EFFECTS OF PLANT DENSITY AND ROW SPACING ON THE GROWTH AND YIELD OF SUNFLOWER (*Helianthus annuus* L.)

By

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BEING THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, AHMADU BELLO UNIVERSITY, ZARIA, IN PARTIAL FULFILMENT oF REQUIREMENTS FOR THE AWARD OF MASTERS DEGREE IN AGRONOMY

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DECLARATION

I declare that this thesis is a product of my efforts and has never been presented for a higher degree in the past.

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CERTIFICATION

The thesis entittled "EFFECIS OF PLANT DENSITY AND ROW SPACING ON THE GROWTH AND YIELD OF SUNFLOWER (Helianthus annuus L.) meets the regulations governing the degree of masters of Science of the Ahmadu Bello University, Zaria and is approved for its valuable contribution to scientific knowledge.

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DEDICATION

This work is dedicated to my family

ACKNOWLEDGEMENT

I wish to express my sincere gratitude and appreciation to my major supervisor, Dr. O. O. Olufajo for the considerable advice and assistance he has given me in the preparation of this work. I am also grateful to Prof. V. B. Ogunlela and Late Dr. I. O. E. Asenime for going through the manuscripts and making valuable contributions.

I gratefully appreciate the assistance and moral support of Mallam Balarabe Tanimu, Lamido Aliyu, Sani Maiko, Abdu Ahmed Manga, Umar Mohd Majia, Alhaji Sani Nuhu Yakasai and Mond Auwal Hussaini.

I am most sincerely grateful to my family for giving me moral and financial support through out my studies.

My sincere thanks also go to Dr. O. E. Asiribo of the IAR data processing unit and his men. I finally wish to extend my appreciation to the Kano State and later Jigawa State Polytechnic for allowing me to undergo the study.

ABSTRACT

A field study was conducted during the 1990 cropping season at Samaru to investigate the effects of plant density and row spacing an the growth and yield of sunflower (Helianthus annuus L.) Var. Isaanka. The treatments which consisted of plant densities (17,800; 35,600; 53,300; 71,100 and 88,900 plants) and three row spacings (25, 50 and 75cm), were laid out in a randomized complete block design with Four replications.

The highest seed and oil yields per hectare were obtained at 53,300 plants/ha. The number of seeds per head, 1000 - seed weight, seed yield per plant, plant height, leaf area per plant, number of leaves per plant, plant dry weight, head dry weight, stem and head diameters were significantly decreased while plant height was significantly increased by increasing plant density. Lodging was more severe at low and high densities compared with medium density.

Seed yield was significantly higher at 50cm than 25cm row spacing while the difference between 50 and 75cm was not. significant. Plant dry weight and head diameter significantly increased with increasing raw spacing up to 75cm while stem diameter, head dry weight number of seeds per head and seed yield per plant increased with increasing row spacing up to 50cm only.

The interaction between plant density and raw spacing was significant on plant dry weight (12 WAS) and head diameter Both parameters were highest at 17,800 plants/ha and 75cm row spacing. Correlation analysis indicated that seed yield was significantly negatively correlated with most of the yield components, but the reletionship between seed yield, plant height and lead area index was significantly postive.

The results obtained in this study indicated that the highest seed and oil yields of sunflower were obtained at 53,300 plants/ha and at a spacing oF 75cm between raws.

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CHAPTER 1

INTRODUCTION

Sunflower (Helianthus annuus L.) is a dicotyledenous plant which belongs to the family Compositae. It was believed to have originated from the Great Plains of North America (Hurt 1949). Sunflower is adapted to both tropical and temperate regions where annual rainfal is below 3,500mm (Weiss, 1966). It can best be grown at medium to high elevations in the tropics, but it can also be grown in the lowlands (Purseglove, 1968). The major sunflower producing countries of the world include the U.S.S.R., Romania, Hungary, Canada, China, Argentina, Bulgaria and Yugoslavia (Martin, 1976).

Sunflower seed contains about 25 to 50% oil, depending on variety. The oil is composed of mainly glycerides of oleic, linoliec and palmatic acids (Martin, 1970). It is used in cooking, salad dressing, magarine and soap making (Kinman, 1963). Being semi-drying oil, it is used to blend linnseed oil and other drying oils in paints, varnishes and cosmetics (Hurt, 1949). Sunflower seed is an excellent feed for livestock and also an excellent food for human diet (Anon, 1976). Its high oil and protein contents make it entirely balanced poultry feed (Purseglove, 1968).

In Nigeria, groundnut and palm oil are the two main sources of vegetable oil. However, over the years the local production of these two crops has continued to decline in the face of increasing demand for vegetable

oil. It therefore became necessary to identify alternative vegetable oil-producing crops. Sunflower oil was considered as a potential alternative source of vegetable oil in Nigeria (Kinman, 1963). The crop was therefore introduced into the country in the early sixties as an arable crop that could possibly be grown on a large scale to supplement the shortfall in edible oil and meal (Ogunremi, 1978).

Limited research work has been conducted on sunflower in Nigeria. In order to promote the crop successfully, it is essential to understand its agronomy, particularly its optimum plant population (i.e plant spacing between and within rows). It is generally recognised that plant density plays an importnat role in determining the yield of a crop per unit area of land. For highest yield, optimum density is essential. However, it is not only high or optimum density which contibutes to high seed yield but also the way or manner the plants are arranged i.e spatial arrangement or planting geometry.

Growth and yield of sunflower elsewhere are known to be affected by plant density (Massey, 1971; Zubriski and Zimmerman, 1974 and Miller et al., 1984) and row spacing (Vijayalakshmi et al., 1975 and Rweyemamu, 1990). Tanimu et al. (1986) using plant densities ranging between 22,222 and 88,888 plants/ha in the northern Guinea savanna ecological zone of Nigeria, showed that

the highest seed yield was obtained at 88,888 plants/ha. However, Atuk (1988) using plant densities ranging between 30,000 and 240,000 plants/ha at the same location found that plant density had no effect on seed yield.

In the light of the above, this study was conducted to investigate the effects of plant density and row spacing on the growth and yield of sunflower in the norther Guinea Savanna.

CHAPTER 2

2.0.0. LITERATURE REVIEW

2.1.0. EFFECT OF PLANT DENSITY ON GROWTH AND YIELD OF SUNFLOWER

2.1.1. Growth and Development

Studies on the effect of plant density on growth and development of sunflower have revealed conflicting results.

In a study conducted at Samaru using plant densities ranging from 30,000 to 240,000 plants/ha. Atuk (1988) found that plant height increased with increasing plant density. However, plant density had no significant effect on number of days to 50% flowering, days to maturity and lodging percentage. Miller and Fick (1978) who worked with a sunflower hybrid in North Dakota, United States of America (USA), using 36,000; 48,000 and 72,000 plants/ha reproted that as plant density increased plant height also increased, but floweing was delayed and days to maturity decreased. Using plant densities of 40,000 to 85,000 plants/ha, Holt and Campbell (1984) found that as plant density increased so also did plant height and days to flowering, while days to maturity and head diameters were decreased. However, Eshete (1987) and Kweyemamu (1990) using plant densities ranging from 35,000 to 88,888 plants/ha reported that plant density had no significant effect on days to flowering and maturity.

Smith et al., (1981) using densities ranging from 40,000 to 120,000 plants/ha in North Florida, USA, found that stem and head diameters and leaf area of sunflowers significantly decreased while leaf area index and plant height significantly increased with increased density. High density delayed flowering but did not affect maturity. The increase in plant height at higher densities has been attributed to greater competition for light, a situation which induced etiolation, resulting in tall plants (Nars et al., 1978). However, Workayehu (1990) using plant densities ranging from 36,000 to 125,000 plants/ha at Awasa, Ethiopia, observed that if other factors such as soil moisture were limiting, plant height was not affected by plant density.

Rao and Reddy (1982) reported that increasing plant density within the range of 55,555 to 111,111 plants/ha resulted in increased leaf area index (LAI) while head diameter decreased. Similarly, Umrani and Bhoi (1985) and Leon and Moreno (1982) reported an inverse relationship between head diameter and plant density. According to Burn (1970), sunflower adjusts to low plant density by increasing head diameter while it adjusts to high plant density by decreasing head diameter. This report is in agreement with those of Massey (1971) and Zubriski and Zimmerman (1974) who found that increasing planting density

within the range of 20,000 to 72,000 plants/ha reduced head diameter. Such results according to Kweyemamu (1990) show that head diameter was influenced by envronmental factors.

