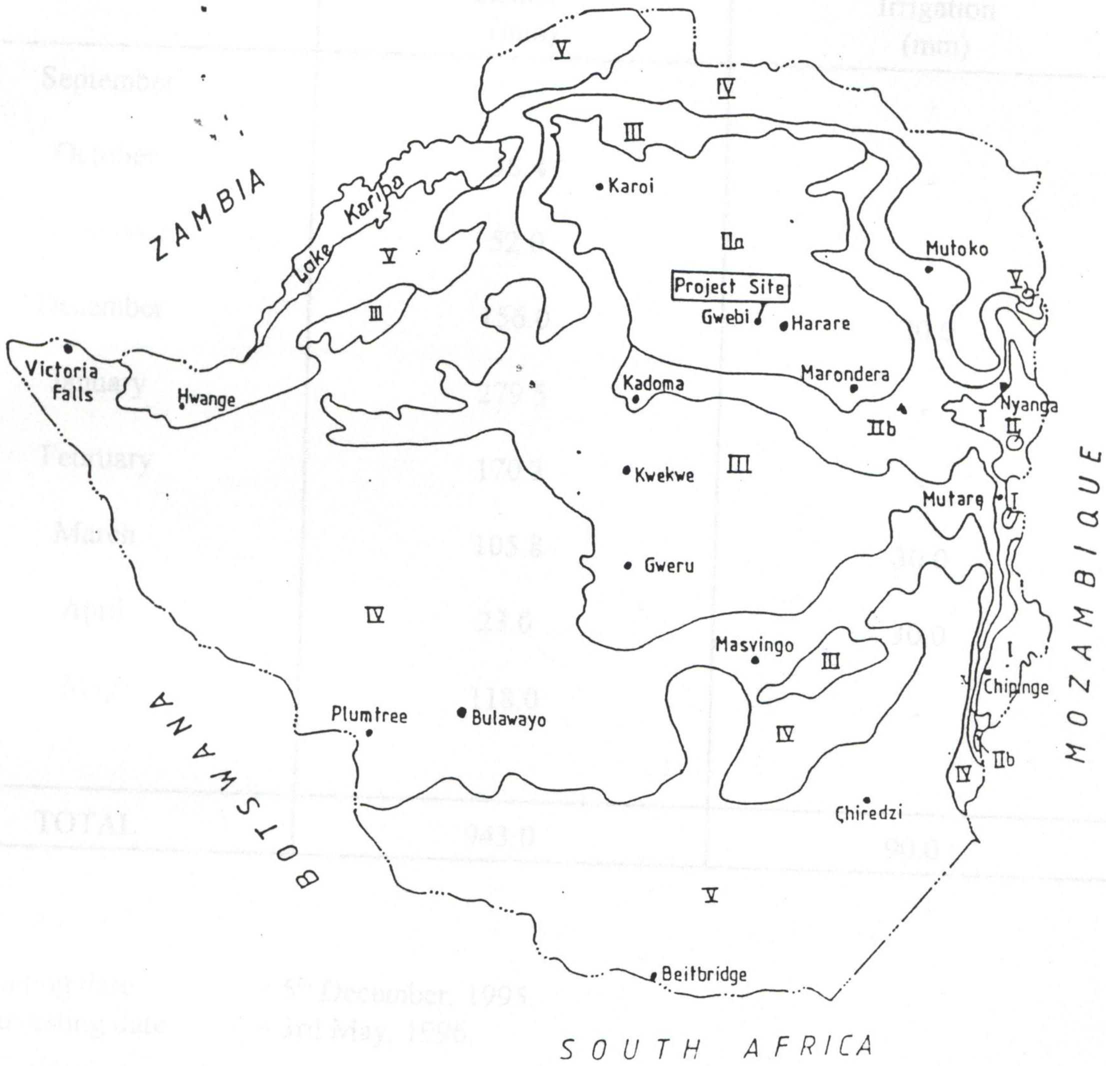
Appendix 1. Agro - ecological regions of Zimbabwe



