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THE EFFECT OF INTER-ROW SPACING, PLANT POPULATION AND PLANTING DATE ON THE SEED YIELD, YIELD COMPONENTS AND OIL CONTENT OF SUNFLOWER (Helianthus annuus)

BY

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DECLARATION

I hereby declare that this is my original work and has not been presented in any other University.

Date 2nd July 1987 .... Signed. Gauma ....
CANDIDATE

This thesis has been submitted for examination with our approval as supervisors.

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ABSTRACT

This thesis reports on experimental work carried out on sunflower (*Helianthus annuus*) over two seasons; short rains of 1984 and long rains of 1985 at the Faculty of Agriculture Field Station of the University of Nairobi, Kenya. The Field Station is located at an altitude of 1850 metres above sea level and has an average rainfall of 925 millimetres. The rainfall recorded in the two seasons was 489.7 mm for the short rains and 631.4 millimetres for the long rains.

The main objectives of the experiment were to find the effect of rowspacing, plant population and planting date on yield, yield components and oil content.

The experiment was carried out in a split plot design with dates of planting as main plots and rowspacing and plant population as subplots. The difference between the first date of planting was two weeks while the difference between the second date of planting and third date of planting was three weeks. The rowspacings used were 30 cm and 90 cm while the plant populations used were 25,000, 50,000, 75,000 and 100,000 plants per hectare. The following were the subplot treatments which came out after working out the plant-plant spacings; 90 x 11 (100, 000 plants per hectare), 90 x 15 (75,000 plants per hectare),

90 x 22 (50,000 plants per hectare), 90 x 44 (25,000 plants per hectare), 30 x 33 (100,000 plants per hectare), 30 x 44 (75,000 plants per hectare), 30 x 66 (50,000 plants per hectare) and 30 x 133 (25,000 plants per hectare). All these subplot treatments were replicated three times in the three main plots.

The results were as follows;

(i) Delay in planting by five weeks caused a reduction in seed yield of 30% - 40% but an increase in oil content. It also caused a significant reduction in the yield components.

(ii) The increase in plant population from 25,000 plants per hectare to 100,000 plants per hectare had no significant effect on seed yield but reduced the yield components. The plant populations of 50,000 and 75,000 had significantly higher oil content than 25,000 and 100,000 plants per hectare.

(iii) Increasing rowspacing from 30 cm to 90 cm had no significant effect on seed yield and yield components but had a significant effect on oil content in one season only.

(iv) There was no interaction among planting date, plant population and rowspacing.

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1.0 INTRODUCTION:

1.1 Origin and Geographical distribution of sunflower:

Cultivated sunflower is a crop native of America. It was grown by Indians for food at Roarioke island as long as in 1586, and in New England for hair oil in 1615. It was introduced to Europe in the 16th Century by the Spaniards. Its cultivation then spread to many countries especially the Soviet Union. At the end of the 19th century, improved varieties were re-introduced to Latin America especially Argentina where the crop is of economic importance. (Arnon, 1972).

Sunflower is a relatively new crop to most areas of the world though it has been grown as a major source of oil in the Eastern European countries for several decades (Litzenberger, 1974). At present sunflower constitutes the second most important oil seed crop (following soybeans) in world production. World production is led by the temperate countries where Argentina, Bulgaria, Romania, Yugoslavia, U.S.S.R. and Uruguay are the major producers. In the Tropics and Sub tropics; Ethiopia, Morocco, Kenya, Tanzania and Turkey are notable producers.

(Litzenberger, 1974). In the coutries mentioned above sunflower is usually grown as a major crop in rotation with maize, sorghum and millet and competes for land with such crops as groundnuts and the food grain legumes.

1.2 Ecological requirements of sunflower:

Sunflower requires warmth and ample light but is not sensitive to daylength. It is fairly resistant to heat and cold conditions. It thrives well when temperatures are not less than $10^{\circ}C$ though it can stand lower temperatures without damage. This nature of adaptability makes sunflower to be grown in a wide range of climates.

Sunflower is fairly drought resistant due to its well developed root-system. It grows well in areas receiving 750 millimetres of annual rainfall and above (Acland, 1971). Dry weather is required during ripening to avoid head rot. It can be grown up to 2600 metres above sea level. It can grow in most soils including sandy soil and is far more tolerant to low soil fertility than other crops.

1.3 Sunflower production in Kenya:

Kenya is the largest producer of sunflower in East Africa and the crop is mainly grown in the maize growing areas such as Western and Rift Valley Provinces (Acland, 1971).

The crop has been grown for many years on large farms in Western Kenya with varying degrees of success (Weiss, 1965). Generally, it has not been possible for sunflower to replace maize as a cash crop because the seed yields have been too low. It is however a possible alternative cash crop for farmers in the wetter altitudes and the drier low altitude areas of Kenya.

The Ministry of Agriculture and the Oil Crop Division of East Africa industries are making significant contributions to sunflower production in Kenya. Efforts are already being made to increase sunflower production in the marginal areas of Central and Eastern Provinces. This is manifested by the fact that an estimated 5,000, 18,000, 39,000, 66,000 hectares were under sunflower in 1972, 1978, 1979, and 1980 respectively. (Central Bureau of Statistics 1979 - 1980) in terms of production in tonnes sunflower has increased sevenfold from 1985 to 1988 (Nganga, 1988). Sunflower exports alone earned about 7 to 8 million Kenya shillings between 1939 and 1951 (Statistical Abstract (Kenya), 1976). Sunflowr and other oil seeds have been earning Kenya an average of 9.5 million Kenya Shillings annually in the last ten years (Statistical Abstract (Kenya), 1976).

Raw sunflower seeds are marketed locally. This is indicated by the increasing number of oil mills in Nakuru, Mombasa, Nairobi and Kisumu; some find their way into world markets (Lihanda, 1978).

1.4 Utilization of Sunflower.

Sunflower has a number of uses which make it a potential economically important crop. Some of the uses discussed below may not be considered important in Kenya at the moment but show the potential value of the crop.

(i) Sunflower seed as food.

Sunflower seeds can be eaten as salted whole seeds and as roasted nut-meats (dehulled). The crop may be processed for oil extraction by using seed with or without hulls. The cake containing hulls is an excellent feed for ruminant livestock and the cake and meal produced by processing dehulled seed is an excellent protein food for humans (Sandhu, 1977).

While being slightly deficient in lysine, the net dietary value of sunflower protein is 93% which is as high as egg protein while soybean protein rates 62% and groundnut protein 69%. It is comparable to soybean protein in terms of digestibility and in biological value and more balanced in essential amino acids than most other vegetable proteins (Litzernberger, 1974).

The sunflower seed and meal are also high in Calcium, Phosphorus and Iron that are essential in human diets. It has high contents of vitamins; thiamine , riboflavin and niacin. The oil is used for cooking, fuel in oil lamps and for manufacturing of margarine (Litzenberger, 1974).

ii) Hulls from decortification:

The hulls from decortification of sunflower seeds can be used as a food supplement for livestock. The hulls may serve as raw materials for furfural production and can be used as chicken litter or for burning in industrial furnaces.

iii) Threshed heads and stalks:

The dried sunflower heads after de-seeding can be ground for animal feed due to their high pectin content.

iv) In weed control:

Sunflower was originally introduced to Africa as a weed control crop, before the adoption of mechanical and chemical control measures. It grows rapidly and vigorously and is well able to compete with weeds. This is particularly so once the large leaves form a dense canopy to shade and smother the weeds.

v) As green manure and silage crop:

Due to its quick growth sunflower can act as a green manure crop when mixed with a legume such as bean. When ploughed in, it improves the soil organic matter status.

In dry areas, sunflower mixed with maize, cowpeas and broadcast gives a good silage of much higher protein value than a sole maize crop.

vi) Therapeutic use:

Since sunflower is rich in linoleic

acid, it is used in hospitals for treating patients suffering from physiological disorders of the arteries which cause heart attack due to its property of arresting the cholesterol level in blood.

1.5 JUSTIFICATION OF THE STUDY

Date of planting and planting spacing are some of the most important factors limiting the production of annual crops such as sunflower in Kenya. It is important to note that one of the factors leading to poor yields in most small scale farms is low plant populations. This makes the plants not use the available soil resources well. It is therefore imperative that optimum stand is established for each crop planted (Acland, 1970).

Many farmers have also often been faced with the problem of using the rowspacing which will allow most of the farm operations to be carried out. Operations like weeding, spraying and harvesting need a wider rowspacing for them to be carried out efficiently. The use of this wide rowspacing may affect the yield of some annual crops. A balance should therefore be struck in choosing a rowspacing which does not reduce yields. Further,many farmers are usually faced with the problem of late planting. It must be emphasised that late planting has often resulted in serious yield reductions of many crop such as maize in Kenya.

Sunflower was chosen for the experiment because it is one of the most important and most popular oil crop among farmers.indeed as the country embarks on programmes to ensure self-sufficiency in edible oil production through the East Africa Industries there is need for more research on the agronomy of these oil crops.

The objectives of the present study were;

(a) To determine the effect of different plant populations on seed yield, yield components and oil content of sunflower.

(b) To determine the effect of planting date on the factors listed in (a).

(c) To determine the effect of inter-rowspacing on the factors listed in (a).

(d) To determine the influence of yield components on the final yield.

2.0 LITERATURE REVIEW:

2.1.1 Effect of planting date on the seed yield of sunflower:

Research workers investigating the effect of planting date on sunflower seed yield have documented reduction in seed yield from late planting. Thus Alessi et al (1977) In his trials using pereduvik (oiltype) variety in the drier parts of Northern Great plains in Canada reported a reduction of 300 kg/ha in seed yield as a result of delaying planting by two weeks. Johnson and Jellum (1972) reported similar results in Minnesota, United States of America. In an experiment to determine the effect of six planting dates differing with 75 heat units in three cultivar of sunflower, Enns (1970) reported consistent reductions in seed yield from each delay in planting. He did not, however, report the magnitude of seed yield reductions nor the intervals in the planting dates. Miller et. al (1984) reported that delaying planting from Mid May to early June reduced yields by an average of 8% and delaying planting until late June resulted in an additional 24% yield reduction at two experimental sites in the United States of America: Arlington having more favourable climate and spooner having cooler and shorter growing season. They reported that at plant populations of 45,000 plants per hectare to 72,000 plants per hectare delaying planting reduced seed yield and yield components. In his investigations of the factors affecting yield, water use efficiency and quality of dryland sunflower grown in the Southern high plains of United States, Jones (1984) obtained seed yields from early planting. He reported that delaying planting from May to July, from 1975-1977 resulted in large reductions in seed yield caused primarily by poor plant emergence resulting from dry conditions at the soil surface after seeding. He argued that the large differences in yield among planting dates in the various years resulted mainly from the effect of precipitation amount and distribution during the growing period. Thus, 1975 plantings resulted in high yields in May and April plantings because sunflower flowered in July when rainfall was abnormally high but later plantings, low seed yields because of severe water stress resulting from low August and September rainfall. In Western Kenya, Weiss (1966) has reported a sharp decline in seed yield from delayed plantings.

2.1.2 <u>Effect of planting date on the yield components of sunflower</u>:

Yield components of sunflower include: diameter of sterile centre of sunflower head, head diameter and 1000 seed weight. Few research workers on sunflower have investigated the effect of planting date on yield components of sunflower. Johnson and Jellum (1972) reported that head diameter and 1000 seed weight decreased as planting dates was delayed. Unger and Thompson (1982) found no consistent trends on the effect of planting date on head diameter in United States. Apart from the past work on this aspect of sunflower production being inadequate, it has also not been exhaustive of all the yield components.

2.1.3 Effect of planting date on oil content of sunflower:

Alessi et. al. (1977) in the first season of this trials in Northern Great Plains, Canada reported an increase in oil content from 36% to 40% between the 21st May and June 5th plantings and 40% to 44% between 5th June and 26th June plantings. In the second season of his trials he reported a reduction of 45% to 43% between the 23rd May and 10th June plantings and 43% to 30% between the 10th June and 27th June plantings. He argued that the dry conditions present during seed development in the second season of his trials reduced only content. Nevertheless, Robinson (1970) found decreased oil content from late plantings. In a study to investigate the effect of planting date on growth, yield and oil content of irrigated sunflower in United States of America, Unger (1980) reported that oil content decreased with delay in planting. He found that oil content was relatively constant with early plantings but progressively decreased with later plantings. He argued that oil content was strongly affected by planting date because the different planting dates resulted in seed development during periods of different temperatures. He observed that rainfall had little effect on the optimum date for irrigated sunflower implying that both temperature and rainfall may affect the optimum date for non-irrigated or rainfed sunflower. However, Enns (1970) working on 3 cultivars of sunflower and using six planting dates from May 9th to June 12th reported that there was an average increase in oil content from 39.9% to 44.2% from the first to last plantings. He reported that the early maturing cultivar, Armavirec had the highest increase (34.6 - 42.9%). He argued that this was probably due to the fact that the period of oil synthesis and accumulation for the first planting fell during very hot weather whereas later plantings matured under more favourable conditions. Johnson and Jellum (1972) working in Minnesota, United States have reported that oil content of sunflower decreased from early May to late June plantings when the crop was grown in temperatures either lower or higher than 21°C. Unger and Thompson (1982) however cites Robinson et. al. (1979) as having reported that latitude and average temperature from the full bloom stage to harvest of field - grown sunflower did not significantly affect oil content of seed obtained from 22 locations in 1976 and 35 locations in 1977 in North America. Sunflower grown at a constant temperature of 21°C has been observed to have a higher oil content than that grown at either a lower or higher temperature (Canvin, 1965 cited by Unger and Thompson (1982). In contrast, Johnson and Jellum (1972) found that the oil content of seed from late planted sunflower maturing during cooler weather was lower than from earlier planted sunflower maturing during warmer weather. These different responses may have been due to temperature effects at specific developmental stages or to factors other than temperature. In Australia Unger and Thompson (1982) also cited Anderson (1975) as having reported that sunflower seed developement occurring when the mean daily temperature was above 15°C accumulated dry matter and oil more rapidly than when the mean daily temperature was below 15°C. He argued that the maxima for oil content was reached at about the same time as that for drymatter. He who observed that the later planted sunflower had reduced seed yields and oil content because of severe water stress during flowering, Unger (1980) using irrigation and planting at two week intervals in the United States and Robinson (1970) using six sunflower varieties and seven dates of planting ranging from 24th April to 28th June in the United States.