Robinson et al. (1976) in Minnensota, using densities ranging from 17,000 to 62,000 plants/ha reported that as density increased head diameter decreased while plant height and lodging increased. Increased lodging was most noticeable at densities above 49,000 plants/ha. Similarly, Miller et al. (1984) reported that plant height and lodging were increased from 30,000 to 75,000 plants/ha. Eshete (1987) attributed high percentage lodging at high plant density to thin stems. Shaik and Sagar (1983) using plant densities ranging from 27,556 to 166,500 plants/ha at Hydrabad, India also reported that lodging at low and high plant densities was due to heaviness of disc and week/brittle stem, respectively.

Leon and Mareno (1982) reported that straw production was increased by increasing the plant density from 25,000 to 75,000 plants/ha. Similar results were obtained by Workayehu (1990) using 36,000 to 125,000 plants/ha.

2.1.2. Yield and Yield Components

Plant density can be an important factor in increasing or decreasing the yield of a crop per unit

area of land. For highest yield the use of an optimum plant density is essential. Increasing the yield of individual plants by decreasing the plant density below a certain limit does not compensate for the loss due to deminished plant density while increasing the plant density above a certain limit makes individual plants too weak to produce normal yield (Massam, 1982).

There are varying reports on the effect of plant density on the seed yield of sunflower. Some researchers observed increased seed yield as plant density was increased. For example, in North Dakota, USA, Zubriski and Zimmerman (1974) reported that increasing the plant density from 36,000 to 72,000 plants/ha increased seed yield from 2,258 to 3,190 kg/ha. Robinson et al. (1976) in Minnesota, USA, reported that average seed yield increased from 1,841 to 2,946 kg/ha when density was increased from 17,000 to 62,000 plants/ha. However, seed weight and the number of seeds per head decreased with increasing plant density. Similarly, Rao and Reddy (1982) using densities ranging from 55,555 to111.111 plants/ha reported that seed yield increased while number of seeds per head decreased with increasing density. Harmati (1990) also observed reduction in number of seeds per head with increased plant density. According to Smith et al. (1981) the high seed yield that is usually obtained under a high plant density may be attributed

to increased number of seeds per unit area.

In a trial conducted at two locations in Minnesota, USA, using densities varying from 37,000 to 86,000 plants/ha, Robinson (1973) observed that seed yield increased with increasing density at only one location. In Saskatchewan, Canada, Holt and Zentner (1985) used a range of density from 22,000 to 76,000 plants/ha and reported that seed yield increased with increased plant density in the first trial while there was no treatment effect in the second trial. Smith et al. (1981) using 40,000 to 120,000 plants/ha also observed increased seed yield as plant density increased at one location, suggesting that yield was limited by factors other than plant density.

Some researchers have obtained highest seed yields at intermediate plant densities. Belayneh (1983) who used densities ranging from 21,000 to 104,000 plants/ha in Central Washington, USA, obtained the highest seed yield at 41,000 - 61,000 plants/ha. Within a range of densities varying from 40,000 to 85,000 plants/ha. Wilson et al. (1988) obtained the highest yield at 55,000 plants/ha in Canterbury. In a 3-year field study at two locations using densities ranging from 17,000 to 60,000 plants/ha Loubser et al. (1986) observed that average seed yields were highest at intermediate plant densities and 1000 - seed weight tended to decrease with increasing density. Similar reports were made by other workers (Umrani and Bhoi,

1985; Hedge et al., 1987; Kovacik and Skaloud, 1988). Robinson (1987) observed that in a location where seed yield is low to intermediate factors other than plant density such as soil moisture, could limit yield.

Some other workers however, reported lack of seed yield response to increasing plant density. Mathers and Stewart (1984) reported that seed yields were not affected by densities ranging from 37,000 to 99,000 plants/ha. Working at three locations in India, Holt and Campbell (1984) found that at plant densities ranging from 40,000 to 85,000 plants/ha there was no significant effect on seed yield but average seed weight decreased with increasing plant density. At Swift Current, Canada, Vijayalakshmi et al. (1975) found no significant yield difference at plant densities ranging between 25,000 and 75,000 plants/ha but seed yield was significantly reduced when the density was increased to 125,000 plants/ha. Miller and Fick (1978) reported that although plant density did not affect sunflower seed yield, seed weight decreased significantly. Similar decrease in seed weight with increasing plant density was observed by Smith et al. (1981).

Ogunremi (1978) and Prunty (1981) also reported lack of seed yield response to plant densities ranging from 36,000 to 75,000 plants/ha while Shaik and Sagar (1983) did not observe any significant yield difference between densities ranging from 27,586 - 166,000 plants/ha. Shaik and Sagar (1983) indicated that compensation in yield occurred at lower plant densities

through large disc, higher 1000 - seed weight and number of seeds per plant. Sunflower compensates for low plant density by increasing number of seeds per head and seed weight while it compensates for high plant density by decreasing number of seeds per head and seed weight (Smith et al., 1981). In other words, the relatively constant yields at varying plant densities were a consequence of reduced seed weight and number of seeds per head as plant density increased (Miller et al., 1984).

Some researchers have observed decreased seed yield with increasing plant density. Silva et al. (1983) found that sunflower seed yield decreased linearly with increasing plant density from 1.85t at 25,000 plants/ha to 1.38t at 75,000 plants/ha. Number of seeds per head and 1000 - seed weight also decreased. Curotti et al. (1977) and Alessi et al. (1977) also obtained highest yields at lower plant densities.

According to Robinson et al. (1980) the inconsistent yield response of sunflower to increasing plant density may be attributed to great difference in the environment under which the trials were conducted.

2.1.3. Protein and Oil Content

Reports on the effect of plant density on sunflower seed protein contents are scanty compared to those on seed oil content.

While some researchers recorded increased oil content as plant density increased others reported that oil content was not affected by plant density.

Robinson et al. (1976) reported that seed oil content increased from 37.5 to 42.5% when plant density was increased from 17,000 to 62,000 plants/ha. Smith et al. (1981) in North Florida, found that increasing plant density from 40,000 to 120,000 plants/ha resulted in significant increase in seed oil content. In another study, Harmati (1990) observed that sunflower seed oil content increased from 46.5% to 48.21% as density was increased from 40,000 to 80,000 plants/ha but oil yield was reduced because of reduction in the number of seeds produced. Similarly, Zubriski and Zimmerman (1974) in North Dakota, reported that increasing plant density from 36,000 to 72,000 plants/ha significantly increased oil yield from 1,046 to 1,500 kg/ha but plant density had no significant effect on oil content. In contrast, Rao and Reddy (1985) using plant densities ranging from 41,666 to 166,666 plants/ha showed that increasing plant density decreased seed oil content.

Using plant densities varying from 36,000 to 92,000 plants/ha, Miller and Fick (1978) in North Dakota showed that seed oil content was not

significantly affected by density. Similar observation were made by Miller et al. (1984); Narwal and Malik (1985); Eshete (1987) and Rweyemamu (1990). Using plant density levels ranging from 30,000 to 240,000 plants/ha at Samaru, Nigeria, Atuk (1988) found that the crude protein content of sunflower seed decreased significantly with increasing plant density up to 120,000 plants/ha.

2.2.0. EFFECT OF ROW SPACING ON GROWTH AND YIELD OF SUNFLOWER

Reports on the effect of row spacing on growth and yield of sunflower is relatively scanty, and the few available reports are conflicting. While some investigators reported increased yield with increasing row spacing (Chauhan, 1979; Goyal et al., 1985 and Shivakumar et al., 1973), others observed decreased yield (Alessi et al., 1977 and Narwal and Malik, 1986) or lack of yield response (Mathers and Stewart, 1984 and Holt and Zentner, 1985).

2.2.1. Growth and Development

Some investigators have observed significant effect or row spacing on growth and development of sunflower. In a two-year field experiment using row spacings varying from 41 to 91cm, Smith et al., (1981) found that plants were taller at the wide-row spacings

than at narrow rows. They attributed this to the closer intra-row spacing that was adopted under wider rows. They also found that row spacing had no significant effect on stem and head diameter. However, leaf area index increased significantly as row spacing was increased.