REGION	MEAN ANNUAL RAINFALL (mm)	MEAN ANNUAL TEMPERATURE (°C)	RELATED FARMING SYSTEM
I	Very High >1000	<15	Specialised and diversified farming
IIa	High with rare severe dry spells 700 - 1000	18 - 22	Intensive farming
IIb	High but with more severe dry spells or short rainy seasons 700 - 1000	18 - 22	Intensive farming
III	Moderate with dry spells 550 - 700	18 - 24	Semi - intensive farming
IV	Low with seasonal droughts 450 - 600	20 - 25	Semi - intensive farming
V	Very low with seasonal droughts <500	22-30	Extensive farming

Source: School Atlas for Zimbabwe. Esselte Map Service AB. Stockholm. Sweden. 1987.

Appendix 2: Rainfall and irrigation data for Gwebi Variety Testing Centre.

Month	Rainfall (mm)	Irrigation (mm)
September	-	-
October	38.4	-
November	52.0	-
December	156.0	30.0
January	279.5	-
February	170.3	-
March	105.8	30.0
April	23.0	30.0
May	118.0	-
TOTAL	943.0	90.0

NB:

1. Planting date = 5th December, 1995.
2. Harvesting date = 3rd May, 1996.

Appendix 3 Analysis of variance for leaf nitrogen concentration

Source of Variation	DF	SS	MS	F value
Replication	2	0.054	0.027	
Population (P)	3	0.020	0.007	0.03^{ns}
Error (a)	6	1.216	0.203	
Nitrogen (N)	3	1.517	0.506	2.67^{ns}
P X N	9	1.838	0.204	1.08^{ns}
Error (b)	24	4.551	0.190	
Total	47	9.195		

CV(a) = 6.4% **CV(b) = 12.3%**

ns = not significant.

Appendix 4: Analysis of variance for stem nitrogen concentration

Source of Variation	DF	SS	MS	F Value
Replication	2	0.323	0.161	
Population **(P)**	3	0.218	0.073	0.68^{ns}
Error (a)	6	0.637	0.106	
Nitrogen **(N)**	3	0.467	0.156	3.88^{*}
P X N	9	0.315	0.035	0.87^{ns}
Error (b)	24	0.964	0.040	
Total	47	2.923		

CV (a) = 8% **CV (b) = 9.8%**

ns = not significant
* = significant at 5% level.

Appendix 5 Analysis of variance for combined stem and leaf nitrogen content

Source of Variation	DF	SS	MS	F value
Replication	2	0.007	0.004	
Population (P)	3	0.445	0.148	0.97ns
Error (a)	6	0.921	0.153	
Nitrogen (N)	3	1.782	0.594	3.98*
P X N	9	2.023	0.225	0.20ns
Error (b)	24	3.579	0.149	
Total	47	8.757		

CV (a) = 14.2% **CV (b) = 27.9%**

ns = not significant
* = significant at 5% level

Appendix 6 Analysis of variance for plant height

Source of Variation	DF	SS	MS	F value
Replication	2	1027.563	513.782	
Population (P)	3	840.879	280.293	3.17[ns]
Error (a)	6	530.083	88.347	
Nitrogen (N)	3	435.947	145.316	2.32[ns]
P X N	9	727.045	80.783	1.29[ns]
Error (b)	24	1501.340	62.556	
Total	47	5062.857		