Alessi et. al. (1977) carrying out his experiments in the drier parts of Northern Great Plains in Canada and using three dates of planting; Mid may (Early), Early June (Midseason) and end of June (late) observed that seed yield decreased from 21st May to 26th June in 1973 when it was hot and dry. He reported a reduction of 300 kg/ha as a result of two week's delay-and an increase in oil content from 36% to 40% between 21st May and June 25th and 40% to 44% between 5th June and 26th June plantings. In 1974 when there was enough rainfall during the early stages of sunflower growth but drought after flowering he reported a reduction of 45 to 43% between 23rd May and 10th June plantings and 43% to 30% between the 10th June and 27th June plantings and concluded that sunflower reached physiological maturity at about the same time at which the maxima for any of the above factors was reached. He realized, however, that environmental conditions, mainly different temperatures could affect these results. Jones (1984) has also reported reduction in oil content from late planting in dryland sunflower grown in the Southern High plains - U.S.A.

2.1.5 Relationship between seed yield and yield components.

Johnson and Jellum (1972) in their studies to determine the effect of planting date on sunflower yield, oil and plant characteristics in United States of America observed that head diameter and 1000 seed weight decreased as planting date was delayed. Seed yield also decreased during the same period showing positive correlation between seed yield and yield components. Nevertheless Unger and Thompson (1982) found no consistent trends on the effect of planting date on head diameter in United States.

With respect to effects of plant population Campbell (1975) reported that yields were relatively constant at plant populations from 40,000 to 85,000 plants per hectare and attributed this observation to the fact that sunflower compensated for differences in plant populations by producing larger seeds and heads at lower plant populations.

In their studies on the effect of plant population and rowspacing on sunflower agronomy at swift current in Canada , Vijayalakshmi et. al. (1975) reported that yields from 25,000 plants per hectare were 28% higher than those of 125,000 plants per hectare but were significantly different from 75,000 plants per hectare. They showed that similarity within each range of plant population resulted from an internal adjustment of yield components; the number of filled seeds per head and 1,000 seed weight both of which decreased exponentially as plant population increased. Similar results and explanations have been provided by Miller et al. (1984) who worked on the effect of planting date and plant population in Northern United States. These workers reported that sunflower seed yields were generally not affected by differences in plant populations ranging from 28,700 plants per hectare to 73,000 plants per hectare arguing that relatively constant yield obtained as the population increased was a consequence of reduced yield components. The experimental conditions under which these experiments were carried out are however not mentioned.

2.2.1 Effect of Plant Population on Seed Yield:

Muigai and Amiyo (1975) reported that increased plant population increased yield to a certain maximum level then further increase in plant population decreased yield at Thika Research Station in Kenya. Conversely, Campbell

(1975) argued that sunflower compensates for differences in plant populations by producing larger seeds and heads at lower plant populations. He reported that yieds were relatively constant at plant populations from 40,000 to 85,000 plants per hectare. In their studies on the effect of plant population and rowspacing on sunflower agronomy at Hyderabad, India and at swift current and Saskatchewan in Canada, Vijayalakshmi et. al. (1975) reported that sunflower can be grown over a wide range of plant populations and rowspacings. At Hyderabad, India they reported yield plateaus of approximately 900 and 1350 kg/ha over population ranges of 18,000 to 32,000 plants per hectare and 56,000 to 98,000 plants per hectare respectively.

At swift current in Canada they reported that yields from 25,000 plants per hectare were 28% higher than those of 125,000 plants per hectare but were significantly different from 75,000 plants per hectare. They showed that similarity within each range of plant population resulted from an internal adjustment of yield components, the number of filled seeds per head and the 1,000 seed weight both of which decreased exponentially as plant population increased. Alessi et al. (1977) reported that seed yields decreased with increase in plant population from his trials at the semi arid conditions of Northern Great Plains, Canada. Nevertheless, Lofgren and Vance (1970) reported that populations of 37,500, 50,000, 62,500, 75,000, 87,500 and 100,000 plants per hectare had no effects on seed yield in U.S.A. He did not, however, give the conditions under which the trials were carried out. Similar results have been reported by Jones (1984) and Robinson et. al. (1980). Jones (1984) argues that the reported effects of plant population on sunflower seed yield appear contradictory but agreement is general that sunflower compensates within a wide range of populations for too thick or too thin stands by adjusting headsize and seedsize and seed numbers. Zubriski and Zimmerman (1974) found out that increasing plant density increased seed yields at all locations. The highest and intermediate plant densities outyielded lowest plant populations by an average of 898 and 322 kg/ha respectively. Nevertheless, Miller et. al. (1984) reported that sunflower seed yields were generally not affected by differences in plant populations ranging from 28,700 plants per hectare to 73,200 plants per hectare arguing that relatively constant yield obtained as the population increased was a consequence of redu ed yield components.

2.2.2. Effect of plant population on oil content:

Alessi et. al. (1977) reported that oil content was not affected by plant population. Similar results have been observed by Vijayalakshmi et. al.. (1975). Nevertheless Lofgren and Vance (1970) and Zubriski and Zimmerman (1974) have reported only a small increase in oil content from increased plant densities. Jones (1984) in his trials in sunflower in Southern United States has reported a small but significant increase. Plant populations of 17,000 to 62,000 plants per hectare have been reported to increase oil content (Robinson et. al., 1980) Miller et. al. (1984) has also reported oil content was consistently higher in plant populations between 43,800 and 70,700 plants per hectare at one of his experimental sites in the United States.

2.2.3 Effect of plant population on yield components:

Vijayalakshmi et. al. (I975) reported that 1000 seed weight decreased as plant population increased in Canada. He did not, however, set limits in population for this result to be obtained. Lofgren and Vance (1970) using plant populations of 37,500, 50,000, 62,500, 75,000, 87,500 and 100,000 plants per hectare reported reduction in head diameter and 1000 seed weight as plant population increased. Similar results have been obtained by Robinson et. al (1980) but with plant populations ranging between 17,000 and 62,000 plants per hectare

2.3.1 Effect of rowspacing on seed yield:

Determination of the effects of inter-rowspacing on the seed yield, yield components and oil content is based on the agronomic fact that plant spacing consists of two aspects;. plant density and planting rectangularity. The latter gives rise to three types of planting patterns: square planting pattern where inter-rowspacing is equal to or almost equal to intrarowspacing, rectangular pattern where inter-rowspacing is greater than intra-rowspacing and a pattern consisting of very wide rows and very small intra-row spacing (Arnon, 1972) As can be noticed in the naming of planting patterns, rowspacing is the factor which dictates the type of planting pattern. The names of planting patterns are derived from the area occupied by an individual plant. As the inter-rowspacing increases the degree of rectangularity increases and vice versa.

It would be logical to expect that square arrangements of plants would be more efficient in the utilization of the light, water and nutrients available to the individual plant than would be a rectangular pattern as square pattern would reduce to a minimum the competitive effects of neighbouring plants. Holliday (1960) has shown that reducing rowspacing below 15-20 cm i.e. reducing rectangularity generally increases yield slightly and vice versa. In a rectangular pattern it was found in a number of crops that with increasing plant density, increasing the inter-row distance was more beneficial than reducing intra-row distances, to adjust to higher levels of potential yield (Holliday, 1960).

The introduction of selective herbicides especially preplant and pre-emergence application of them to replace inter-row mechanical cultivation has suggested that narrower rows can now be used (Arnon, 1972). Nevertheless, extremely narrow rows would be necessary to achieve square arrangements with plant-density required for maximum yields of many crops such as the small grain cereals (Arnon, 1972).

Much research has shown that quite considerable variations in planting patterns have relatively little influence on yield per unit area for a wide range of crops (Harper, 1961). With broadbeans, at equal numbers of plants per unit area, rowspacings of 17, 34 and 51 cm had no influence on yields per hectare (Hodgson and Blackman, 1956 cited by Arnon, 1972). Extreme rectangularity may be detrimental to yield but usually some degree of rectangularity may just be as satisfactory as square planting (Holliday, 1960).

When moisture supply is limited, plant population may be adjusted to available soil-moisture levels, either within rows or between rows but increasing the distance between rows is preferred because if the distance between the plants is increased the young plants with little or no intra-row competition show excessive vegetative development; soil moisture is rapidly depleted and plants are unable to mature their ears, tubers or grain etc. conversely if the distance between rows is increased and plants spaced more closely within the rows the soil moisture supply is not exhausted as rapidly as in narrow rows (Brown and Shrader, 1959) These people (Brown and Shrader, 1959) argue that intra-row competition prevents excessive vegetative growth and the laterally developing roots have to grow further to reach moisture. They therefore continue to find available moisture between the rows later in the season when it can be used for example, in grain production provided the distance between rows has been well adjusted to available soil moisture. Brown and Shradeer (1959) also reason that it might be expected that wide rowspacings by exposing large areas of bare soil to radiation would increase moisture losses due to evaporation thereby defeating the purpose of the wider rowspacings but under dryland conditions, they reason, evaporation is influenced more by the moisture supply at the soil surface than by radiation. Therefore once the upper soil layer has dried further moisture losses by evaporation become negligibile. Under these conditions wide rows are not more conducive to greater water loss by evaporation than are narrow rows.

When moisture is not limiting, planting arrangements may affect the efficiency of radiant energy interception or of moisture utilization. The main effect of rowspacing on yield is believed to be largely due to differences in radiant energy distribution closer and more uniform plant distribution should increase the proportions of radiant energy which is intercepted by plants and reduce that reaching the soil surface (Arnon, 1972). In experiments with maize it was shown that the proportions of radiant energy which is intercepted by the plants was higher when inter-rowspacing decreased (Yao and Shaw, 1964 cited by Arnon, 1972). It has been estimated that 60 cm inter-rowspacings might increase the energy available for photosynthesis by 15 to 20% compared with 100 cm rows (Denmead et. al., 1962).

Tanner and Lemon (1962) have shown that, when soil moisture is available and a substantial crop cover shades the ground, most of the net radiation is used for evapotranspiration. Therefore differences in net radiation resulting from different plant populations and rowspacings should also result in differences in water use efficiency in trials carried out by Yao and Shaw (1964) it was found that, in maize fields when inter-rowspacings were maintained constant, doubling the plant density increased water use, but the increase in water use was much smaller than the increase in plant density. The narrowest - rowspacing (52 cm) used significantly less water than did wider spacings, with differences in water use between treatments becoming more apparent as the season progressed. The highest efficiency of water-use was achieved at the narrowest spacings with the double plant density.

With sorghum grown with two or more irrigations, narrow rows produced considerably more grain than did wider rows with identical plant populations. Soil moisture was extracted more rapidly, after irrigation, directly under plants than midway between rows, for rows more than 35 cm apart. It is therefore assumed that a more uniform extraction of soil moisture under narrow rows led to their grain producing ability when water was not limiting. (Grimes and Musick, 1960).

Several research workers have reported conflicting results on the effect of rowspacing on seed yield. Vijayalakshmi et. al. (1975) using rowspacings of 36, 53, and 89 cm at Hyderabad, India and at swift current in Canada on the variety Armaveric reported no effect of rowspacing on seed yield. When they used the cultivar sunrise at the same site using rowspacings of 45, 60, 90 and 135 cm at plant populations of 37,000, 44,000, 56,000 and 74,000 plants per hectare they again reported no effect on seed yield concluding that sunflower can be manipulated over a wide range of rowspacings without affecting seed yield. However, Alessi et. al. (1977) reported that rowspacings of between 30 cm and 90 cm significantly increased seed yield at the semi-arid Northern Great plains of United States. Row spacing of 30 cm has been reported to outyield 45 cm and 60 cm in India (Kabaaria, 1975). The conditions under which such findings were obtained were however not disclosed. Rowspacings of 30.48, 60.96 and 91.44 cm have been reported to have no effect on seed yield using two unnamed high oil content sunflower cultivars in the United States (Lofgren and Vance, 1970). Robinson et. al. (1982) reported that in contrast to experience with maize (Zea mays L. and Soybean (Glycine max. L.) and grain sorghum (Sorghum bicolor (L.) rowspacing variation from 50 to 100 cm did not affect seed yield. They suggested that the height and phototropic growth habit of sunflower may be involved in its lack of response to rowspacing variation.