Gubbles and Dedio (1985) who used 45 and 90cm row spacings found that at 90cm row spacing plants were taller by 9cm compared with 45cm row. In their study on sunflower using row spacings varying from 18 to 53cm, Read et al. (1982) reported that head diameter increased with increasing row spacing and there was greater competition for moisture at narrow row spacing.

Using row spacings of 50 to 70cm Vega and Quaino (1986) found that lodging and stem breakage decreased as row spacing increased. Woon (1987) using 61 and 91cm row spacings reported that row spacing had little effect on plant height and head diameter in the first year but in the second year head diameter was significantly greater at 91cm compared with 61cm row. Rweyemamu (1990) using row spacings varying between 65 to 80cm at two locations in Morogoro, Tanzania, however, found that head diameter decreased as row spacing was increased. He further showed that row spacing had no effect on days to 50% flowering.

Vijayalakshmi et al. (1975) showed that row spacing varying from 22 to 75cm had no effect on root

development as well as the response of plant to moisture stress during the early growth period and at flowering. They further showed that at wider row spacing competition for moisture within the row was severe, forcing the roots to go deep down the soil profile thus enabling the plants to withstand prolonged dry spell later in the season better than plants in narrow rows.

2.2.2. Yield and Yield Components

Some researchers found significant yield increase as row width was increased. Goyal *et al.* (1985) working on sunflower at 30, 45 and 60cm rows reported that the widest row spacing of 60cm gave significantly higher yield than narrower rows. Similarly, Chauhan (1979) recorded increased yield at a row spacing of 60cm compared with 45 and 30cm row spacings. Shivakumar *et al.* (1973) also using 45 and 60cm row spacing reported that seed yields were higher at 60cm row.

In contrast however, some researchers observed decreases in seed yield with increasing row width. Working on sunflower at row spacings of 45 and 90cm, Wilson *et al.* (1988) observed that seed yield was higher at 45cm row spacing. Alessi *et al.* (1977) who studied sunflower at 30 and 90cm row spacings reported that a higher seed yield was obtained at 30cm compared with 90cm row spacing. Narwal and Malik

(1986) reported that seed yields were higher in 30 and 45cm rows than in 60cm row. Similarly, working on sunflower at 50 and 70cm rows, Vega and Quaino (1986) found that the average seed yield was higher at 50cm row spacing compared with 70cm row spacing. Srisvastava (1980) also recorded a decresed seed yield when row spacing was increased from 30 to 60cm.

Other workers however, reported that sunflower seed yields increased up to certain limits and then declined as row width was increased. Rweyemamu (1990) using row spacings ranging between 65 and 85cm, showed that seed yield was highest at 75cm compared with the other row spacings but row spacing had no significant effect on 1000 - seed weight. In another study, Read et al. (1982) working on sunflower at 18, 36 and 53cm row spacings observed that the 36cm row spacing produced greater yield than either the 18 ro 53cm row spacing. They observed that yields were greater at narrower row spacings in wetter years and wider row spacings in drier years. According to Kilcher (1961) wider row spacings would be advantageous to yield during drier years because of reduced competition ror limited soil moisture supply.

Some investigators have reported that seed yield of sunflower was not significantly affected by row spacing. Mathers and Stewart (1984) showed that

seed yield was not affected by row spacing ranging from 30 to 60cm. Holt and Zentner (1985) who worked at three sites in India, observed that row spacing varying from 30 to 90cm had little effect on seed yield and seed size. Using 61 and 91cm rows, Woon (1989) found that row spacing had little effect on 1000 - seed weight in the first year but in the following year plants sown in 91cm rows had significantly greater 1000 - seed weight than those in 61cm rows.

In view of the above conflicting reports, It could be concluded that the effect of row spacing on the seed yield of sunflower depends on the environment under which the crop is grown.

2.2.3. Protein and Oil Content

Reports in the literature on the effect of row spacing on sunflower seed oil and protein contents are rather limited. While some workers observed significant effect of row spacing on sunflower seed oil content others found that row spacing had no significant effect on seed oil content.

Rao et al. (1976) using row spacings of 30, 45 and 60cm reported that sunflower seed oil content was highest at the narrowest spacing of 30cm. Similarly, Putt and Unrau (1943) observed that narrow spacing resulted in higher seed oil concentration.

However, some workers have reported that row spacing had no significant effect on oil content of sunflower seeds. Vijayalakshmi et al. (1975) using

row spacings varying between 22 and 74cm reported that seed oil content was not affected by row spacing. Smith et al. (1981) working with sunflower at 41, 61 and 91cm rows apart also showed that seed oil percentage was not affected by row spacing. A similar observation was made by Rweyemamu (1990) using 65 to 85cm row spacings.

Studying sunflower in rows of 30 and 90cm, Alessi et al. (1977) reported that oil yield of sunflower decreased as row spacing increased; the oil yield at 30cm row being 24% higher than that at 90cm row. Similar results were obtained by Rao et al. (1976) and Smith et al. (1981) using row spacings ranging between 30 and 91cm. However, Samui et al. (1987) using 40, 60 and 80cm rows reported that oil yield at 60 and 80cm row was significantly higher than that at 40cm row.

These inconsistent results probably show that environment plays a great role on the response of sunflower seed oil content to row spacing.

CHAPTER 3

3.0. MATERIALS AND METHODS

3.1. Location

The experiment was conducted during the 1990 cropping season at the Institute for Agricultural Research (I.A.R.) Farm, Ahmadu Bello University, Samaru, Zaria ($11^{0}11^{'}$N and $7^{0}38'$E; 686 meters above the sea level) in the northern Guinea savanna ecological zone. The soil of the experimental site was a sandy loam and the field was cropped to cowpea the previous season. Details of the physico-chemical composition of the soil at the experimental site are shown in Table 1. During the 1990 cropping seasson, Samaru recorded a total of 1018.9mm of rainfall concentrated almost entirely between June and September; mean maximum and minimum temperaturesof 26^{0}C and 17.9^{0}C respectively and mean sunshine hours of 6.80 (Appendix 1).

3.2. Treatments

The treatments tested consisted of factorial combinations of five plant density levels and three row spacings. The density levels tested were 17,800; 35,600; 53,300; 71,100 and 88,900 plants/ha while the row spacings were 25, 50 and 75cm. Sunflower variety Issanka was used.

3.3. Experimental design and plot size

The experiment was laid out in a randomized

complete block design with four replications. The gross plot size was 30.375m^2 (6.75m x 4.5m) and the net plot size was 10.125m^2 (6.75m x 1.5m), while the total experimental area was 2728m^2 or 0.273ha (62, x 44m).

3.4. Cultural Practices

3.4.1. Land preparation

The land was ploughed and harrowed to a fine tilth. The field was then levelled and marked out into 60 plots.

3.4.2. Sowing

Seeds of sunflower (Var. Isaanka) were sown on the flat on 18th July, 1990. The seeds were over-sown and thinned 15 days later to give the desired densities of 17,800; 35,600; 53, 300; 71,100 and 88,900 plants/ha at row spacings of 25, 50 and 75cm.

3.4.3. Fertilizer application

The experimental area received 100kg N, 50kg P_2O_5 and 50kg K_2O/ha as calcium ammonium nitrate (26% N), single super phosphate (19% P_2O_5) and muriate of potash (60% K_2O). The fertilizers were applied in shallow furrows along the rows about 10cm away from the plants at two weeks after sowing.

3.4.4. Weed control

The first weeding was carried out manually using hand hoe at three weeks after sowing while a second hoe-weeding was done at seven weeks after sowing.

3.4.5. Harvesting

At maturity the back of the head turned yellow while the outer bracts turned brown. Before harvesting the heads were allowed to dry on the plants to avoid seed losses during post harvest head drying.

The mature plants from each net plot were harvested manually by cutting the heads with sharp knife. The net plot area ($10.125m^2$) for 25, 50 and 75cm row spacings consisted of 6, 3 and 2 inner-most rows respectively.

The dried heads were threshed using pestle and mortar, after which the seed were separated from the chaff by winnowing.

3.5.0. Data Collection

Establishment count was taken at three weeks after sowing i.e. immediately after thinning. Beginning from four weeks after sowing, two plants were sampled from each plot at fortnightly intervals and were used for the determination of the underlisted 1 to 5 parameters.