CV (a) = 3.4% **CV (b) = 5.7%**

ns = not significant

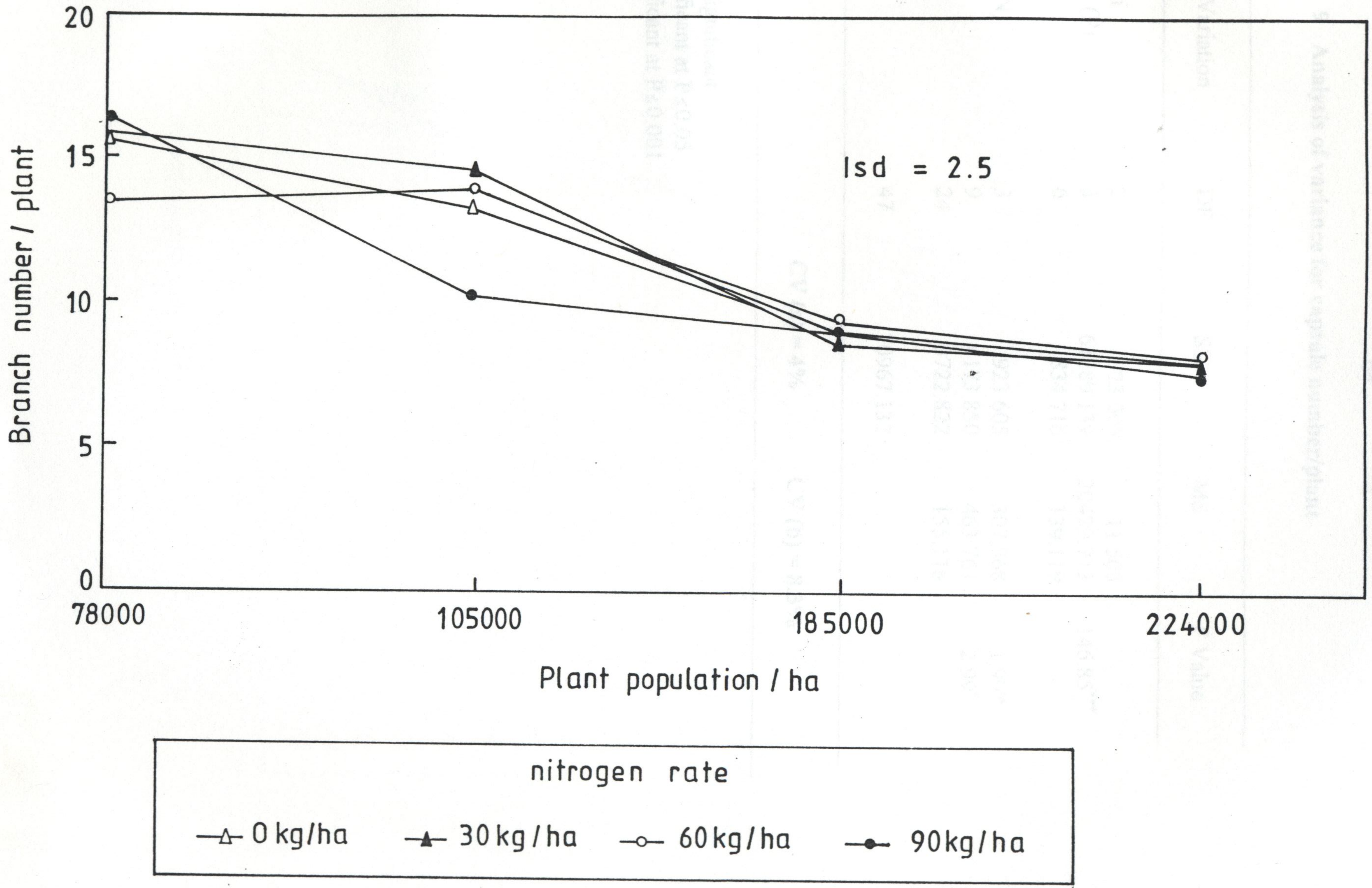
Appendix 7: Analysis of variance for branch number/plant

Source of Variation	DF	SS	MS	F Value
Replication	2	3.133	1.566	
Population (P)	3	438.709	146.236	46.83***
Error (a)	6	18.738	3.123	
Nitrogen (N)	3	6.152	2.051	1.32ns
P X N	9	43.832	4.870	3.13*
Error (b)	24	37.338	1.556	
Total	47	547.902		