2.3.2 Effect of rowspacing on yield components:

Vijayalakshmi et. al. (1975) working in India reported that rowspacings of 36,53 and 89 cm used with plant populations of 25,000, 75,000 and 125,000 plants per hectare had a significant effect at swift current in India. He did not however describe the experimental conditions and which range of rowspacings affected 1000 seed weight. Nevertheless, Lofgren and Vance (1970) using open pollinated sunflower cultivars and rowspacings of 30.48, 60.96 and 91.44 cm in plant populations of 37,500, 50,000, 62,500, 75,000, 87,500 and 100,000 plants per hectare found significant increase in 1000 seed weight and head diameter from increased row spacing. He also did not specify other experimental conditions and other observations. The experiment was done in the United States of America.

2.3.3. Effect of rowspacing on oil content:

Both studies by Vijayalakshmi et al. (1975) using Armaveric sunflower variety in Canada and India at rowspacings of 37,89 and 53 cm and Lofgren and Vance (1970) using open pollinated sunflower cultivar in the

United States of America at rowspacings of 30.48, 60.96 and 91.66 cm rowspacing, have reported no effect on oil content. Nevertheless Alessi et. al. (1977) has reported increase in oil content from increased rowspacings in one season only in the semi-arid Northern Great Plains of Canada. Investigations on the effect of rowspacing on oil content of sunflower are therefore still few and inconclusive.

The literature review above shows that information is lacking on the combined effects of the factors reviewed on sunflower performance. Past investigations on these factors have focussed mainly on their individual effects. It must be stressed that, timely planting for example, is just one of the many factors which influence crop yields. Plant density and planting rectangularity are also important in determining the final yield of most crops.

The review also shows that results of some of the aspects of sunflower production, like yield components and oil content as affected by the factors investigated are inconclusive. Besides, many of the research findings on these factors have been mainly reported for United States of America. It is necessary to try such experiments under Kenya's agroecological conditions.

2.4.0 The effect of date of planting, plant population and rowspacing on other annual crops:

2.4.I Effect of date of planting on maize yields:

Several research workers have reported declines in maize yields due to late planting in East Africa. In Kenya Evans (1963) quoted a trial carried out at Kabete, Nairobi in 1914 and another at Bukura, Kakamega in 1927. Goldson (1963) found that maize yields at Kakamega declined from 9,600 kg/ha with early planting to almost zero when planted 3 months later. He got similar results with the same treatments at Busia. Moberly (1962) In experiments at Kitale obtained yields of over 4500 kg/ha from maize planted in March compared with yields of 1390 kg/ha from plantings at the end of May. At Katumani, Machakos yield reductions of 5 - 6% for each day's delay in planting after the start of the rains were reported by Dowker (1964). In Tanzania the results of 36 time of planting trials on maize carried out at several different stations from 1953 to 1962 were reviewed by Akehurst and Sreedham (1965). They concluded that maize yields tended to reach their peak with planting shortly after the onset of the rains and thereafter yields declined rapidly. Hemingway (1955) working at Nachingwea, Tanzania on "Southern Corn Rust" infections caused by *Puccinia polysora underw* obtained yields of 2943 kg/ha from early and 760 kg/ha from late plantings. Similar results were obtained by Brown (1963) from Central Africa and by Cammack (1953) from West Africa.

Several hypothesis have been advanced to explain the time of planting effect. Hemingway (1957) suggested that the yields of later plantings were reduced because they were more severely attacked by fungal diseases than earlier plantings. Various workers have suggested that the time of planting effect is linked with seasonal fluctuations in the levels of soil Nitrogen while others have concluded that it is caused by moisture deficits at critical stages of growth. Some other possible causes mentioned by MacDonald (1968) include changes in solar radiation and daylengths and seasonal variations in the incidence of insect pests.

It has now been shown that the main explanations for the time of planting effect are:

(i) There is a connection between time of planting and the incidence of fungal leaf disease (Allan, 1971).

It has been frequently observed by farmers as well as scientists that later planted maize appears to be more heavily attacked by common Rust, puccinia sorghi schw and white blight (The main maize growing areas of Kenya are at altitudes of over 1200 metres where P. polysora rarely occurs and is not a serious pathogen. The important fungal leaf diseases in Kenya are puccinia and white blight and Moberly (1962) reported that in his trials late planted maize was heavily attacked by P. sorghi and Helminthosporium Turcicum or white blight. Which must have contributed to the reduction in yield. Goldson (1963) recorded a large increase in the percentage of diseased cobs in the later planted maize at Kakamega in Kenya.

(ii) Time of planting in relation to the moisture demand and supply.

Several workers have suggested that the decline in yields of late planted maize is due mainly to moisture deficit stresses. In such crops (Dowker, 1964) attributed the low yields of maize to lack of moisture during the critical stages of growth. Turner (1965) also found that water shortages during the post flowering period were an important cause of the lower yields of late planted maize.

Allan (1971) concluded that in areas with long rainy seasons such as Kitale the main cause of the decline in yields of late planted maize is the early growth check caused by planting in wet, poorly aerated soils. In areas with shorter rains, late planted maize may suffer this early check and then may also suffer from moisture deficits at grain filling. Allan cited effects of excess moisture as poor root aeration which reduces root growth, nutrient uptake, shoot development and hence grain initiation.

2.4.2 Effect of plant population and rowspacing on maize yields:

Experimental conditions have tended to influence the effect of plant population and rowspacing on maize yields.Giesbrecht (1969) reported that rowspacings of between 50 and 95 cm had no significant effect on maize yield while increasing the population from 30,000 to 75,000 plants per hectare resulted in a substantial increase in yield under adequate moisture conditions. Under less than adequate moisture conditions, peak production occurred at 60,000 plants per hectare. This obviously shows that when moisture is limited using a high plant population will not maximise yields due to too much competition for it-and vice versa. Mannering and Johnson (1967) reported that soil erosion on fields of maize planted at narrow rowspacing (51 cm) was 24% below that on fields planted on widely spaced rows (102 cm) in United States of America. Nunez and Kamprath (1969) reported an optimum maize production at 51,750 plants per hectare in India. They found no significant effect of rowspacing on yield except under drought conditions when 53 cm rows gave higher yields than 106 cm rows. This tends to contradict the hypothesis that under limited moisture conditions the distance between the rows has to be increased to create intra competition which prevents excessive vegetative growth (Brown and Shrader, 1959). Moll and Kamprath (1977) found that increased population density resulted in higher yields in India. They did not however give the experimental conditions. In a previous study conducted in the long rains of 1978, it was found that maize yields increased significantly with decrease in rowspacing at one plant per hill (Nadar, 1983). At two plants per hill, maize planted at 75 cm rowspacings with about 70,000 plants per hectare yielded the highest. Nadar (1983) carried out experiments in three localities for several seasons with different rainfall conditions in order to study the effect of population densities and rowspacings on maize yields as influenced by different environments. The results indicated that there was a significant effect of rowspacings on maize yields at any given population density. These effects were influenced by population levels as well as by rainfall conditions. It was found that planting maize at 75 cm rowspacing would optimize maize yields under almost all rainfall conditions tested. The optimum population to be planted under favourable rainfall conditions was found to be around 70,000 plants per hectare. Under less than favourable conditions, 20,000 plants or less would produce the highest yields. These experiments were carried out at Katumani, Kampi ya Mawe and Muguga. In a study conducted to determine maize yield response to relay planting and conventional planting as affected by population, rowspacing and cropping systems under Katumani conditions in 1978. Nadar (1983) reported that maize response to planting methods was influnced by rowspacing and cropping systems. While yields of relay-planted crops were lower than those of conventionally planted crops in the sole-crop systems, they were mostly higher in the intercrop systems. Under both planting systems, rowspacing, like population had a significant effect on maize yields with 75 cm rowspacing producing the highest yields.

Allan (1971) in his maize husbandry trials in Western Kenya reported that hybrid maize outyielded the local maize by 13.9 quintals per hectare whereas at the higher population the margin increased to 20.5 quintals per hectare. Alternatively, increasing the population of local maize raised yields by 10 quintals whereas the higher population increased the yields of the hybrid by 16.6 quintals per hectare. This shows an interaction between genotype and environment. When he added the Nitrogen fertilizer factor to the above experiment he found that the yields of maize at the low population increased by 4 quintals but at the higher population the increase due to Nitrogen was 8.7 quintals. Increasing the population without Nitrogen raised yields by 10.9 quintals and with nitrogen the increase was 15.6 quintals per hectare. There was a positive interaction between Population and Nitrogen. Without phosphate fertilizer Nitrogen increased yields by 4.0 quintals per hectare whereas with phosphate fertilizer the increase from Nitrogen fertilizer was 8.6 quintals per hectare,without Nitrogen fertilizer phosphate raised yields by 4.1 quintals. There was a positive interaction between Nitrogen and phosphate. It is therefore obvious from these observations that the effect of rowspacing and plant population on maize yield depends on environmental conditions.

This experiment was designed to find how these factors affect sunflower, an annual crop similar to maize in its cultural practices.

3.0 MATERIALS AND METHODS:

3.1 Site description:

The experiment was conducted during the short rains of 1984 and long rains season of 1985 at the Field station farm of the Faculty of agriculture, University of Nairobi. The soils of the farm are of nitosol type, dark-reddish brown with clay content of about 60% (Nyandat and Michieka, 1970). There is little sand ranging between 3 - 4%. The soil is of kaolinitic class 1:1 clay silicate and is rich in iron and Manganese Oxides. Organic carbon content at 0 - 10 centimetres is 3 - 5% and at 10 - 20 cm depth is 4.5% and at deeper than 100 centimetres is less than 1%. The soil pH ranges between 4.5 and 7.0 with an average of 5.5 (Nyandat and Michieka, 1970).

The total amount of rainfall during the first season (short rains) of the experiment was 489.7 millimetres and 631.4 millimetres during the second season (long rains) of the experiment. These rainfall amounts were normal for Kabete except for their monthly distributions which were very poor. Other weather factors like temperatures and meanly monthly evaporations were also normal for Kabete.

3.2 Planting materials, land preparation and planting:

The land was ploughed and harrowed two weeks before the onset of the rains. Planting was done after one-week after the onset of rains for the first season's experiment (short rains) and after three days from the onset of rains in the second season (long rains). The variety planted was "commet". This variety does well at altitudes of 1000-2000 metres above sea level and it is tall, late maturing taking 125 days to mature. It is planted at a seed rate of 4 kilogrammes per hectare and has lower yields per hectare than most sunflower varieties. It gives yields of up to 1350 kg/ha. It has a fair oil content. The seeds were planted at a depth of 2 cm and at varying spacings according to treatments applied to each plot. The fertilizer used during the two seasons was Diammonium phosphate (Nitrogen 18%, P_2O_5, 46%) at the rate of 150 kg per hectare. The planting dates were as follows; 6th October, 24th October and 12th November during the first season and 29th March, 11th April and 2nd May during the second season. The crop was weeded twice in the experiment during its growth-for the first and second seasons respectively.

3.3 Experimental design and treatments:

The experimental plot measured 74 metres by 39 metres. Mainplots, consisting of planting dates were split into subplots measuring 1.6 metres by 8 metres.

A split plot design was used with main plots consisting of two weeks between first and second planting dates and three weeks between second and third planting dates. The subplots consisted of rowspacing and plant population variables. Two rowspacings: 30 and 90 cm and four plant populations: 25,000; 50,000; 75,000 and 100,000 plants per hectare were used. At each rowspacing and plant population, plant-plant spacing was calculated using the method shown in Appendix XXI to give a total of 8 spacing treatments shown below.

TABLE 1: Subplot treatments and their corresponding rectangularities and plant populations.

	Subplot treatment	Rectangularity	Plant population
1)	90 x 11	8.2:1	100,000
2)	90 x 15	6:1	75,000
3)	90 x 22	4.1:1	50,000
4)	90 x 44	2.1:1	25,000
5)	30 x 33	0.9:1	100,000
6)	30 x 44	0.7:1	75,000
7)	30 x 66	0.45:1	50,000
8)	30 x 133	0.25:1	25,000

These spacing treatments formed the subplots and were randomised in the three main plots.

The experiment was replicated three times. The guard rows consisted of all plants outside each subplot.

Besides each spacing treatement in Table 1.

are shown the corresponding rectangularities i.e. the ratio of inter-rowspacing to intra-rowspacing.

3.4. Sampling procedure:

Ten plants were randomly selected from each plot or treatment during the measurements of the yield components and growth characteristics of sun-flower.

3.5 Procedures used in the determination of the various parameters:

The following plant parameters were measured:

a) Head diameter
b) Heights of plants
c) 1000 seed weight
d) Percent oil content
e) Seed yield per hectare
f) Diameter of sterile centre of the head
g) Stem diameter.

(a) Head diameter:

This was measured at harvesting time

which was 105 days after planting. It was measured by placing a ruler across the head of the plant. The measurement was made on ten plants per replication of each treatment.

(b) Height of plants.

The height was measured by using a ruler, from the ground to the highest point of the plant. The measurement was made on ten plants per replication of each treatment.

(c) 1000 seed weight.

This was determined by weighing a sample of 100 seeds picked at random using a Mettler P. 163 weighing balance. Three samples were weighed for each replication per treatment. The sample weighings were then averaged and multiplied by 10 to get 1000 seed weight.