3.5.1. Plant height

Heights of plants were measured from stem base to the apex.

3.5.2. Number of leaves per plant

The number of green leaves on each plant was counted and the means worked out.

3.5.3. Leaf area per plant

Leaf area per plant was estimated using a formular described by Schneiter (1978);

$$LA = \lceil (L \times W) \times 0.6683 - 2.45 \rceil$$

where LA = Leaf area

L = Lenght of leaf

W = Width of leaf

0.6683 = Constant factor

-2.45 = Constant factor

3.5.4 Leaf area index

This was determined by dividing the leaf area by the area of land occupied by a given plant.

3.5.5. Dry weight per plant

Sampled plants were harvested close to the ground level, oven dried at 80^{0}C for 3 days and then weighed. The values were then divided by two to get the mean values.

3.5.6. Days to first flowering

Number of days from sowing to the time of first appearance of flower in each plot.

3.5.7. Days to 50% flowering

Number of days from sowing to the time about 50% of the plants in each plot had flowered.

3.5.8. Days to maturity

Days from sowing to the time about 95% of the heads have attained maturity. At maturity the back of the head turned yellow and the outer bracts turned brown.

3.5.9. Stem diameter

At maturity the diameter of ten randomly selected plants were measured 1 metre above the stem base using a measuring tape. The values were summed up and the means were computed.

3.5.10. Stand count at harvest

At harvest, all plants within each net plot were counted. The value obtained was then expressed as percentage of the expected number.

3.5.11. Percent lodging

Plants that were inclined 30^{0} or more from the vertical were considered as having lodged. Plants that lodged within each net plot were counted and the number expressed as percentage of the stand count at harvest.

3.5.12. Head diameter

The diameter of ten randomly selected heads from each net plot was measured using a measuring tape.

3.5.13. Head weight

The weight of ten heads from each plot used for the determination of head diameter was dtermined and the mean worked out.

3.5.14. Weight of 1000 seeds

For each of the plots, 1000 seeds were counted and weighed. This procedure was repeated twice and the

means worked out.

3.5.15. Number of filled seeds per head

Ten heads from each net plot were threshed to obtain clean seeds. The seeds were counted using an electronic seed counter to determine the total number of seeds in the ten sampled heads. The total number was divided by ten to get the mean number of filled seeds per head.

3.5.16. Seed yield/head (seed yield/plant)

Seeds from the ten heads above were weighed. The value was then divided by ten to determine the seed yield per head (plant) for each plot.

3.5.17. Seed yield (kg/ha)

Heads from the net plots were harvested and threshed separately. The seeds from each net plot were weighed to obtain the seed yield per plot which was extrapolated to seed yield per hectare.

3.5.18. Stover yield

After harvesting the heads, the stover for each plot was cut and left on the field to dry before weighing. The weights were converted into kg/ha.

3.5.19. Crude protein content

Seed crude protein content was obtained by analysing the seeds from each plot for N-content and

multiplying the value by a conversion factor of 5.30 (AOAC, 1980).

3.5.20. Seed oil content

The percentage of oil content of harvested seeds from each net plot was analysed as described by the Association of Analytical Chemist (AOAC, 1980).

The percent oil content of seeds for each plot was muliplied by the seed yield (kg/ha) to obtain the oil yield (kg/ha) for the individual plots.

3.5.21. Determination of soil nutrient status

Soil samples were collected from random locations at two depths (0 - 15cm and 15 - 30cm) prior to cultivation. The bulked samples were analysed for the physical and chemical properties using standard procedures.

The total nitrogen was determined by the Macro-Kjeldhal Procedure (Bremner, 1965). Calcium and magnesium were determined by atomic absorption spectrophotometry, sodium and potassium were determined by flame emission spectrophotometry while cation exchange capacity was determined using IN ammonium molybdate method (Bray and Kurtz, 1945).

The texture was determined by the hygrometer method (Day, 1965).

3.6. Statistical Analysis of Data

Analysis of variance was carried out to test for significance in the treatment effects using the F test as described by Snedecor and Cochran (1967). Where the F test was significant, Duncan Multiple Range Test (Duncan, 1955) was used to evaluate differences among treatment means. Correlation analysis was carried out between yield and some characters to evaluate the degree of their association.

CHAPTER 4

RESULTS

4.1.0. Soil Physical and Chemical Properties

The soil was sandy loam, low in PH, low in total nitrogen, low in organic carbon, low in Cation Exchange Capacity and high in available phosophorus (Table 1).

4.2.0. Effects of Plant Density and Row Spacing on Growth Characters of Sunflower

4.2.1. Establishment count and stand count at harvest

The percentage establishment and percentage stand count at harvest generally decreased with increasing density (Table 2). However, the difference in the percent establishment between 35,600 and 71,100 plants/ha as well as between 71,100 and 88,900 plants/ha was not significant. Similarly, there was no significant difference between the percentage stand count at 35,600 and 53,300 plants/ha as well as between 71,100 and 88,900 plants/ha.

Percent establishment count and stand count at harvest were not significantly affected by row spacing. The interaction between plant density and row spacing on these parameters was not significant.

4.2.2. Plant height

Plant density significantly affected plant height at 6, 8 and 12 WAS (Table 3). At 6 WAS, only plants at the highest density tested were significantly taller than

Table 1: Physical and Chemical Properties of the Soil of the Experimental Site.

Soil characteristics	Soil depths (cm) 0 - 15	15 - 30
PH in water	5.10	4.90
PH in 0.01m $CaCl_2$	4.10	4.10
Organic carbon (%)	0.41	0.30
Total nitrogen (%)	0.081	0.060
Available phosphorus (ppm)	28.46	18.02
Exchangeable bases (Meq/100g)		
K	0.16	0.19
Ca	1.54	2.21
Mg	0.30	0.38
Na	0.07	0.07
CEC	3.08	3.41
Particle size distribution		
Sand (%)	58	55
Silt (%)	30	30
Clay (%)	12	15
Textural class	Sandy loam	Sandy loam

Table 2 Effects of plant density and row spacing on establishment count and stand count at harvest of sunflower at Samaru, 1990.

Treatment	Establishment count %	Stand count at harvest %
Plant density(D) (plants/ha)		
17,800	94.9a	91.9a
35,600	87.8b	83.8b
53,300	87.3b	77.6bc
71,100	82.5bc	73.1cd
88,900	77.7c	69.2d
SE±	2.1	2.3
Row spacing(S) (cm)		
25	84.5	77.8
50	86.6	79.1
75	87.7	80.5
SE±	1.6	1.8
DxS Interaction	NS	NS

Means followed by the same letter(s) within a column are not significantly different at 5% level using DMRT.

NS = Not significant.

Table 3: Effects of plant density and row spacing on plant height (cm) of sunflower at Samaru, 1990.

Treatment	4	6	8	10	12
	Weeks after sowing				
Plant density(D) (plants/ha)					
17,800	21.4	97.1b	118.3b	125.6	123.1c
35,600	22.8	98.5ab	124.9b	135.8	133.4b
53,300	21.9	103.7ab	131.9a	139.8	135.5ab
71,100	21.2	105.2ab	133.3a	140.0	135.7ab
88,900	22.6	107.2a	134.7a	136.5	141.8a
SE±	1.3	3.1	2.4	5.6	2.2
Row spacing(S) (cm)					
25	21.7	102.1	128.6	130.1	133.8
50	22.1	103.2	128.7	138.7	124.1
75	22.2	101.6	128.6	137.8	133.8
SE±	1.0	2.4	1.9	4.3	1.7
DxS Interaction	NS	NS	NS	NS	NS

Means followed by the same letter(s)within a column are not significantly different at 5% level using DMRT.

NS = Not significant.

those from the lowest density. At 12 WAS, increasing the plant density from 17,800 to 35,600 plants/ha resulted in a significant increase in plant height. However, the difference in plant height between 35,600 and 71,100 plants/ha as well as that between 53,300 and 88,900 plants/ha was not significant.

Row spacing had no significant effect on plant height throughout the sampling period. The plant density X row spacing interaction was not significant throughout the sampling period.