CV (a) = 7.8% **CV (b) = 11.1%**

ns = not significant
* = significant at P≤ 0.05
*** = significant at P≤ 0.001

Appendix 8 Population and nitrogen interaction on sesame branch number per plant



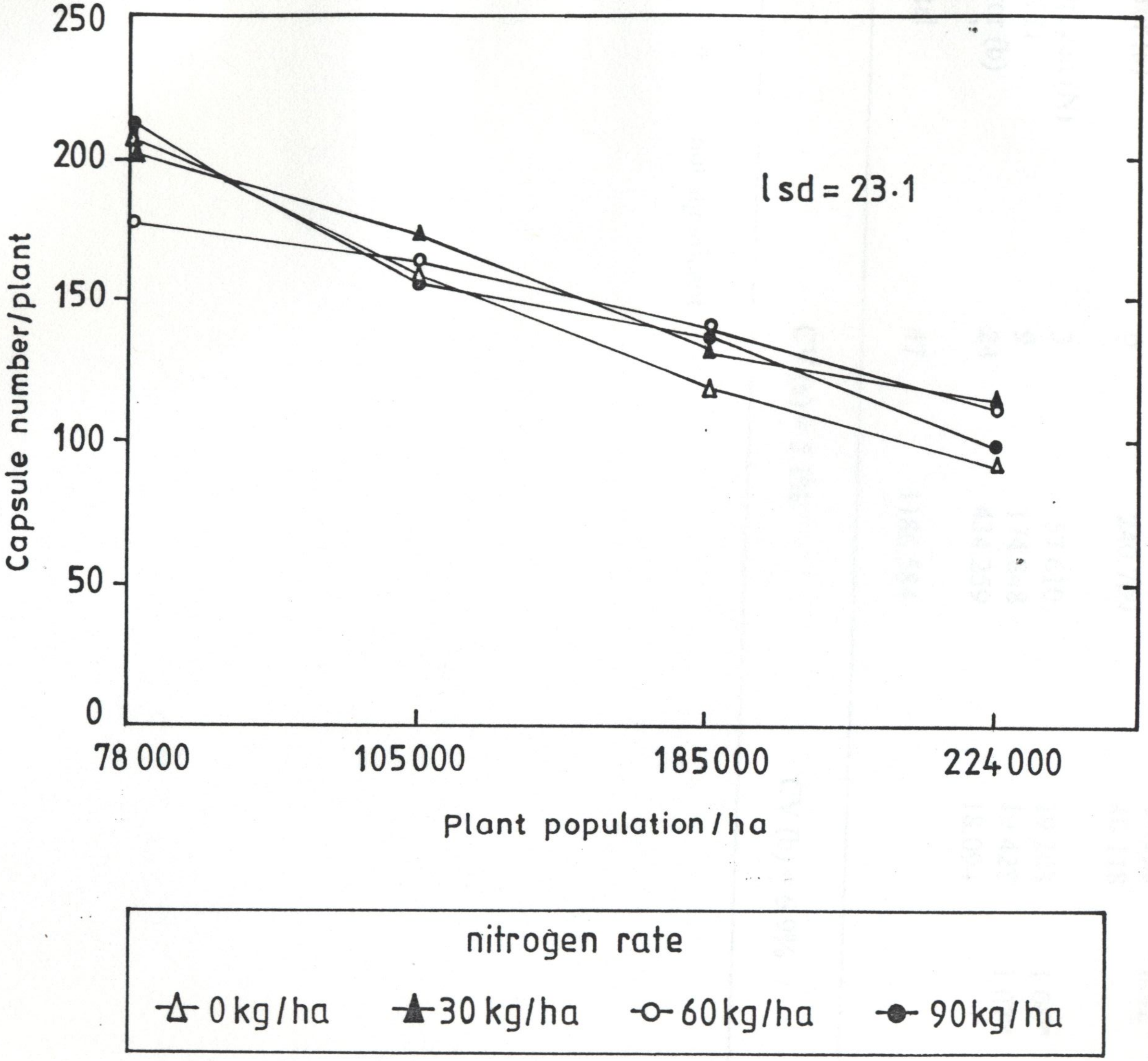
Appendix 9 Analysis of variance for capsule number/plant

Source of Variation	DF	SS	MS	F Value
Replication	2	23.005	11.503	
Population (P)	3	61289.139	20429.713	146.85***
Error (a)	6	834.716	139.119	
Nitrogen (N)	3	923.605	307.868	1.99ns
P X N	9	4173.850	463.761	2.99*
Error (b)	24	3722.822	155.118	
Total	47	70967.137		