(d) Oil content determination.

The method used for this determination was one of Foss-let S.N. (1982). To determine oil content in seed, 45.5 g of sunflower seeds were placed in the Foss-let crushing beaker. One hundred and twenty millimetres of ethylene tetrachloride was added and then covered by Foss-let oil quantitizer until the optimum temperature (25^{o}C) for oil content determination was attained. The oil content was determined by adjusting the Foss-let scale until the bubbles ran up from the mixtures of the seeds and ethylene tetrachloride. The scale reading was converted into percent oil using a conversion table on the machine.

(e) Seed yield per hectare.

This was determined by first oven drying the harvested seeds at 70^{o}C to constant weight and then weighing using 25 kg x 250 g WAYMASTER balance. Since plot measurements were known, the weights from each plot were converted to give yield in kilogrammes per hectare.

(f) Stem diameter.

This was measured at eight points on the plant at harvesting time starting from the first node to the eighth node. The measurement was done by placing a string around the nodes and spreading it on the ruler. Measurements for each plant were averaged to find the average diameter for each plant.

(g) Diameter of sterile centre.

This is the diameter of the Central portion of the head which consists of sterile or unfertilized flowers. It therefore lacks filled seeds. The measurement was carried out at harvesting time using a ruler, for 10 plants for each replication per treatment then averaged.

SOIL SAMPLING

Soil from the experimental plot was sampled up to a depth of 30 centimetres and taken for analysis at the National Agricultural Laboratories (Appendix I).

Sampling was done using the method whereby two diagonal lines were made at the corners of the experimental plot. Soil samples were taken at each of these diagonal lines. At each diagonal line 20 soil samples were taken. A total of 40 soil samples were taken in the whole experimental plot. These samples were then mixed and a sub-sample taken to the National Agricultural Laboratories for analysis. The results of the analysis (Appendix I) showed that the soil reaction of the soils was moderately acidic during the two seasons. It also showed that there were adequate amounts of organic matter, potassium, magnessium, manganese, calcium and phosphorus.

The determinations of these nutrients were done as follows:

(i) Determination of pH:

The pH of the soil sample was determined by the glass electrode method. This method involved scooping 20 ml of air-dry soil and transferring it into a 100 ml plastic shaking bottle. An addition of 50 ml of 1 molar potassium was made giving a 1:2½ soil-water suspension. Shaking was next done in a reciprocal shaker and the pH of the suspension measured using a pH metre after homogenising by a short but vigorous manual shaking.

(ii) Determination of organic carbon:

This was done by grinding about 5 grammes of soil to a fineness of less than 0.5 mm in a pestle and mortar sieving through 0.5 mm sieve. A 0.5 gramme sample was then weighed and transferred to a 500 ml conical flask including a reference sample. An addition of 10 ml 1N potassium dichromate was made and the flask swirled gently to disperse the soil in the solution. Concentrated solution of 15 ml H_2SO_4 was added and swirled until soil and reagents were mixed. Phosphoric acid was added at 5 ml and then 10 drops of diphenyla mine indicator was added and the solution titrated with 0.5 N ammonium ferrous sulphate. Calculations of percent carbon was done using the formula below:

$$\% \text{ carbon} = \frac{B - T \times 0.3 \times V}{W \qquad B}$$

where B = Blank titre

T = Sample titre

W = Weight of oven dry-soil in grammes

V = Volume of $K_2cr_2O_7$

0.3 = (1 ml N $K_2cr_2O_7$ ≡ 0.003 g C) x 100

Note: Potassium dichromate was used to determine the end point for the titration.

(iii) Determination of available phosphorus:

This was determined by weighing 5 g soil into 100 ml shaking bottle. An addition of 50 ml 0.5 M $NaHCO_3$ was made and shaken for 30 minutes. Filtering was then done through Whatman No. 42 filter paper in each series one blank and one standard sample were included. Soil extract or standard series solution was pipetted at 10 ml into 50 ml volumetric flasks. An addition of 8 ml mixed reagent was made and mixed well. Reading was done after 15 minutes on the spectrophotometer using a red filter. The results were expressed as PPM P from the standard curve.

(iv) Determination of available magnesium:

Magnesium standard solution or soil extract was pipetted into test tubes at 1 ml. An addition of 5 ml magnesium compensating solution, 2 ml each of thiazol yellow sodium polyacrylate and 8% sodium hydroxide was made. A reading of the optical density was made on the calorimetre after one hour at 540 μm using filter No. 625. The results were expressed as me Mg/100 g soil from standard curve.

(v) Determination of manganese:

Manganese standard solution or soil extract solution was pipetted at 1 ml into test tubes and an addition of 4 ml phosphoric acid-potassium periodate and 2 ml % sodium hydroxide made. The optical density on the calorimetre was then read after one hour within six hours at 520 μm using filter No. 624. The results were expressed as me Mn/100 g soil from standard cuve.

(vi) Determination of Calcium, Potassium and Sodium:

Standard solution or soil extract was pipetted into 25 ml vials. Anion exchange resin at 5 ml was added to remove interfering phosphate and sulphate anions and 15 ml distilled water added. Shaking was done from time to time by hand over a period of three hours and allowed to stand overnight. The supernatant liquid was decanted into 10 ml vials and reading made on the flame photometer using appropriate filter. The results were expressed as me ca, K and Na/100 g soil from standard curves.

STATISTICAL ANALYSIS OF THE DATA COLLECTED:

The analysis of variance was done by calculating the degrees of freedom of dates of planting, plant population, rowspacing, main plot error, blocks, subplots and subplot error and then calculating the sum of squares and mean squares. Finally the "F" values were calculated to determine which factors were significantly different.

The means were separated by calculating the least significant differences and multiplying them by a value obtained from studentized tables. This value is determined from the number of means compared. It is called the Duncan's multiple range test and is used to investigate which means were significantly different. The means were firstly arranged in order of magnitude and then comparisons made as follows; largest mean minus smallest, largest mean minus second smallest, second largest mean minus smallest, second largest mean minus second smallest etc. The differences between these means were declared significant if the value of the Duncan's multiple range test was equal to or bigger than the mean. The formulae for these determinations were as follows:

(i) Standard errors between means.

Means compared	Standard error of a mean
(a) Main plot treatments (Dates of planting)	$\sqrt{\frac{Ea}{rb}}$
(b) Subplot treatments (plant population and rowspacing)	$\sqrt{\frac{Eb}{ra}}$

(c) Subplot treatments for the same main plot treatment

$$\sqrt{\frac{Eb}{r}}$$

(d) Subplot treatments for different main plot treatments

$$\sqrt{\frac{(b-1)\ Eb+Ea}{rb}}$$

Where Ea = Mean square for main plot error

b = Number of subplot treatments

r = Number of main plot treatments.

(ii) Least Significant Differences; (LSD)

(a) LSD for differences between main plot treatments (i.e. between dates of planting means)

$$L.S.D._{0.05} = ta \sqrt{\frac{2(Ea)}{rb}}$$

Where ta is the tabular value for df for Ea.

(b) LSD for differences between subplot treatments (i.e. Among plant population or rowspacing means)

$$L.S.D._{0.05} = tb \sqrt{\frac{2(Eb)}{ra}}$$

Where tb = tabular 't' value for df for Eb

(c) LSD for differences between subplot treatments for the same main plot treatment (i.e. among plant population or rowspacing means for the same date of planting)

$$LSD_{0.05} = t_b\sqrt{\frac{2E_b}{r}}$$

(d) LSD for differences between subplot treatments for different main plot treatments (to compare rowspacing or plant population means at different dates of planting)

$$LSD_{0.05} = t_{ab}\sqrt{\frac{2[(b-1)(E_b+E_a]}{rb}}$$

Where tab is a weighted 't' value somewhere between the tabular values for 't'a and 'tb'

*The above methods for analysis of variance is recommended by Thomas Little and Hills and Steel and Torrie.

4.0 RESULTS:

4.1 Effect of date of planting on the yield components and growth characteristics:

Delay in planting time consistently resulted in reduction in plant heights. There was, however, no significant differences (0.05) between the first two planting dates during the first season. During the second growing season the trend was similar to that of the first season but differences between planting dates were significant. The effect of planting date on plant height was more pronounced at high plant populations (75,000 and 100,000) than at low plant populations (25,000 and 50,000) (Table VIII and IX).

The effect of planting date on head diameter was similar to that for plant height. Late plantings at high plant populations resulted in smaller heads than early plantings at low plant populations (Table VI and VII).

Early planting resulted in plants with bigger stem diameters than late planting (Table X and XI). There was however, no significant difference between

TABLE VI: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON HEAD DIAMETER. (IN CM) FIRST SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING 1	2	3	MEANS
30 CM	25,000	r 17.3a	r 19.5b	r 16.8c	17.9v
	50,000	r 18.7ac	s 17.1b	s 18.1ca	18.0v
	75,000	s 20.2a	t 14.4b	rt 15.7b	16.8v
	100,000	t 16.2a	t 15.4b	ts 14.0c	15.2w
	MEAN	e 18.1	f 16.6	f 16.1	16.9p
90 CM	25,000	r 16.7a	r 17.9a	r 14.7b	16.4k
	50,000	rt 17.2a	tr 18.9a	r 15.2b	17.1k
	75,000	s 15.9a	s 15.9a	s 13.5b	15.1ℓ
	100,000	tr 18.9a	rt 18.3a	s 14.6b	17.3mk
	MEAN	e 17.2	e 17.7	f 14.5	16.5
Means of dates		17.6a	17.1a	b 15.3	

*Means followed by the same letter in the same column are not significant according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.14.

ii) Standard error for means of plant population and rowspacing means = ±0.21.

iii) Standard error for means of plant population and rowspacing for same date = ±0.79.

iv) Standard error for means of plant population and rowspacing for different dates = ±1.24.

TABLE VII: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON HEAD DIAMETER (IN CM) - SECOND SEASON.

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING 1	2	3	MEANS
30 CM	25,000	r 17.1a	r 19.1b	r 16.8ac	17.7v
	50,000	rk 18.6a	s 17.2cb	r 18 ba	17.9v
	75,000	s 20.1a	t 14.4b	s 15.9b	16.8v
	100,000	tr 16.4a	t 15.3a	t 14 b	15.2w
		e 18.0	f 16.5	f 16.2	16.9p
90 CM	25,000	r 16.7a	r 17.6a	ra 16.8a	17.0km
	50,000	r 17.0a	r 18.6b	sr 18.0ac	17.9k
	75,000	s 15.8a	r 16.0a	str 13.6b	15.1ℓ
	100,000	t 19 a	s 18.1a	trs 14.6b	17.2mk
		e 17.1	e 17.6	f 15.7	16.8p
Means of dates		a 17.5	a 17.0	b 15.9	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05)

i) Standard error for means of dates = ±0.14.

ii) Standard error for means of rowspacing and or plant population = ±0.21.

iii) Standard error for means of plant population and or rowspacing for same date = ±0.79.

iv) Standard error for means of plant population and or rowspacing for different dates = ±1.24.

TABLE VIII. THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON PLANT HEIGHT (IN CENTIMETRES) - FIRST SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING 1	2	3	MEANS
30 CM	25,000	r 198 a	sr 187.5b	r 171.8c	185.8v
	50,000	s 206.7a	rs 197.1a	r 165.8b	189.9v
	75,000	t 218.3a	ut 208.3a	r 159.1b	195.2v
	100,000	u 233.8a	tu 216.7b	r 173.4c	208 w
	MEAN	e 214.2	f 202.4	g 167.5	194.7p
90 CM	25,000	r 191.7a	r 201.7a	r 160 b	184.5wv
	50,000	r 187.1a	s 186.1a	r 164.7b	179.3v
	75,000	s 216.2a	t 205.4a	r 157.1b	192.9vw
	100,000	s 212.9a	t 215.6a	s 183 b	203.8vw
	MEAN	e 202	e 202.2	f 166.3	190.1p
Means of dates		208.1a	202.3a	166.8b	

*Means followed by the same letter of the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±2.54

ii) Standard error for plant population and rowspacing means for same date = ±6.67.

iii) Standard error for plant population and or rowspacing means for different dates = ±9.2.

TABLE IX: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON PLANT HEIGHT (IN CM) - SECOND SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING			MEANS
		1	2	3	
30 CM	25,000	r 197.5a	r 190.3a	sr 174.3b	187.4v
	50,000	s 209.3a	r 198.4b	rs 166.4c	191.4v
	75,000	t 222 a	r 210.5b	t 158.9c	197.1v
	100,000	u 237.4a	s 215.6b	ru 172.8c	208.6w
	MEAN	e 216.5	f 203.7	g 168.1	196.1p
90 CM	25,000	r 176.1a	r 203.3b	r 161.6c	180.3v
	50,000	r 189.9a	rs 188.6a	r 162.9b	180.5v
	75,000	s 220 a	sr 208.5b	r 156.2c	194.9w
	100,000	s 215.4a	ts 215.9q	s 185.3b	205.5x
	MEAN	e 200.3	e 204.1	f 166.5	190.3p
Means of dates		208.4a	203.9a	167.3b	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±1.99.

ii) Standard error for rowspacing and plant population means = ±4.11.

iii) Standard error for means of plant population and or rowspacing for same date = ±7.1.

iv) Standard error for means of plant population and rowspacing for differed dates = ±8.5.