4.2.3. Number of leaves per plant

The effect of plant density on the number of leaves per plant was significant at 4 and 8 WAS (Table 4). At 4 WAS, number of leaves per plant in all density treatments was similar except 88,900 plants/ha which has a lower leaf number than the other treatments. At 8 WAS number of leaves per plant decreased with increased plant density. Plants sown at 17,800 and 35,600 plants/ha had statistically similar number of leaves followed by those sown at 53,300 and 71,100 plants/ha which in turn had significantly higher number of leaves than plants sown at 88,900 plants/ha.

The effect of row spacing on number of leaves per plant was significant at 6 WAS only. Increasing row spacing from 25 to 50cm had no effect on the number of leaves per plant. However, a further increase in row spacing to 75cm resulted in a significant increase in the number of leaves per plant. The plant density X

Table 4: Effects of plant density and row spacing on the number of leaves per plant of sunflower at Samaru, 1990

Treatment	4	6	8	10
	Weeks after sowing			
Plant density(D) (plants/ha)				
17,800	13.8a	20.1	19.0a	7.3
35,600	14.1a	19.0	18.9a	7.3
53,300	14.3a	19.6	17.2b	7.3
71,100	14.0a	19.8	17.3b	6.8
88,900	12.9b	20.0	15.1c	6.4
SE±	0.3	0.4	0.5	0.4
Row spacing(S) (cm)				
25	13.7	19.3b	17.6	6.9
50	13.8	19.4b	17.50	7.2
75	14.0	20.4a	17.4	7.1
SE±	0.2	0.3	0.4	0.3
DxS Interaction	NS	NS	NS	NS

Means followed by the same letter(s) within a column are not significantly at 5% level DMRT.

NS = Not significant.

row spacing interaction was not significant throughout the sampling period.

4.2.4. Leaf area per plant

Leaf area per plant decreased with increasing plant density throughout the sampling period (Table 5). However, on all sampling dates, the difference between 17,800 and 35,600 plants/ha was not significant.

Row spacing had no significant effect on leaf area per plant throughout the sampling period. The plant density X row spacing interaction was not significant throughout the sampling period.

4.2.5. Leaf area index

On all sampling dates, leaf area index (LAI) increased with increasing density; 71,100 and 88,900 plants/ha having significantly higher LAI than the other treatments except at 10 WAS when 71,100 and 53,300 plants/ha were at par (Table 6).

Row spacing had no significant effect on LAI throughout the sampling period.

Regardless of plant density and row spacing, the highest LAI value was attained at 6 WAS. The plant density X row spacing interaction was not significant throughout the sampling period.

4.2.6. Plant dry weight

Except at 4 WAS dry weight per plant decreased significantly with increasing plant density (Table 7). Plants sown at 17,800 plants/ha produced significantly

Table 5: Effects of plant density and row spacing on leaf area per plant (cm^2) of sunflower at Samaru, 1990.

Treatment	4	6	8	10
	Weeks after sowing			
Plant density(D) (plants/ha)				
17,800	1253.4a	5077.7a	5123.7a	1268.9a
35,600	1223.2a	4898.4ab	4885.4a	1147.2ab
53,300	1222.4a	4709.8ab	3651.1b	1002.6bc
71,100	1211.2a	4502.8ab	3517.5b	857.8cd
88,900	1054.5b	4047.2b	3201.3b	824.0d
SE±	55.5	299.4	247.3	61.3
Row spacing(S) (cm)				
25	1185.2	4530.3	3940.3	978.8
50	1203.6	4693.9	4106.4	1029.1
75	1190.1	4717.4	4180.8	1052.4
SE±	43.0	231.9	191.6	47.5
DxS Interaction	NS	NS	NS	NS

Means followed by the same letter(s) within a column are not significantly different at 5% level using DMRT.

NS = Not significant.

Table 6: Effects of plant density and row spacing on leaf area index of sunflower at Samaru, 1990.

Treatment	4	6	8	10
	Weeks after sowing			
Plant density(D) (plants/ha)				
17,800	0.2d	0.9d	0.9c	0.2d
35,600	0.4c	1.7c	1.7b	0.4c
53,300	0.7b	2.5b	2.0b	0.5b
71,100	0.9a	3.2a	2.5a	0.6b
88,900	0.9a	3.6a	2.9a	0.7a
SE±	0.03	0.2	0.14	0.04
Row spacing(S) (cm)				
25	0.6	2.3	1.9	0.5
50	0.6	2.4	2.0	0.5
75	0.6	2.4	2.0	0.5
SE±	0.03	0.11	0.11	0.03
DxS Interaction	NS	NS	NS	NS

Means followed by the same letter(s) within a column are not significantly different at 5% level using DMRT.

NS = Not significant.

Table 7: Effects of plant density and row spacing on plant dry weight (g/plant.) of sunflower at Samaru, 1990.

Treatment	4	6	8	10	12
	Weeks after sowing				
Plant density(D) (plants/ha)					
17,800	3.6	52.5a	94.1a	119.5a	101.0a
35,600	3.9	41.5b	73.4b	110.5a	93.0b
53,300	3.8	34.9bc	64.0bc	93.4b	69.3c
71,100	3.6	31.5cd	57.6c	78.1c	57.5d
88,900	3.4	26.3d	44.2d	73.3c	44.2e
SE±	0.2	2.5	4.8	4.1	2.4
Row spacing(S) (cm)					
25	3.7	35.4	64.4	88.9	67.0c
50	3.6	38.7	67.0	98.1	73.3b
75	3.6	37.8	68.5	98.0	78.1a
SE±	0.1	1.9	3.7	3.2	1.9
DxS Interaction	NS	NS	NS	NS	*

Means followed by the same letter(s) within a column are not significantly different a 5% level using DMRT.

NS = Not significant

* = Significant at 5% probability level

higher dry matter per plant compared with the other treatments while at 88,900 plants/ha dry weight was significantly lower than for other plant density treatments with the exception of 71,100 plants/ha.

Row spacing had significant effect on plant dry weight at 12 WAS only. Plant dry weight increased significantly with each successive increase in row spacing from 25 to 75cm.

The interaction between plant density and row spacing was also significant at 12 WAS (Table 8). Row spacing significantly increased plant dry weight at densities of 17,800 and 35,600 plants/ha whereas at higher densities row spacing had no significant effect on dry weight per plant.

4.2.7. Days to first flowering, 50% flowering and maturity

Neither plant density nor row spacing had significant effect on number of days to first flowering, 50% floweing and days to maturity (Table 9). The plant density X row spacing interactions on these parameters were also not significant.

4.2.8. Lodging percentage

Lodging was significantly influenced by plant density (Table 10). The highest lodging percentage was obtained at 88,900 plants/ha, but this was statistically at par with values obtained at 17,800 and 71,100 plants/ha.

Table 8: The interaction between density and row spacing on plant dry weight (g) of sunflower at 12 WAS at Samaru, 1990.

Plant density (plant/ha)	Row spacing (cm) 25	50	75
17,800	87.7cd	99.0bc	116.3a
35,600	80.0de	97.2bc	101.9b
53,300	66.0f	68.8ef	73.1ef
71,100	57.3g	57.1g	58.0g
88,900	43.9h	44.2h	44.4h
SE±	4.13		

Means followed by the same letter(s) are not significantly different at 5% level using DMRT.

Table 9: Effects of plant density and row spacing on number of days to first flowering, 50% flowering and maturity of sunflower at Samaru, 1990.

Treatment	Days to 1st flowering	Days to 50% flowering	Days to Maturity
Plant density(D) (plants/ha)			
17,800	52.3	61.5	104.3
35,600	52.8	60.8	104.2
53,300	52.9	60.8	104.4
71,100	53.3	61.3	104.4
88,900	53.1	61.3	104.5
SE±	0.5	0.4	1.9
Row spacing(S) (cm)			
25	53.1	61.6	104.4
50	52.8	60.9	104.3
75	52.8	60.9	104.5
SE±	0.4	0.3	1.4
DxS Interaction	NS	NS	NS

NS = Not significant.

Table 10: Effects of plant density and row spacing on lodging %,stem diameter, head dry weight and head diameter of sunflower at Samaru, 1990.