CV (a) = 4% **CV (b) = 8.3%**

ns = not significant
* = significant at $P \leq 0.05$
*** = significant at $P \leq 0.001$

Appendix 10 Population and nitrogen interaction on capsule number/plant



Appendix 11 Analysis of variance for seed number/capsule

Source of Variation	DF	SS	MS	F Value
Replication	2	228.673	114.337	
Population (P)	3	50.486	16.829	0.42^{ns}
Error (a)	6	240.709	40.118	
Nitrogen (N)	3	57.610	19.203	1.06^{ns}
P X N	9	174.848	19.428	1.07^{ns}
Error (b)	24	434.259	18.094	
Total	47	1186.584		
	CV (a) = 5.1%		CV (b) = 6.9%	

ns = not significant

Appendix 12 **ANALYSIS OF VARIANCE FOR SEED WEIGHT/CAPSULE**

Source of Variation	DF	SS	MS	F Value
Replication	2	0.0024245	0.0012122	
Population (P)	3	0.0003740	0.0001246	0.21^{ns}
Error (a)	6	0.0034955	0.0005825	
Nitrogen (N)	3	0.0095660	0.0003188	2.54^{ns}
P X N	9	0.0020547	0.0002283	1.82^{ns}
Error (b)	24	0.0030138	0.0001255	
Total	47	0.0123191		
	CV (a) = 6.8%		**CV (b) = 6.3%**	

ns = not significant

Appendix 13 Analysis of variance and trend analysis for seed yield/ha

Source of Variation	df	SS	MS	F value
Replication	2	4020707	2010353	
Population (P)	3	1127149	375716	3.39^{ns}
Lin.	1	819680	819680	7.39*
Quad.	1	199460	199460	1.80^{ns}
Deviations	1	108010	108010	0.97^{ns}
Error (a)	6	665177	110863	
Nitrogen (N)	3	841128	280376	2.14^{ns}
Lin.	1	641473	641473	4.89*
Quad.	1	786	786	0.01^{ns}
Deviations	1	198870	198870	1.51^{ns}
P x N	9	1293547	143727	1.09^{ns}
Error (b)	24	3150425	131268	
Total	47	13066412		

CV (population) = 12.9% **CV (nitrogen) = 28%**

NS = not significant

* = significant at P≤0.05.

Appendix 14 **ANALYSIS OF VARIANCE FOR OIL CONTENT**

Source of Variation	DF	SS	MS	F Value
Replication	2	35.364	17.682	
Population (P)	3	5.096	1.699	0.12^{ns}
Error (a)	6	86.794	14.466	
Nitrogen (N)	3	6.897	2.299	0.37^{ns}
P X N	9	96.506	10.723	1.74^{ns}
Error (b)	24	147.628	6.151	
Total	47	378.285		
	CV (a) = 4.5%		CV (b) = 5.8%	

ns = not significant

Appendix 15 Correlation coefficients (r) among sesame yield components and the treatment variables.

	Correlation coefficients (r)							
	SY	SLN	PH	BNP	CNP	SNC	SWC	OC
SLN	0.26							
PH	0.77**	0.20						
BNP	-0.47**	0.02	-0.46**					
CNP	-0.36*	0.06	-0.35*	0.92**				
SNC	0.38**	0.17	0.44**	-0.27	-0.22			
SWC	0.33*	0.19	0.37**	-0.11	-0.06	0.89**		
OC	0.23	0.10	0.33*	-0.13	-0.15	-0.07	-0.04	
PP	0.70**	-0.06	0.62**	-0.74**	-0.74**	0.12	0.06	0.29*
NR	0.24	0.31*	0.23	-0.08	0.03	0.09	0.04	-0.06

* = P≤0.05
** = P≤0.01

KEY

SY = seed yield
SLN = combined stem and leaf nitrogen concentration
PH = plant height
BNP = branch number per plant
CNP = capsule number per plant
SNC = seed number per capsule
SWC = seed weight per capsule
OC = oil content
PP = plant population
NR = nitrogen rate