TABLE X: THE EFFECT OF INTER-SPACING, PLANT POPULATION AND PLANTING DATE ON STEM DIAMETER (IN CM) FIRST SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING 1	2	3	MEANS
30 CM	25,000	rt 2.5a	r 2.5a	r 2.4b	2.4v
	50,000	s 2.6a	r 2.4a	s 2.1b	2.4v
	75,000	s 2.7a	s 2.2cb	s 2.0bc	2.3v
	100,000	tr 2.4a	s 2.2a	t 1.8b	2.1w
	MEAN	e 2.5	f 2.3	f 2.1	2.3p
90 CM	25,000	r 2.7a	r 2.4a	r 1.5b	2.2v
	50,000	s 2.4a	rt 2.3b	s 2.0c	2.2v
	75,000	s 2.3a	s 2.5a	t 1.4b	2.1v
	100,000	t 2.0a	tr 2.3b	u 1.6c	1.9w
	MEAN	e 2.3	e 2.4	f 1.6	2.1q
Means of dates		2.4a	2.4a	1.8b	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.08.

ii) Standard error for rowspacing and plant population means = ±0.06.

iii) Standard error for rowspacing and plant population means for same date = ±0.11.

iv) Standard error for rowspacing and plant population means for different dates = ±0.23.

TABLE XI: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON STEM DIAMETER (IN CM): SECOND SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING 1	2	3	MEANS
30 CM	25,000	tr 2.4a	r 2.4a	r 2.3ab	2.4v
	50,000	r 2.5a	sr 2.3b	s 2.0c	2.3v
	75,000	s 2.7a	rt 2.2b	s 1.9c	2.3v
	100,000	rt 2.3a	st 2.1b	t 1.7c	2.0w
	MEAN	e 2.5	f 2.2	g 1.9	2.2p
90 CM	25,000	r 2.2a	r 2.3a	tr 1.3b	1.9x
	50,000	s 2.7a	r 2.3b	s 1.9c	2.3v
	75,000	tr 2.3a	s 2.0a	rt 1.3b	1.9x
	100,000	su 2.7a	t 2.2b	st 1.2c	2.0x
	MEAN	e 2.5	f 2.2	g 2.0	2.0q
Means of dates		2.5a	2.2b	3.3c	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.06.

ii) Standard error for means of plant population and rowspacing = ±0.06.

iii) Standard error for means of plant population and rowspacing for same date = ±0.1.

iv) Standard error for means of plant population and rowspacing for different dates = ±0.18.

the first and second plantings in the first season. The differences between early and late dates of planting at high plant populations was much more in the first season than second season.

The second plantings generally had heavier seeds than the other plantings (Table XV and XIV). The last plantings had the lightest seeds in the two seasons. As planting date was delayed, increase in plant population tended to result in bigger differences among the dates especially in the second season.

In the first season, there was an increase in the diameter of sterile centre with delay in planting reaching maximum values at higher plant populations (75,000 and 100,000) at the last plantings (Table XII). This trend changed in the second season when the second plantings tended to have the biggest values of sterile centre diameters (Table XIII). Nevertheless, the last plantings still had higher values of diameter of sterile centre than the first planting.

TABLE XV: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON SEED WEIGHT (1000) IN GRAMS - SECOND SEASON.

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING 1	2	3	MEANS
30 CM	25,000	r 6.6a	r 7.1b	r 7.2b	7.0v
	50,000	s 7.1a	s 6.9a	s 5.3b	6.4w
	75,000	t 5.5ac	t 6.3b	t 5.0ca	5.6x
	100,000	t 5.6a	u 6.0a	u 4.8b	5.5x
	MEAN	6.2e	6.6e	f 5.6	6.1p
90 CM	25,000	r 8.0a	r 6.8b	r 6.2c	7.0v
	50,000	s 4.9a	s 6.5b	s 5.5c	5.5w
	75,000	t 5.6a	t 5.2b	t 5.0b	5.3x
	100,000	t 5.5a	t 5.9a	t 4.2b	5.2x
	MEAN	e 6.0	e 6.1	f 5.2	5.8
Means of dates		6.0a	6.3a	5.6b	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.11.

ii) Standard error for means of plant population and rowspacing means = ±0.17.

iii) Standard error for means of plant population and or rowspacing for same date = ±0.31.

iv) Standard error for means of plant population and or rowspacing for different dates = ±0.4.

TABLE XIV: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON SEED WEIGHT (1000) IN GRAMS - FIRST SEASON.

ROWSPACING*	PLANT POPULATION	DATE OF PLANTING 1	DATE OF PLANTING 2	DATE OF PLANTING 3	MEANS
30 CM	25,000	r 8.3a	r 7.8b	r 7.6b	7.9v
	50,000	s 7.7a	su 6.4b	s 5.4c	6.5w
	75,000	t 5.6a	t 5.9a	s 5.2b	5.6x
	100,000	t 5.8a	us 6.6b	s 5.1c	5.8x
		e 6.8	e 6.7	f 5.8	6.4
90 CM	25,000	r 7.6a	r 8.3b	r 8.1b	8.0v
	50,000	su 6.7a	s 8.1b	s 5.8b	6.2w
	75,000	t 6.1a	s 5.9a	s 6.0a	6.0w
	100,000	us 6.6a	s 6.0	s 6.1c	6.2w
		e 6.7	f 6.3	g 5.9	6.3p
Means of dates		6.7a	6.5a	5.8b	

*Means followed by the same letter in the same row or column do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.03 grams

ii) Standard error for plant population means and row spacing means = ±0.18 grams

iii) Standard error for plant population and or rowspacing means for same date = ±0.3 grams.

iv) Standard error for plant population and rowspacing means for different dates = ±0.3 grams.

TABLE XII: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON DIAMETER OF STERILE CENTRE (IN CM) - FIRST SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING			MEANS
		1	2	3	
30 CM	25,000	r 2.2a	r 2.5bc	r 2.8cb	2.5v
	50,000	r 2.3a	s 2.6b	r 2.9b	2.6v
	75,000	s 3.0a	t 3.9b	s 4.8c	3.9w
	100,000	s 3.1a	t 3.8b	t 4.0b	3.6w
		e 2.6	3.2f	3.6f	3.1p
90 CM	25,000	r 2.3a	r 2.9b	r 3.5b	2.9k
	50,000	r 2.2a	r 2.4a	s 2.9b	2.5k
	75,000	s 2.8a	s 3.9b	t 3.8b	3.5ℓ
	100,000	s 2.8a	t 3.0a	t 3.9b	3.2mk
		e 2.5	3.0f	3.5f	2.7p
Means of dates		a 2.5	3.1	3.5	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.03.

ii) Standard error for means of plant populations and row spacing = ±0.08.

iii) Standard error for means of plant populations and row spacings for same date = ±0.15.

iv) Standard error for means of plant populations and rowspacing for different dates = ±0.16.

TABLE XIII: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON DIAMETER OF STERILE CENTRE (IN CM) - SECOND SEASON.

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING 1	2	3	MEANS
30 CM	25,000	r 3.7a	r 5.7a	r 5.0a	4.9v
	50,000	s 4.1a	s 5.2b	s 5.5b	5.2v
	75,000	s 4.1a	t 5.8b	t 5.6b	4.9v
	100,000	s 4.9a	t 4.9b	t 5.0c	4.8v
	MEANS	4.2e	5.4f	5.3f	5.0p
90 CM	25,000	r 4.9a	r 5.6b	r 4.0ac	4.8k
	50,000	s 4.3ac	s 6.2b	r 4.5ca	5.0k
	75,000	t 3.9a	s 5.3b	s 5.3c	4.8k
	100,000	u 5.5ca	t 6.5b	^{s}ac 5.1ac	5.7k
	MEANS	ef 4.6	g 5.9	f$_{e}$ 4.7	5.1
Means of dates		4.4a	5.6b	5.0b	

*Means, followed by the same letter in the same row or column do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.15.

ii) Standard error for plant population and rowspacing means = ±0.20.

iii) Standard error for plant population and rowspacing means for same date = ±0.35.

iv) Standard error for plant population and rowspacing means for different dates =± 0.51.

4.2 Effect of date of planting on the seed yield and oil content of sunflower:

There was a reduction in seed yield of 30% - 40% between the first planting and last planting in the two seasons. The trends in seed yield generally followed those of planting dates (Table II and III). The differences between the first and last plantings was bigger at higher plant populations.

The effect of planting dates on oil content was the reverse of that on seed yield. As planting was delayed there was an increase in oil content. In the first season the second planting had the highest oil content whereas in the second season the last planting had the highest oil content. (Table IV and V).

4.3 Effect of rowspacing on the yield components any growth characteristics of sunflower:

Although rowspacing did not significantly (0.05) affect most of the yield components, there tended to be taller plants (Table VIII and IX), greater values of stem diameter (Table X) and 1000 seed weight (Table XIV and XV) at 30 cm rowspacing than 90 cm rowspacing. There were no consistent effects of

TABLE OF RESULTS

TABLE II: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON SEED YIELD PER HECTARE FIRST SEASON (KG PER HECTARE).

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING			MEANS
		1	2	3	
30 cm	25,000	r 553.9a	r 567.6a	r 358 b	493.2v
	50,000	rs 686.1a	s 396.5b	r 293.5b	458.7v
	75,000	sr 719.1a	tr 587 b	s 485 b	597.3v
	100,000	rt 645.3a	us 267.1b	rt 206.7b	373 w
	MEAN	e 651.1	f 454.5	f 336	480.5p
90 cm	25,000	r 649.2a	r 423.7a	r 289.6b	454.2k
	50,000	s 431.5a	st 544.2a	s 427.6a	467.8k
	75,000	rt 622 a	ts 406.2b	tr 350 c	459.4k
	100,000	sut 505.3a	ur 498.9a	ust 421.2b	475.1k
	MEAN	e 552	e 468.2	e 372.1	464p
	Means of dates	a 601.5	b 461.3	b 354	

*Means followed by the same letter in the same column or row are not significantly different according to Duncan's multiple range test (0.05).

(i) Standard error for means of dates = ±33.5

(ii) Standard error for means of plant populations and/or rowspacing for different dates = ±115.4.

TABLE III: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON SEED YIELD PER HECTARE - SECOND SEASON: (KG PER HECTARE)

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING			MEANS
		1	2	3	
30 CM	25,000	r 585.0a	r 583.1a	r 427.6b	531.9v
	50,000	s 674.4a	r 587 a	r 365.4b	542.3v
	75,000	s 625.9a	s 406.2b	s 311 c	447.7v
	100,000	t 645.3a	s 450.9b	s 219.6c	438.6v
	MEAN	e 632.6	e 506.8	f 330.9	490.1p
90 CM	25,000	rt 656.9a	r 424 b	r 307.1b	462.7k
	50,000	su 353.8a	s 604.5b	rt 449.1ac	469.1k
	75,000	tr 622 a	rt 359 b	s 235.2b	405.4k
	100,000	us 465.5a	us 719.1b	tr 498.7ac	561.1k
	MEAN	524.5e	e 526.6a	372.5f	474.5p
Means of dates		578.5a	516.7a	351.7b	

*Means followed by the same letter in the same column or row are not significantly different according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±35.47

ii) Standard error for means of plant populations and/or rowspacing for different dates = ±121.3.

TABLE IV: THE EFFECT OF INTER-ROWSPACING PLANT POPULATION AND PLANTING DATE ON OIL CONTENT (%) FIRST SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING			MEANS
		1	2	3	
30 CM	25,000	r 33.2a	r 34.9b	r 34.6b	34.2v
	50,000	r 33.7a	r 35.1b	s 36.4c	35.1w
	75,000	r 33.9a	r 33.5a	t 33.5a	33.6x
	100,000	r 33.4ca	s 37.5b	u 32.9ac	34.6y
		e 33.6	f 35.2	f 34.3	34.4p
90 CM	25,000	r 34.3ca	r 33.2b	r 34.5ac	34.0 vx
	50,000	r 33.9a	s 35.7b	s 35.4b	35.0 w
	75,000	r 34.4a	s 35.9b	s 35.1b	35.1 w
	100,000	r 33.8ca	t 35.1b	u 33.2ac	34 xv
		e 34.1	f 34.9	f 34.5	34.5 p
Means of dates		33.8	35.0	34.4	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.13

ii) Standard error for plant population and/or rowspacing means = ±0.19.

iii) Standard error for plant population means and row spacing means for same date = ±0.36.

iv) Standard error for plant population or rowspacing means for different dates = ±0.46.

NB Percentages of oil content were angularly transformed into statistically analysable values using fishers tables.