Treatment	Lodging %	Stem diameter (cm)	Head dry weight (g)	Head diameter (cm)
Plant density(D) (plants/ha)				
17,800	19.5ab	2.7a	59.6a	14.6a
35,600	14.4b	2.2b	54.8ab	13.1b
53,300	16.8b	2.0b	48.4b	12.5c
71,100	18.8ab	1.7c	34.8c	11.1d
88,900	24.3a	1.6d	30.0c	9.5e
SE±	1.9	0.1	2.7	0.2
Row spacing(S) (cm)				
25	19.3	1.9b	41.7b	11.6c
50	18.4	2.1b	46.3ab	12.2b
75	18.6	2.1a	48.6a	12.8a
SE±	1.5	0.1	2.1	0.2
DxS Interaction	NS	NS	NS	**

Means followed by the same letter(s) within a column are not significantly different at 5% level using DMRT.

NS = Not significant.

** = Significant at 1% probability level.

Row spacing had no significant effect on lodging percentage. The plant density X row spacing interaction was also not significant.

4.2.9. Stem diameter

Stem diameter decreased significantly with increased plant density (Table 10). However, the difference between 35,600 and 53,300 plants/ha was not significant.

Increasing row spacing from 25 to 50cm significantly increased stem diameter while a further increase to 75cm and no significant effect on stem diameter. The plant density X row spacing interaction was not significant on stem diameter.

4.2.10. Head dry weight

Plant density and row spacing had significant effect on head dry weight (Table 10). Head dry weight decreased with increase in plant density. However, the difference between 17,800 and 35,600 as well as that between 35,600 and 53,300 plants/ha was not significant. Similarly, plant densities of 71,100 and 88,900 plants/ha were statistically at par.

Increasing row spacing from 25 to 75cm increased head dry weight; the difference between 25 and 75cm row spacings being significant. The plant density X row spacing interaction was not significant.

4.1.11. Head diameter

There was a significant decrease in head diameter with each successive increase in plant density from 17,800 to 88,900 plants/ha (Table 10). Similarly, increasing row spacing from 25cm to 75cm significantly increased head diameter.

There was significant interaction between plant density and row spacing on head diameter (Table 11). At plant densities of 17,800 and 35,600 plants/ha increasing row spacing resulted in significant increase in head diameter whereas at higher densities row spacing had no such influence.

4.3.0. Effect of Plant Density and Row Spacing on Yield and Yield Components of Sunflower

4.3.1. Number of seeds per head

Number of seeds per head decreased significantly with increasing plant density (Table 12).

Increasing row spacing from 25 to 50cm resulted in a significant increase in the number of seeds per head. However, there was no significant change in the number of seeds per head when the row spacing was further increased to 75cm. The plant density x row spacing interaction was not significant.

4.3.2. 1000 - seed weight

In general, 1000-seed weight decreased with increasing plant density (Table 12). However, the

Table 11: Interaction between plant density and row spacing on head diameter (cm) of sunflower at Samaru, 1990.

Plant density (plants/ha)	Row spacing (cm) 25	50	75
17,800	13.4bc	14.2b	16.4a
35,600	12.0de	13.4bc	14.0b
53,300	12.0de	12.7cd	12.8cd
71,100	11.1f	11.1f	11.2ef
88,900	9.5g	9.5g	9.5g
	0.3		

Means followed by the same letter(s) are not significantly different at 5% using DMRT.

Table 12: Effects of plant density and row spacing on number of seeds per head, 1000-seed weight, seed yield per plant, stover yield and seed yield of sunflower at Samaru, 1990.

Treatment	No. of seeds/ head	1000-seed weight (g)	Seed yield per plant (g)	Stover yield (kg/ha	Seed yield kg/ha
Plant density(D) (plants/ha)					
17,800	636.4a	50.0a	37.3a	7066.7d	620.0d
35,600	534.2b	37.8b	27.5b	11491.7c	835.3c
53,300	473.0c	35.5bc	24.1c	13916.76	1054.0a
71,100	413.0d	32.3cd	17.7d	14741.7a	982.2b
88,900	356.3c	30.5d	14.4e	14958.3a	968.1b
SE±	16.6	1.3	0.8	276.3	25.0
Row spacing(S) (cm)					
25	448.7b	35.7	20.9b	11790.0b	849.0b
50	489.3a	37.7	25.0a	12665.0a	898.9a
75	509.8a	38.2	26.7a	12850.0a	929.5a
SE±	12.9	1.0	0.7	214.0	19.3
DxS Interaction	NS	NS	NS	NS	NS

Means followed by the same letter(s) within a are not significantly different at 5% level using DMRT.

NS = Not significant.

difference between 35,600 and 53,300 plants/ha was not significant.

Although 1000-seed weight increased with increasing row spacing, the differences were not significant. The plant density X row spacing interaction was not significant.

4.3.3. Seed yield per plant

Seed yield per plant decreased significantly with each successive increase in plant density from 17,800 to 88,900 plants/ha (Table 12). In contrast, increasing row spacing from 25 to 50cm resulted in significant increase in seed yield per plant while a further increase to 75cm had no significant effect on seed yield per plant. The pant density x row spacing interaction was not significant.

4.3.4. Seed yield (kg/ha)

Seed yield increased significantly up to 53,300 plants/ha (Table 12); thereafter, there was a significant decrease in yield. However, the difference between 71,100 and 88,900 plants/ha was not significant.

Increasing the row spacing from 25 to 75cm increased seed yield. However, only the difference between 25 and 75cm was significant. The plant density X row spacing interaction was not significant.

4.3.5. Stover yield

There was a significant increase in stover yield with each increase in plant density up to 71,100 plants/ha (Table 12).

Increasing row spacing from 25 to 50cm significantly increased stover yield. A further increase in row spacing to 75cm had no significant effect on stover yield. The plant density X row spacing interaction was not significant.

4.4.0. Seed Quality

4.4.1. Crude protein content

Seed crude protein content decreased with increasing plant density but differences were not significant. Similarly, row spacing had not significant effect on seed crude protein content (Table 13). The plant density x row spacing interaction was also not significant.

4.4.2. Seed oil content

Seed oil content was not significantly influenced by either plant density or row spacing (Table 13). The plant density x row spacing interaction was also not significant.

4.4.3. Oil yield (Kg/ha)

Oil yield was significantly affected by plant density and row spacing (Table 13). Oil yield increased significantly up to 53,300 plants/ha.

Table 13: Effects of plant density and row spacing on seed crude protein content, seed oil content (concentration) and oil yield of sunflower at Samaru, 1990.

Treatment	Crude protein content %	Seed oil content %	Oil yield (kg/ha)
Plant density(D) (plants/ha)			
17,800	26.8	42.2	262.4d
35,600	26.6	43.1	360.4c
53,300	26.1	42.4	446.3a
71,100	25.8	42.1	414.1ab
88,900	25.5	41.5	402.1b
SE±	0.5	0.6	12.5
Row spacing(S) (cm)			
25	25.9	42.2	358.5b
50	26.3	42.5	382.4ab
75	26.2	42.0	390.4a
SE±	0.4	0.5	9.7
DxS Interaction	NS	NS	NS

Means followed by the same letter(s) within a column are not significantly different at 5% level using DMRT.

NS = Not significant

Increasing the density further to 88,900 plants/ha decreased the oil yield significantly. However, the difference between 71,100 and 88,900 plants/ha was not significant.

Increasing the row spacing from 25 to 75cm increased oil yield but only the difference between 25 and 75cm was significant. The plant density x row spacing interaction was not significant.

4.5.0. Correlation

Results of crrelation analysis between seed yield and some growth and yield components obtained using correlation coefficient (Table 14) show highly significant positive correlation between seed yield (kg/ha) and plant height, leaf area index (10 WAS) and oil yield. Similarly, there was a highly significant and positive correlation between seed yield per plant and 1000-seed weight, number of seeds per plant, leaf area per plant, head dry weight and head diameter.

Seed yield (kg/ha) was significantly and negatively correlated with yield per plant, 1000-seed weight, number of seeds per head, leaf area per plant (10 WAS), head diameter and head dry weight.

Table 14: Coefficient of correlation between sunflower seed yield and some growth and yield components

	1	2	3	4	5	6	7	8	9	10	11	12	13
1	1												
2	.477**	1											
3	-.652**	-.489**	1										
4	-.532**	-.582**	.790**	1									
5	.641**	.524**	-.658**	-.685**	1								
6	-.402**	-.391**	.553**	0.550**	-.124	1							
7	-.470**	-.531**	.791**	0.834**	-.675**	.642**	1						
8	-.329**	-.426**	.683**	.694**	-.558**	.597**	.786**	1					
9	-.005	.034	-.084	-.217	.287*	-.136	-.291*	-.263*	1				
10	-.436**	-.509**	.566**	.734**	-.593**	.497**	.639**	.616**	-.186	1			
11	-.535**	-.568**	.849**	.866**	-.764**	.570**	.901**	.811**	-.218	.674**	1		
12	.021	-.150	-.116	.163	.053	.337**	-.209	-.149	-.092	-.243	.013	1	
13	.965**	.415**	-.595**	-.463**	.628**	-.303*	-.394**	-.281*	-.028	-.352**	-.484**	.279*	1

KEY:

1. Seed yield kg/ha
2. Plant height 12 WAS
3. 1000-seed weight
4. Stand count at harvest (%)
5. Number of seeds per head
6. Leaf area index (LAI) 10 WAS
7. Leaf area per plant 10 WAS
8. Seed yield per plant
9. Head diameter
10. Lodging %
11. Head dry weight
12. Oil content (%)
13. Oil yield kg/ha.

* = Significant at 5% probability level

** = Significant at 1% probability level

CHAPTER 5

5.0. DISCUSSION

5.1. Effect of Plant Density

5.1.1. Growth Characters

Generally the response of the growth characters to increasing plant density became more significant as the plants grew older. This may be due to increased inter and intra plant competition for growth factors with advancement in plant age.

Both the percent plant establishment and stand-count at harvest decreased significantly with increasing density up to 71,100 plants/ha. This pattern of response could probably be attributed to intense competition at higher plant densities resulting in the death of weaker and slow growing seedlings and/or plants. Similar observations were reported by Atuk (1988) and Workayehu (1990). Self thinning is a well known phenomemon at high plant density (Harper and White, 1970).

Plant height increased significantly with increase in plant density. This positive response is associated with the phenomenon of competition for light among individual plants at higher plant densities resulting in etiolation (Donald, 1963). However, Massey (1971) and Klochkov (1977) reported that if other factors such as soil moisture were limiting, plant height was not affected by plant density.

At 4 WAS when the plants were relatively younger, number of leaves per plant was significantly reduced only when plant density was increased up to 88,900 plants/ha. However, at 8 WAS significant reduction in the number of leaves per plant occurred at densities higher than 35,600 plants/ha. The decrease in number of leaves per plant as density increased might be attributed to the adverse effect of high density on the development of buds from which leaves develop, as a result of competition for growth factors. Also plants at higher densities had longer internodes and thus fewer nodes from which leaves develop. This result is similar to the findings of Vijayalakshmi et al. (1975). Plant density had no significant effect on leave number at 10 WAS possibly due to bacterial blight attack late in the season.

Leaf area per plant decrease significantly as plant density increased throughout the growing period. The response to each increment in plant density was more significant with age possibly due to the fact that as the plants grew older there was increased demand for growth factors resulting in intense competition. According to Smith et al. (1981) at higher densities plant had smaller and fewer leaves compared with lower densities because of senescence of the lower leaves due to mutual shading and intense competition for growth factors.

Leaf area index was significantly increased as plant density increased up to 88,900 plants/ha. This

positive response could be due to the increase in the number of plants per unit area which more than compensated for the lower or smaller leaf area per plant at higher densities.

Increasing plant density from 17,800 to 88,900 plants/ha significantly decreased plant dry weight between 6 and 12 WAS. Similarly, head dry weight was significantly decreased when the density was increased from 17,800 to 71,100 plants/ha while stem and head diameters decreased significantly with increasing density up to 88,900 plants/ha.

The negative responses of these parameters to increasing plant density could be attributed to competition for limited growth factors as density was increased. At lower plant densities individual plants had relatively abundant supply of growth factors which enabled them to grow and produce bigger stems and larger heads. However, at higher densities, plants were subjected to intense competition which resulted in taller plants with thinner stems and smaller heads. This pattern of response is not unexpected since increasing density reduced leaf area per plant signficantly. Large stem diameter has been associated with greater light penetration of the canopy at low plant densities (Vijayalakshmi et al., 1975).

Plant density had no significant effect on number of days to first flowering, days to 50% flowering and

days to maturity. These results are in agreement with those of Eshete (1987) and Atuk (1988) but Holt and Campbell (1984) observed increased number of days to maturity at higher plant densities. Robinson et al. (1980) reported that increasing plant density resulted in reduced head moisture percentage and crops matured early.

Lodging was observed to be severe both at the lowest and the highest plant densities. This pattern of response was also recorded by Shaik and Sagar (1980) who indicated that lodging at low density was due to heaviness of disc (head) while that at higher density resulted from thin and weak/brittle stems. Similarly, Miller et al. (1984) and Robinson et al. (1976) recorded increased lodging of sunflower plants with increased plant density but Atuk (1988) did not record any significant effect of plant density on lodging.

5.1.2. Yield Components

The number of seeds per head and seed yield per plant significantly decreased with increasing density up to the highest plant density tested while 1000 - seed weight decreased significantly with increasing density up to 71,100 plants/ha. The decrease in these parameters with increasing plant density could be associated with the smaller and lighter heads that were produced at higher densities. The inter

and intra plant competition for soil moisture, nutrients, space, light and assimilates at high densities might have accounted for the decrease in these parameters with increase in plant density. At higher plant densities the upper leaves tend to shade the lower leaves, thus making the latter unable to intercept adequate light for photosynthesis. This mutual shading could have reduced the total amount of assimilates available for partitioning to the seeds, hence the decreased 1000 - seed weight and seed yield per plant at higher plant densities.

5.1.3. Yields

Seed yield (kg/ha)

Seed yield significantly increased with increasing density up to 53,300 plants/ha while further increases in density resulted in decreases in seed yield. This result is similar to the findings of Wilson et al. (1988); Umrani and Bhoi (1985) and Tanimu et al., (1991) who obtained highest seed yield of sunflower at 55,000; 50.000 and 53,333 plants/ha respectively. Several other workers have also obtained highest seed yield of sunflower at intermediate plant densities (Loubser et al.,1986; Kovacik and Skaloud , 1988 and Hedge et al., 1987).

The significant seed yield response up to 53,331 plants/ha and its decline thereafter could be attributed to lodging (Table 10)and mutual competition

among individual plants for growth factors at higher densities. At lower densities seed yields (Table 10) were low because the increases in number of seeds per plant and individual seed weight could not compensate for the fewer number of plants per unit area. Moreover, at 53,300 plants/ha lodging percentage was low relative to higher densities. Miller et al. (1984) demostrated that excessive lodging especially following severe rain and wind storm late in the season could reduce sunflower yield significantly. When plants lodge they become positionally shaded by the unlodged standing plants resulting in reduction in light with consequent reduction in yield.

Stover yield

Stover yield increased significantly as plant density increased. This could be due to the increase in the number of plants per unit area and the enhancement of LAI as density increased. Similar observations have been reported by other workers (Workayehu, 1990; Leon and Mareno, 1982).

5.1.4. Seed quality

The lack of significant effect of plant density on percent seed oil content in this trial conforms with results of Zubiriski and Zimmerman (1974) and Miller and Frick (1978) who used plant densities ranging from 36,000 to 72,000 plants/ha. However, Smith et al., (1981) showed that increasing plant density from 40,000 to 120,000 plants/ha resulted in a signifcant increase

in seed oil content. It is therefore possible that the plant density range used in the present study was not high enough to exert significant effect on seed oil concentration.

The response of oil yield to increasing plant density is similar to that of seed yield ; oil yield increasing significantly up to 53,300 plants/ha. As earlier observed by Harmati (1990), the reduction in oil yield at higher plant densities could be attributed to the decrease in the number of seeds produced.

5.2.0. Effect of Row Spacing

5.2.1. Growth Characters

Row spacing had no effect on establishment count, stand count at harvest and plant height. According to Woon (1987) row spacing had little effect on plant height, but Smith et al. (1981) observed that wider row spacings produced significantly taller plants than narrow row spacings because of the closer intra plant spacing within the wider rows.

The number of leaves per plant increased significantly when the row spacing was increased from 50 - 75cm. This might be attributed to the reduction in plant competition as row width increased.