TABLE V: THE EFFECT OF INTER-ROWSPACING, PLANT POPULATION AND PLANTING DATE ON OIL CONTENT (%) SECOND SEASON:

ROWSPACING*	PLANT POPULATION	DATES OF PLANTING			MEANS
		1	2	3	
30 CM	25,000	r 31.8a	r 35.1b	r 36.8c	34.6v
	50,000	s 31.2a	s 35.7b	s 38.2c	35.0v
	75,000	t 32.0a	t 36 b	rt 37.0c	35.0v
	100,000	u 32.7a	u 35.4b	u 34.5c	34.2w
	MEAN	e 31.9	f 35.5	f 36.6	34.7p
90 CM	25,000	r 29.5a	r 35.1b	r 37.1c	33.9v
	50,000	s 31.6a	r 35.4b	s 36.7c	34.6w
	75,000	t 30.2a	r 35.2b	s 36.7c	34 w
	100,000	u 28.2a	s 36.6b	t 34.3c	33 x
	MEAN	e 29.9	f 35.6	f 36.2	33.9q
Means of dates		a 30.9	b 35.5	c 36.4	

*Means followed by the same letter in the same column or row do not differ significantly according to Duncan's multiple range test (0.05).

i) Standard error for means of dates = ±0.24.

ii) Standard error for plant population and or rowspacing means = ±0.30

iii) Standard error for plant population means and or rowspacing means for same dates = ±0.81.

iv) Standard error for plant population means and rowspacing means for different dates = ±0.81.

NB Percentages of oil content were angularly transformed into statistically analysable values using Fisher's tables.

rowspacing on the diameter of sterile centre in both seasons; 30 cm rowspacing having higher values of sterile centre than 90 cm in the first season and 90 cm having higher values in the second season (Table XII and XIII).

4.4 <u>Effect of rowspacing on the seed yield and oil content:</u>

In the first and second seasons, rowspacing had little and insignificant effect on seed yield (Table II and III). In both seasons 30 cm row spacing had on overall, higher values of seed yield than 90 cm rowspacing expressing its effect in the first date of planting (Table II and III).

The effect of rowspacing was significant (0.05) for oil content only in the second season where 30 cm rowspacing had higher oil content than 90 cm (Table V). In the first season there tended to be lack of consistency in oil content between the two rowspacings.

4.5 <u>Effect of plant population on the yield components and growth characteristics:</u>

Increase in plant population from 25,000 to 100, 000 plants per hectare led to a progressive increase in plant heights. (Table X and IX). At later dates of planting there were no significant differences (0.05) among plant populations of 25,000, 50,000 and 75,000 plants per hectare. This trend was more pronounced in the second than in the first season.

Head diameter also followed similar trends as plant height except that it tended to occur in the later dates of planting. At early dates, of planting and at 90 cm rowspacing there was no clearcut reduction of head diameter with increase in plant population (Table VI and VII).

There was a general decrease in stem diameters, with increase in plant population (Table X and XI). This decrease was insignificant (0.05) especially in the second season.

As plant population increased there was a decrease in 1,000 seed weights (Table XIV and XV). However, there was no consistent trend between populations of 75,000 and 100,000 plants per hectare. The differences among these populations were not significant (0.05) at the second and last plantings in the first season.

Diameter of sterile centre increased with increase of plant population (Tâble XII and XIII). Higher plant population (75,000 and 100,000) at later dates of planting had far much higher values of diameters of sterile centre. There appeared to be lack of significant difference (0.05) between 75,000 and 100,000 plants per hectare in most cases and between 25,000 and 50,000 plants per hectare in few cases.

4.6 Effect of plant population on seed yield and oil content:

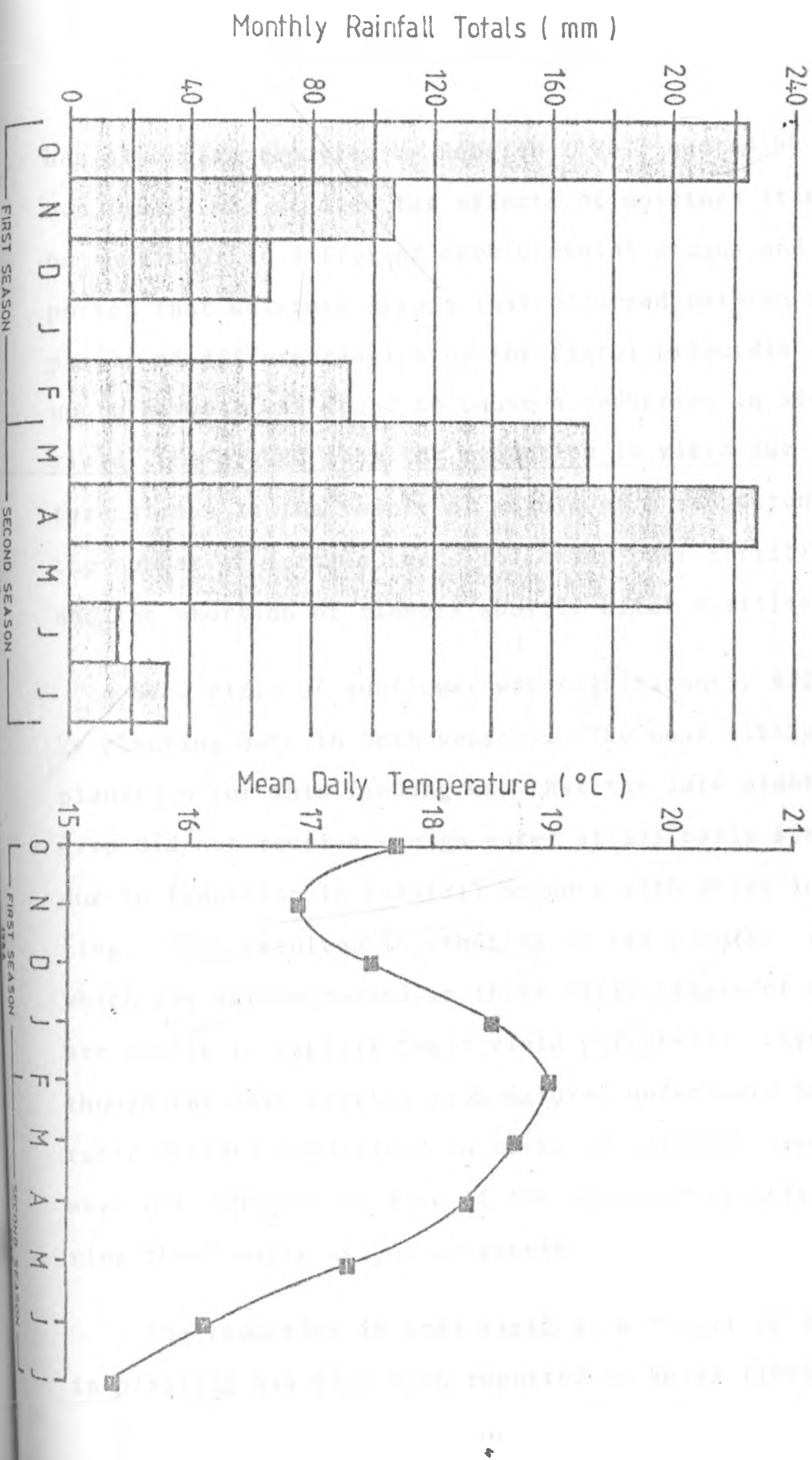
Although plant population did not have a significant effect (0.05) on seed yield there was a tendency for seed yield to decrease with increase in plant population at the rowspacing of 30 cm at the last date of planting (Table II and III). At the row spacing of 90 cm there were no consistent trend of effects of plant populations on seed yield.

In the first season plant population had inconsistent effect on oil content at early dates of planting (Table IV). At the last date of planting there was minimum oil content at 100,000 plants per hectare. There appeared to be maximum values of oil content at 50,000 and 75,000 plants per hectare which were significantly bigger (0.05) than 25,000 and 100,000 plants per hectare.

DISCUSSION:

4.7 EFFECT OF DATE OF PLANTING ON SEED YIELD, YIELD COMPONENTS AND OIL CONTENT:

Seed yields obtained in the two seasons of this trial were below the average yields in Kenya: 900 kg-1200 kg per hectare. This was due to the lack of adequate rainfall (Fig. 1) during the period from the start of flowering to harvesting for the early plantings. This problem was much more serious in the short rains of 1984 when there was no rain in January. This was the time the crop was flowering. Rainfall distribution during the two seasons of the experiment was very poor in December and January 1984 and June and July 1985 respectively when the crop was flowering and filling the seed. The same reasoning can also explain why there were not big differences in seed yields between the two seasons. Water-stress during the last stages of development of the crop cancelled any large seasonal differences which may have been felt. The effect of moisture stress on the seed yield may be explained by reduction in photosynthesis leading to reduced production of assimilates. Further, the translocation of assimilates to the sunflower head to help in flower and seed development may have been curtailed. This effect of waterstress on sunflower yield


Monthly Rainfall Totals (mm)
0
40
80
120
160
200
240
O
N
D
J
F
M
A
M
J
J
FIRST SEASON
1984
SECOND SEASON
1985
Mean Daily Temperature (°C)
15
16
17
18
19
20
21
O
N
D
J
F
M
A
M
J
J
FIRST SEASON
SECOND SEASON

has also been reported by Robelin (1967) quoted by Arnon (1972) who studied the effects of moisture stress on sunflower at different developmental stages and reported that moisture stress that occurred between the period of differentiation of the floral primordia and up to harvest was found to cause a reduction in seed yield. He argued that the reduction in yield due to moisture stress is the result of mainly of a reduction in the number of fertile seeds following poor fertilization and the abortion of flowers shortly after fertilization.

Seed yield of sunflower was significantly affected by planting date in both seasons. The most likely explanation for this finding was that the late planted crop did not receive enough water at its early stages due to reduction in rainfall amounts with delay in planting. This resulted in stunting of the plants. Plants which are waterstressed in their early stages of growth are unable to exploit their yield potentials. Even though the late planted crop matured under more favaourable weather conditions in terms of rainfall seed yields were not improved because of the waterstress effects during their early stages of growth.

The reduction in seed yield as a result of delay in planting has also been reported by Weiss (1965);

Robinson (1970); Johnson and Jellum (1972); Miller (1984) and Jones (1984).

Delayed planting also significantly reduced growth characteristics such as plant height and stem diameter and yield components such as head diameter, 1000 seed weight and increased diameter of sterile centre of sunflower head. These results agree partly with Johnson and Jellum (1972) who reported that head diameter and 1000 seed weight decreased as planting date was delayed. The decrease in the yield components by delay in planting may be due to the fact that rainfall amounts decreased as planting was delayed (Fig. 1). This resulted in plants which had small heads, narrow stem diameters and shorter heights. Conversely, plants which were planted early were more vigorous because they had enough rainfall. They therefore had bigger heads, wider stems and were much taller. It may be concluded that delayed planting reduced 1000 seed weight and head diameter and increased the diameter of sterile centre resulting in lower seed yields and vice versa. This shows that both 1000 seed weight and head diameter are positively correlated with seed yield while the diameter of sterile centre is negatively correlated with seed yield.

As planting was delayed there was an increase in oil content. This can be explained by the fact that the late planted crop flowered under more favourable rainfall conditions than the early plantings. In the first season of the experiment the early plantings matured between December and January when rainfall amounts were decreasing drastically while the late plantings matured in February (Fig. 1 and Appendix XVIJ where there were reasonable amounts of rainfall in the second season the early plantings matured between June and part of July when rainfall amounts were very little (Fig. 1, 2 and Appendix XVI) and poorly distributed. The late planted crop matured under more favourable rainfall conditions in the last half of July. This reasoning agrees with Robelin (1967) who reported that oil content is less affected by water stress than is seed yield and that the reduction in oil content is most marked when the stress occurs during th 20 days following the withering of the flower. It also agrees with Enns (1970) who reported that the reduction in oil content with early planting was due to the fact that the period of oil synthesis and accumulation for the early plantings fell during favourable rainfall and temperature conditions. The increase in oil content with delay in planting has also been reported by Alessi et. al. (1977). In the first season of his trials, Harris et al (1978) and Dounes

(1974) cited by Unger and Thompson (1982). Nevertheless, Johnson and Jellum (1972) and Jones (1984) have reported decrease in oil content from late planting probably due to the fact that their late planted crop matured under weather conditions not favourable for oil synthesis and accumulation. Johnson and Jellum (1972) reported that the oil content of seed from late planted sunflower maturing during cooler weather was lower than from earlier planted sunflower maturing during warmer weather. This is also a possible explanation for the findings of this study. Apart from maturing under favourable conditions of rainfall, the late planted crop may have matured under more favourable temperature conditions for oil synthesis and accumulation (Appendix XVI and XVII).

The yield components were negatively correlated to oil content due to the above reasoning i.e. that oil content is determined by prevailing weather conditions during maturing period but yield components are influenced by prevailing weather during the early stages of growth and maturing period.