Plant dry weight and head diameter increased with increasing row spacing. Similarly, head dry weight and stem diameter significantly increased up

to 50cm row spacing. The positive responses of these parameters to row spacing could be associated with reduction in inter row plant competition for growth factor such as soil moisture, nutrients, light and space. Vijayalakshmi et al. (1975) reported that at wider rows, sunflower roots extended up to 70cm between rows and to a depth of 60cm, whilst at the narrow to square row spacing, roots extended up to 25cm on all the sides of the plants and to a depth of 50cm. Thus, plants at wider rows were better able to withstand prolonged dry periods later in the growing season. Read et al. (1982) also attributed increased head diameter at wider row spacing compared with narrow row spacing to lesser competition.

Row spacing had no significant effect on number of days to first flowering, days to 50% flowering and maturity. Rweyemamu (1990) who investigated the effect of row spacing ranging from 65 - 80cm on sunflower in Morogoro, Tanzania also obtained similar results.

5.2.2. Yield Components

The number of seeds and seed yield per plant were significantly increased by increasing row spacing from 25 to 50cm while a further increase in row spacing to 75cm did not affect these parameters

significantly. Shivakumar et al. (1973) also recorded increased number of seeds per head as row spacing was increased. These positive responses could possibly be attributed to bigger plants and heavier heads produced at wider row spacing compared with narrow rows. Owonubi (1974) showed that more photosynthatically active radiation (PAR) was transmitted through wide - rows canopy of sorghum than narrow - rows canopy. Thus, at wider rows plant are likely to produce more assimilates than narrow - rows and this may be reflected in yield and yield components.

5.2.3. Yields

Seed yield (kg/ha)

Seed yield was significantly increased as row spacing was increased from 25 to 50cm. However, a non-significant increase was obtained when the spacing was further increased to 75cm. The increase in seed yield with increase in row spacing could be associated with the increase in the number of seeds per plant and seed yield per plant resulting from reduced competition at wider rows.

The significant increase in stover yield with increasing row spacing could be attributed to the reduced competition among plants as row spacing increased. Read et al. (1982) reported that at narrow row spacing there was grater competition among plants.

5.2.4. Seed quality

Seed oil content and seed crude protein were not significantly affected by row spacing. Similar result was obtained by Smith et al. (1981) using row spacing of 41 to 91cm in North Florida. Similarly, Rweyemamu (1980) who used row spacings varying from 65 to 80cm in Morogoro, Tanzania showed that sunflower seed oil content was not affected by row spacing. However, oil yield increased significantly with increasing row spacing up to 50cm due to the significant increase in seed yield as row spacing was increased (Table 12).

5.3.0. Interaction between plant density and row spacing

The interaction between plant density and row spacing was significant on plant dry weight (12 WAS) and head diameter.

Increasing row spacing at lower plant densities resulted in insignificant increase in head diameter and head dry weight probably due to reduced inter row plant competition for growth factors as row width increased. According to Vijayalakshmi et al. (1975) competition for moisture at wider rows was low.

However, at higher plant densities row spacing had no significant effect on these parameters (i.e head diameter and head dry weight) probably owing to increased intra row competition (due to reduced

plant spacing) at wider rows, which tends to make plants at wider rows behave like those at narrow rows.

5.4.0. Correlation

The significant positive correlation between seed yield, plant height and leaf area index (LAI) may be attributed to the fact that plant height and LAI are directly or indirectly associated with the determination of the total amount of photosynthate available for growth, development and seed yield. These characters also determine the effeciency of light interception consequently affecting the synthesis of assimilates and hence seed yield.

The significant positive correlation between seed yield per plant, number of seeds per head, head diameter, head dry weight and 1000-seed weight suggests that these parameters are not only related but also dependent on each other.

The highly significant negative correlation between seed yield and 1000-seed weight, number of seeds per head, leaf area per plant (10 WAS), head diameter, head dry weight and seed yield per plant indicates that seed yield is more dependent on plant dnesity than on individual plants' yields and yield

components. This result is similar to that of Smith et al. (1981) who indicated that higher yields at higher densities may be attributed to the increased number of seeds per unit area.

CHAPTER 6

6.0. SUMMARY AND CONCLUSION

A field study was conducted during the 1990 cropping season at Samaru to investigate the effects of plant density and row spacing on the growth and yield of sunflower (Helianthus annuus L.) Var. Issanka. The treatments consisted of five plant densities (17,800; 35,600; 53,300; 71,100 and 88,900 plants/ha) and three row spacings (25, 50 and 75cm). The 15 treatment combinations were laid out in a randomised complete block design with four replications.

Plant density had significant effect on growth characters, seed and oil yields and yield components. Percent establishment count and stand count at harvest, leaf area per plant, number of leaves per plant, plant dry weight, head dry weight, stem and head diameter were significantly decreased by increasing plant density. Plant height significant increased with increasing plant density from 17,800 to 53,300 plants/ha, beyond which there was no significant increase. Lodging was more severe at low and high densities compared with medium density. Plant density had no significant effect on number of the days to maturity.

The number of seeds per head, 1000-seed weight and seed yield per plant decreased with increasing plant density. The highest seed and oil yields per

hectare were obtained at 53,300 plants/ha. Stover yield increased with increasing plant density up to 88,900 plants/ha.

Row spacing had no significant effect on most of the growth characters. However, plant dry weight and head diameter significantly increased with increasing row spacing up to 75cm while stem diameter, head dry weight, number of seeds per head and seed yield per plant increased with increasing row spacing up to 50cm only.

Seed yield was significantly higher at 50cm than 25cm row spacing while the difference between 50 and 75cm was not significant. Similarly, stover yields were significantly higher at 50cm compared with 25cm row spacing. Row spacing had no effect on crude protein and oil concentration.

The interaction between plant density and row spacing was significant on plant dry weight (12 WAS) and head diameter. Both parameters were highest at 17,800 plants/ha and 75cm row spacing. Correlation analysis indicated that seed yield was significantly negatively correlated with most of the yield components, but the relationship between seed yield, plant height and leaf area index was significantly positive.

The results obtained in this study indicated that the highest seed and oil yields of sunflower were obtained at 53,300 plants/ha and at a spacing or 75cm between rows.

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Appendix1 : Mean temperature, relative humidity, sun shine hours and rainfall distribution at 10 days intervals during the period of the trial June - October, 1990.

Month	Days	Total rainfall (mm)	Temperature (^{o}C)		Relative humidity (%)		Sun shine hours
			Max	Min	AM	PM	
June	1-10	20.4	33.3	21.3	68.4	55.8	7.9
	11-20	62.1	31.1	21.1	77.8	60.4	7.6
	21-30	73.2	29.1	19.3	81.2	65.9	6.1
July	1-10	67.8	29.4	20.6	78.7	62.7	6.5
	11-20	84.6	28.2	18.7	81.2	66.7	4.9
	21-31	69.5	28.5	19.7	81.0	67.1	7.8
August	1-10	109.2	28.4	19.2	81.9	67.6	6.2
	11-20	44.7	28.4	19.3	84.3	69.7	6.7
	21-31	101.1	19.8	17.5	78.3	63.0	7.4
September	1-10	54.6	19.4	17.0	78.1	67.4	8.4
	11-20	58.8	19.5	17.1	74.6	63.1	6.6
	21-30	18.1	31.4	19.9	75.0	56.1	7.3
October	1-10	-	32.3	20.1	71.0	53.1	7.9
	11-20	-	32.5	19.0	59.6	54.1	8.1
	21-30	-	33.5	16.2	46.4	34.5	9.2
Mean		63.70	26.6	17.00	69.80	56.7	6.80

BIOGRAPHY

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B.

SCHOOL ATTENDED	YEAR FROM	YEAR TO	QUALIFICATION OBTAINED
1. Kofar Area Pri.Sch.	1966	73	Primary Sch.Cert.
2. G.S.S Birnin-Kudu	1973	78	W.A.S.C.
3. Sch. for Prelim Studies(Rem.Course)	1979	80	W.A.S.C.
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C. JOB EXPERIENCE:

1. Ansarul-Islam-Sec. Sch. Ilorin, Kwara State (N.Y.S.C.)	1986-87	Teaching Agric. Science Subject.
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