4.8 EFFECT OF ROWSPACING ON SEED YIELD, YIELD COMPONENTS AND OIL CONTENT:

The lack of significant effect of rowspacing on seed yield may be explained by its lack of effect on the yield components. It may not have affected yield components possibly due to the fact that 90 cm rowspacing was too close for the variety of sunflower used and the experimental conditions. The results of the present study tend to agree with Harper (1962) who reported that considerable variations in planting patterns (arrangements) have little influence on yield of grain per unit area for a wide range of crops.(Robinson (1982) however argues that sunflower is not affected by rowspacing due to its height and phototropic habit which neutralizes the differential efficiency of utilization of light and water at different rowspacings theory. This may not be convincing because use of soil moisture and nutrients would still be affected. He also argues that the lack of response to increased uniformity from close rowspacing suggests that moderately uneven stands of sunflower may not affect seed yield. The results of the present study agree with those of vance and Lofgren (1970) who found no effect of rowspacings of 30.48, 60.96 and 91.44 cm on oil content of sunflower in the United States of America, and those of Vijayalakshmi et. al. (1975) who found no effect of rowspacings of 37, 89 and 53 cm on oil content of Armaveric variety of sunflower in Canada and India. The lack of consistent results on the effect

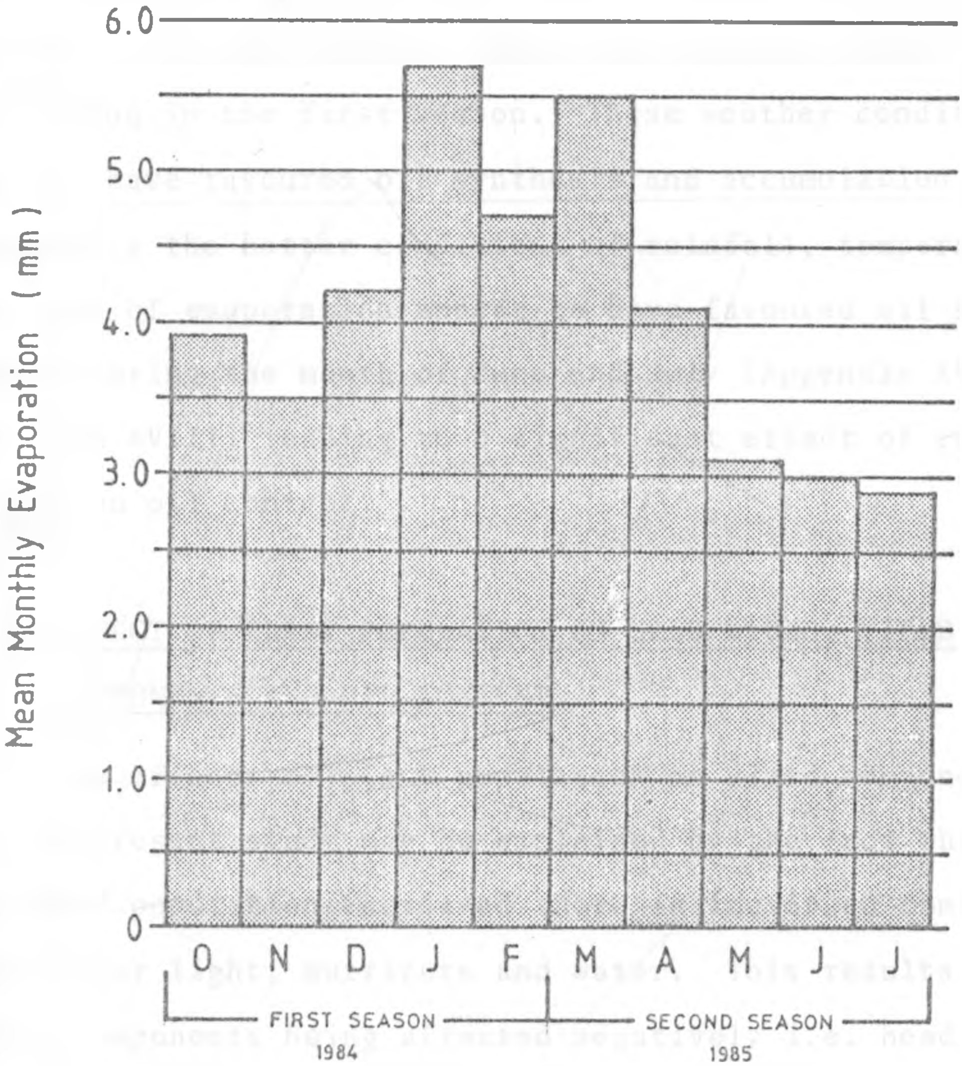


Fig. 3: Mean monthly evaporation (mm) for the period October, 1984 to July, 1985.

of rowspacing on oil content in both seasons may be explained by different weather conditions in the two seasons. It appears that the lack of enough rain fall in January, higher temperatures and high rates of evaporation (Appendix XVI, XVII and XVIII) led to the lack of effect of rowspacing in the first season. These weather conditions may not have favoured oil synthesis and accumulation. Conversely the better conditions of rainfall, temperature and rate of evaporation appear to have favoured oil synthesis during the month of June and July (Appendix XVI, XVII and XVIII) leading to a significant effect of rowspacing on oil content.

4.9 EFFECT OF PLANT POPULATION ON SEED YIELD, YIELD COMPONENTS AND OIL CONTENT.

The effects of plant population on yield components in the present study may be explained by the fact that as plant population increased there is increased competition for light, nutrients and water. This results in these components being affected negatively i.e. head diameter decreases, 1000 seed weight decreases and lack of adequate seed filling.

The lack of effect of plant population on seed yield could be explained in two ways: firstly, the growth habit of sunflower may have been such that it filled the available light space rapidly resulting in a foliage canopy of essentially the same size whatever the plant density. Secondly, by virtue of sunflower having a determinate type of growth (Arnon, 1972) it responded to plant population increase by changes in the sizes of its yield components. Thus, as plant population increased there was an internal adjustment of yield components: the number of filled seeds reflected in the diameter of sterile centre, 1000 seed weight and head diameter which decreased as plant population increased (Campbell, 1975), Robinson (1980) and Jones (1984). This may be the reason why plant population affected all yield components in the present study but did not affect seed yield. However, it seems that with late planted crop at high plant populations the waterstress effect is more serious due to increased plant populations in the late planted crop.

These results agree with those of Lofgren and Vance (1970) who found no effect on seed yields from plant populations of 37,500, 50,000, 62,500, 75,000, 87,500 and 100,000 plants per hectare in United States of America and Robinson _et_. _al_. (1980) who found the same effect as above from plant populations of 17,000, 25,000, 37,000, 49, 000 and 62,000 plants per hectare in United States of America.

6.0 CONCLUSIONS:

From the results discussed above it can be concluded that seed yield and oil content are mainly affected by date of planting. Seed yield is affected through yield components.

Nevertheless, the three factors; rowspacing, plant population and planting date do not collectively affect seed yield, yield components and oil content.

It can also be concluded from this study that late planted crop at high plant population causes even more serious reductions in seed yield and negatively affects the yield components of sunflower.

Finally, date of planting affected all the parameters determined in this study irrespective of the rowspacings or plant populations used. The importance of planting date in sunflower production cannot therefore be overemphasised.

7.0 RECOMMENDATIONS:

Early planting must be done because delay in planting seriously affects seed yield. Since the farmers are usually interested in both seed yield and oil content they should strike a balance by choosing a planting date which gives reasonable yields and oil content. A one-week delay in planting can give satisfactory seed yields and oil content.

Rowspacing should be chosen which allows for ease of undertaking farm operations like hand weeding, harvesting and spraying against pests, diseases and weeds.

In areas with good rainfall a higher population should be used in comparison to water-deficient areas to make use of the available. This also applies when fertilizer is used under those conditions. Nevertheless very high populations of up to 100,000 plants per hectare should be avoided because of 100 much lodging and fast disease spread.

The areas which need further study are:

(i) The relationship between temperature, oil content and seed development in sunflower.

(ii) An extension of the same experiment at different sites with varying climatic conditions and with different varieties of sunflower. The experiment should be done over a longer period.

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9.0 APPENDIX

APPENDIX I: SOIL ANALYSIS REPORT

PH	: 5.4	FOR SHORT RAINY SEASON
Na m.e%	: 0.22	
K m.e%	: 1.15	
Ca m.e%	: 10.84	
Mg m.e%	: 3.7	
Mn m.e%	: 1.4	
P p.p.m	: 31.6	
% C	: 2.1	

PH	: 5.6	FOR LONG RAINY SEASON
Na m.e%	: 0.28	
K m.e%	: 1.04	
Ca m.e%	: 9.6	
Mg m.e%	: 4.2	
Mn m.e%	: 1.9	
P p.p.m	: 33.2%	
C%	: 2.3	

ANALYSIS OF VARIANCE:

APPENDIX II: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON HEAD DIAMETER FIRST SEASON:

Source of variation	df	ss	ms	Observed F
Total	71	1202.7		
Main plots	8	123.95		
Blocks	2	22.14		
Dates	2	72.9	36.45	5.04 NS
Main plot error	4	28.91	7.23	
Row spacing	1	4.35	4.35	2.96 NS
Date x Row spacing	2	8.99	4.5	3.06 NS
Plant population	3	47.06	15.69	10.67**
Date x plant population	6	38.50	6.42	4.37**
Row spacing x plant population	3	40.7	13.57	9.23**
Date x Row spacing x plant population	6	24.2	4.03	2.74NS
Sub plot error	42	61.9	1.47	

Key:

NS = Not significant

* = Significant at 5%

** = Significant at 1%

APPENDIX III: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON HEAD DIAMETER - SECOND SEASON:

Source of variation	df	ss	ms	Observed F
Total	71	315.81		
Main plots	8	87.42		
Dates	2	68.47	34.23	9.98*
Blocks	2	5.22	2.61	
Main plot error	4	13.73	3.43	
Rowspacing	1	5.02	5.02	2.66 NS
Plant population	3	23.56	7.85	4.15*
Date x Rowspacing	2	24.96	12.48	6.6**
Date x plant population	6	31.84	5.31	2.81*
Rowspacing x plant population	3	39.21	13.07	6.91**
Date x Rowspacing x Plant population	6	24.18	4.03	2.13 NS
Sub plot error	42	99.62	1.89	

Key:

NS = Not significant

* = Significant at 5%

** = Significant at 1%.

APPENDIX IV: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON PLANT HEIGHT - FIRST SEASON:

Source of variation	df	ss	ms	Observed F
Total	71	39980.67		
Main plots	8	24823.44		
Dates	2	23800.37	11900.18	77.05**
Blocks	2	405.3	202.6	
Main plot error	4	617.71	154.44	
Row spacing	1	381.4	381.4	2.85 NS
Plant population	3	5361.67	1787.22	13.87**
Date x Row spacing	2	541.37	270.68	2.02 NS
Date x Plant Population	6	1889.27	314.88	2.36*
Rowspacing x plant population	3	239.43	79.81	0.59 NS
Date x Rowspacing x plant population	6	1130.97	188.49	1.4 NS
Sub plot error	42	5612.88	133.64	

Key:

NS = Not significant

** = Significant at 1%

* = Significant at 5%.

APPENDIX V: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON PLANT HEIGHT - SECOND SEASON:

Source of variation	df	ss	ms	Observed F
Total	71	43208.79		
Main plots	8	18706.26		
Dates	2	17534.28	8767.14	91.9*
Blocks	2	790.38		
Main plot error	4	381.6	95.4	
Row spacing	1	445.56	445.56	2.9 NS
Plant population	3	11739.69	3913.23	25.63**
Date x Rowspacing	2	851.2	425.6	2.78 NS
Date x Plant population	6	2875.18	479.2	3.1*
Rowspacing x plant population	3	937.17	312.39	2.04 NS
Date x Rowspacing x plant population	6	1239.48	206.58	1.35 NS
Sub plot error	42	6414.24	152.72	

Key:
NS = Not significant
** = Significant at 1%
* = Significant at 5%.

APPENDIX VI : EFFECT OF PLANT POPULATION, PLANTING DATE AND INTER-ROWSPACING ON STEM DIAMETER - FIRST SEASON

Source of variation	df	ss	ms	Observed F
Total	71	13.19		
Main plots	8	8.29		
Dates	2	7.58	3.79	26.5**
Blocks	2	0.137	0.07	
Main plot error	4	0.573	0.143	
Row spacing	1	0.16	0.16	4.4*
Plant population	3	0.23	0.077	2.14 NS
Date x Row spacing	2	1.0	0.5	13.9**
Date x plant population	6	0.74	0.123	3.42*
Row spacing x plant population	3	0.76	0.25	6.9**
Date x Row spacing x plant population	6	0.512	0.08	2.2 NS
Subplot error	42	1.498	0.03	

NS = Not significant

* = Significant

** = Significant at 1%.

APPENDIX VII: EFFECT OF PLANT POPULATION, PLANTING DATE AND INTER-ROWSPACING ON STEM DIAMETER: - SECOND SEASON.

Source of variation	df	ss	ms	Observed F
Total	71	11.71		
Main plots	8	7.24		
Dates	2	6.71	3.35	41.87**
Blocks	2	0.21		
Main plot error	4	0.32	0.08	
Row spacing	1	0.18	0.18	6.0**
Plant population	3	0.27	0.09	3.0*
Date x Row spacing	2	0.88	0.44	14.6**
Date x Plant population	6	0.62	0.10	3.4**
Row spacing x Plant population	3	0.63	0.21	7.0**
Date x Row spacing x plant population	6	0.63	0.105	3.5**
Sub plot error	42	1.26	0.03	

NS = Not significant

* = Significant at 5%

** = Significant at 1%

APPENDIX VIII: EFFECT OF PLANTING DATE, PLANT POPULATION AND INTER-ROWSPACING ON THE DIAMETER OF STERILE CENTRE OF HEAD - FIRST SEASON

Source of variation	df	ss	ms	Observed F
Total	71	14.26		
Main plots	8	3.29		
Dates	2	2.2	1.1	57.89**
Blocks	2	1.02	1.01	
Main plot error	4	1.077	1.019	
Row spacing	1	0.22	0.22	3.4 NS
Plant population	3	14.93	1.64	25.28**
Date x Row spacing	2	0.08	0.04	0.61 NS
Row spacing x plant population	3	0.38	0.127	1.95 NS
Date x Plant population	6	2.26	0.38	5.79**
Date x Row spacing x plant population	6	0.34	0.056	0.86 NS
Sub plot error	42	2.72	0.065	

Key:

NS = Not significant

* = Significant at 5%

** = Significant at 1%.

APPENDIX IX: EFFECT OF PLANTING DATE, PLANT POPULATION AND INTER-ROWSPACING ON THE DIAMETER OF STERILE CENTRE OF HEAD - SECOND SEASON.

Source of variation	df	ss	ms	Observed F
Total	71	60.3		
Main plots	8	22.69		
Blocks	2	3.05	1.52	
Dates	2	17.55	8.78	16.88*
Main plot error	4	2.09	0.52	
Row spacing	1	0.28	0.28	0.67 NS
Plant population	3	4.31	1.44	3.88*
Date x Row spacing	2	4.21	2.11	5.02*
Date x Plant population	6	6.74	1.12	2.67*
Row spacing x Plant population	3	2.92	0.97	2.31 NS
Date x Row spacing x Plant population	6	3.57	0.59	1.40 NS
Sub plot error	42	15.58	0.37	

Key:

NS = Not significant

* = Significant at 5%

** = Significant at 1%.

APPENDIX X: EFFECT OF PLANTING DATE, PLANT POPULATION AND INTER-ROWSPACING ON 1000 SEED WEIGHT - FIRST SEASON.

Source of Variation:	df	ss	ms	Observed F
Total	71	7.03		
Main plots	8	4.59		
Blocks	2	1.00		
Dates	2	3.51	1.75	87.75**
Main plot error	4	0.08	0.02	
Row spacing	1	0.52	0.52	1.73 NS
Plant population	3	36.54	12.18	40.6**
Date x Row spacing	2	1.09	0.54	1.81 NS
Date x Plant population	6	7.31	1.22	4.06**
Row spacing x Plant population	3	4.23	1.41	4.7**
Date x Row spacing x Plant population	6	3.23	0.54	1.79 NS
Sub plot error	42	12.6	0.3	

Key:
NS = Not significant
* = Significant at 5%
** = Significant at 1%.

APPENDIX XI: EFFECT OF PLANTING DATE, PLANT POPULATION AND INTER-ROWSPACING ON 1000 SEED WEIGHT - SECOND SEASON.

Source of variation	df	ss	ms	Observed F
Total	71	70.3		
Main plots	8	4.59		
Blocks	2	1.00		
Dates	2	3.51	1.75	87.75**
Main plot error	4	0.08	1.02	
Row spacing	1	0.52	0.52	1.73 NS
Plant population	3	36.54	12.18	40.6**
Date x Row spacing	2	1.09	0.54	1.81 NS
Date x Plant population	6	7.31	1.22	4.06**
Row spacing x Plant population	3	4.23	1.41	4.7**
Date x Row spacing x Plant population	6	3.23	0.54	1.79 NS
Sub plot error	42	12.6	0.3	

Key:

NS = Not significant

* = Significant at 5%

** = Significant at 1%.

APPENDIX XII: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON SEED YIELD - FIRST SEASON.

Source of variation	df	ss	ms	Observed F
Total	71	2078308.4		
Main plots	8	712898.26		
Dates	2	533443.6		9.92*
Blocks	2	71907.035	35953.67	
Main plot error	4	107547.24	26886.81	
Rowspacing	2	10601.51	10601.51	0.56 NS
Plant population	3	45179.38	15059.79	0.80 NS
Date x Plant population	6	361385.5	60230.92	3.21*
Rowspacing x Plant population	3	107079.42	33693.14	1.79
Date x Rowspacing	2	26249.72	13124.86	0.69 NS
Date x Rowspacing x plant population	6	33281.58	5546.93	0.29 NS
Sub plot error	42	787633	18753.17	

Key:

NS - Not significant

* - Significant at 5%

** - Significant at 1%.

APPENDIX XIII: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON SEED YIELD - SECOND SEASON

Source of variation	df	ss	ms	Observed F
Total	71	2534804.2		
Main plots	8	883100.05		
Dates	2	660800.68	33400.31	10.94**
Blocks	2	101508.45	50754.22	
Main plot error	4	120790.97	30197.74	
Rowspacing	1	4326.46	4326.46	0.21 NS
Date x Rowspacing	2	78212.21	39106.1	0.93 NS
Plant population	3	75509.13	25169.71	1.24 NS
Date x plant population	6	377625.62	52937.6	2.61*
Rowspacing x plant population	3	117338.86	39112.95	1.92 NS
Date x Rowspacing x plant population	6	20748.69	34580.1	1.7 NS
Sub plot error	42	851211.18	20266.93	

Key:

NS = Not significant

* = Significant at 5%

** = Significant at 1%

APPENDIX XIV: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON OIL CONTENT - FIRST SEASON.

Source of variation:	df	ss	ms	Observed F
Total	71	107.24		
Main plots	8	31.82		
Dates	2	29.33	14.66	36.56**
Main plot error	4	1.603	0.401	
Rowspacing	1	0.64	0.64	2.01 NS
Plant population	3	33.64	11.8	37.1 NS
Date x Rowspacing	2	1.1	0.55	1.73 NS
Date x Plant population	6	4.43	0.74	2.32*
Rowspacing x Plant population	3	5.62	1.87	5.89**
Date x Rowspacing x Plant population	6	5.43	0.9	2.84*
Sub plot error	42	0.318	0.318	

Key:

NS - Not significant

* - Significant at 5%

** - Significant at 1%.

APPENDIX XV: EFFECT OF PLANTING DATE, INTER-ROWSPACING AND PLANT POPULATION ON OIL CONTENT - SECOND SEASON.

Source of variation	df	ss	ms	Observed F
Total	71	235.06		
Main plots	8	171.73		
Blocks	2	1.16	0.58	
Dates	2	164.82	82.41	57.35**
Main plot error	4	5.75	1.431	
Row spacing	1	0.53	0.53	0.66 NS
Plant population	3	8.39	2.8	3.5*
Date x Rowspacing	2	4.24	2.12	2.65 NS
Date x Plant population	6	10.9	1.82	2.27 NS
Rowspacing x Plant population	3	0.09	0.03	0.04 NS
Date x Row spacing x Plant population	6	5.54	0.92	0.15 NS
Sub plot	42	33.64	0.8	

Key:

NS - Not significant

* - Significant at 5%

** - Significant at 1%.

MONTHLY RAINFALL TOTALS AND DAILY TEMPERATURES FROM OCTOBER 1984 TO JULY 1985.

APPENDIX XVI: MONTHLY RAINFALL TOTALS IN MILLIMETRES:

October	1984:	214.7
November	1984:	116.2
December	1984:	64.7
January	1985:	Nil
February	1985:	94.1
March	1985:	171.4
April	1985:	213.6
May	1985:	200.1
June	1985:	16.2
July	1985:	30.1

APPENDIX XVII: MEAN DAILY TEMPERATURES IN DEGREES CELCIUS

October	1984:	17.7
November	1984:	16.9
December	1984:	17.5
January	1985:	18.5
February	1985:	19.0
March	1985:	18.7
April	1985:	18.3
May	1985:	17.3
June	1985:	16.1
July	1985:	15.4

APPENDIX XVII : TOTAL MONTHLY EVAPORATION FIGURES FOR 1984 AND 1985 IN MILLIMETRES.

October 1984	121.7
November 1984	104.1
December 1984	131.8
January 1985	177.0
February 1985	132.1
March 1985	160.0
April 1985	122.4
May 1985	95.8
June 1985	90.8
July 1985	86.1

APPENDIX XIX: LAND AREA UNDER SUNFLOWER IN KENYA IN LARGE ONLY (1976): PROVINCE

YEAR	NYANZA	RIFT VALLEY	WESTERN	CENTRAL	EASTERN	COAST	NAIROBI	TOTAL
1970	16	3902	43			3971	10	7942
1971		3265	11	30		3310		6616
1972		2759	11	46		705		3521
1973		3230	38	13	1	3288	6	6576
1974	13	5682	44	18		5763	6	11526
1975	19	4666	41	52	2	4786	6	9572
TOTAL	48	23503	188	159	3	21823	28	45763
MEAN	8	3917	31	27	0.5	3637	5	7226

<u>SOURCE:</u> Statistical Abstracts (Kenya) 1976

APPENDIX XX: AREA UNDER SUNFLOWER CROP BY DISTRICT 1977 - 1980 IN HECTARES:

DISTRICT

YEAR:	BUNGOMA	KAKAMEGA	KISUMU	KISII	BARINGO	KERICHO	TRANS NZOIA	LAIKIPIA	NAKURU	NANDI	UASIN GISHU	NAIROBI	KIAMBU	NYANDARUA	NYERI	MURANGA	MACHAKOS	MERU	KILIFI	KWALE	TOTAL	TOTAL
1980	-	-	-	4	-	14	2252	1	222	-	50	7	23	-	-	-	10	-	-	-	-	2583
1979	24	2	-	1	-	-	2833	4	64	-	131	5	5	-	-	-	1	-	-	-	-	3068
1978	-	-	-	4	-	-	3779	12	106	1	315	-	-	42	-	-	-	-	12	-	-	4271
1977	-	-	6	-	-	6	2862	21	502	8	154	7	13	44	-	13	10	4	2	-	-	3652

SOURCE: Central Bureau of statistics 1979 - 1980
(Agricultural Census of large farms 1979 and 1980)

APPENDIX XXI: KENYA'S DOMESTIC EXPORTS 1939 - 1975 - VALUE AND QUANTITY OF EXPECTED OIL, SEEDS, OIL NUTS AND KERNELS:

YEAR	QUANTITY IN METRIC TONNES	VALUE K£'000	% OF TOTAL VALUE OF EXPORTS
1939	24	4.4**	
1948	42	26.7**	
1949	95	60.6**	
1950	135	89.6**	
1966	9743	506	0.9
1967	7072	311	0.7
1968	9959	638	1.1
1969	6924	350	0.7
1970	8038	527	0.7
1971	6498	459	0.6
1972	400	263	0.3
1973	5659	457	0.4
1974	4244	502	0.3
1975	6770	643	0.4

Source: Statistical Abstract (Kenya) 1976.

** Quantities are for sunflower only, other quantities include: sunflower, castor, sesame, coconuts.

APPENDIX XXII: CALCULATION OF PLANT-PLANT SPACING FOR EACH ROWSPACING AND PLANT POPULATION

i) At rowspacing of 30 cm;

(a) at plant population of 25,000 plants per hectare

Area of a hectare = 100 x 100 m^2 = 10,000 m^2

Number of rows in one hectare = $\frac{10,000}{30}$ = 333.3 rows

Where 30 is the rowspacing

$\therefore$ Number of plants = $\frac{25,000}{333.3}$ = 75

$\therefore$ Interplant spacing = $\frac{100}{75}$ = 1.33 metres

= 133 cm

(b) at plant population of 50,000 plants per hectare.

Number of rows in one hectare = $\frac{10,000}{30}$

= 333.3 rows

$\therefore$ Number of plants = $\frac{50,000}{333.3}$ = 150.015

$\therefore$ Interplant spacing = $\frac{100}{150.015}$ = 0.66 = 66 cm

(c) at plant population of 75,000 plants per hectare

Number of rows in one hectare = $\frac{10,000}{30}$

= 333.3

∴ Interplant spacing = $\frac{100}{450}$ = 0.22 = 22 cm

(c) at a plant population of 75,000 plants per hectare:

Number of rows = $\frac{10,000}{90}$ = 111.1

Number of plants = $\frac{75,000}{90}$ = 675.1

∴ Interplant spacing = $\frac{100}{675.1}$ = 15 cm

(d) at a plant population of 100,000 plants per hectare:

Number of rows = $\frac{10,000}{90}$ = 111.1

Number of plants = $\frac{100,000}{111.1}$ 900.09

∴ Interplant spacing = $\frac{100}{900.09}$ = 11 cm

∴ interplant spacing = 100/225 = 44 cm.

(d) at plant population of 100,000 plants per hectare

Number of rows in one hectare = $\frac{10,000}{30}$

= 333.3 rows

∴ Number of plants = 100,000/333.3

= 300.03

∴ Interplant spacing = $\frac{100}{300.03}$ = 0.33 = 33 cm.

(ii) At rowspacing of 90 cm

(a) at plant population of 25,000 plants per hectare ares = 100 x 100 m^2 = 10,000 m^2

Number of rows in one hectare = $\frac{10,000}{90}$

= 111.1

Number of plants = $\frac{25,000}{111.1}$ = 225.0

∴ Interplant spacing = $\frac{100}{225}$ = .44 m = 44 cm.

(b) at plant population of 50,000 plants per hectare

Number of rows = $\frac{10,000}{90}$ = 111.1

Number of plants = $\frac{50,000}{111.1}$ = 450

APPENDIX XXIII: YEARLY TRENDS OF SUNFLOWER PRODUCTION IN KENYA: 1982 - 1988.

Year	Tonnage
1982/83	1800
1983/84	3700
1984/85	3600
1985/86	15000
1986/87	17000
1987/88	21000

Source: Nganga, C. (1988)