THE EFFECT OF DIFFERENT WEEDING FREQUENCIES AND PLANT DENSITY ON GROWTH AND YIELD OF SUNFLOWER (*HELIANTHUS ANNUUS*)

by

J.J. MAKOKHA

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Abstract:

The Sunflower trials were conducted during the short-rains 1979 and long-rains 1980, at Kabete University Campus. There were six weeding frequency treatments and three levels of plant density, tested in a 6 X 3 factorial randomized complete block design.

The objectives of the research were (1) to determine the most critical weed competition period in sunflower,(2) to study the effect of weed competition on dry matter distribution and final yield of Sunflower and (3) to study the influence of population density on weed growth and yield of Sunflower.

The results obtained show that the critical weed competition period in sunflower lies between 2 weeks after emergence and anthesis and that the length of this period is dependant on the season, being shorter during the drier than wetter seasons. It was also established from the results that early weeding of the sunflower crop is essential and further that during dry seasons one weeding at two weeks after emergence is sufficient to obtain high yields while in wetter seasons it is necessary to weed up to anthesis, weeding all through the season is not necessary as it does not significantly increase yield of the sunflower. The

reason being that after the crop has established a sufficient cannopy the crop is not only able to suppress further weed growth but it can compete effectively against any weed growth occuring beyond the critical weed competition.

The plant density effects show that when the results are based on single-plants, the dry matter yields of the individual plant organs, the total dry matter and the yield increases with decreasing plant density. However when the results are expressed on a per unit area ofland it was found that total dry matter and the final seed yield increased with increasing plant density and decreased with decreasing plant density. The high numbers of plants at the higher densities compensated for the greater size of plant size at the lower densities. The results also show that there was more weed growth and therefore higher weed competition at the lower densities and this in part explains the better performance at the higher plant densities.

The results also show that the optimal density for sunflower is dependant on the season. The plant density indicated for the short rains was 55,000 plants per hectare and that indicated for the long rains was 74,000 plants per hectare. Higher populations than 55,000 plants/ha. during the short rains will result in severe competition for the limited moisture, hence the lower yields.

DECLARATION

I declare that this thesis is my original work and has not been submitted for a degree in any other University.

Makokha

Date 8th. March 1984 Name: Josephine J. Makokha

Signature:

This thesis has been submitted for examination with my approval as University Supervisor.

2/3/84

Date .... Name: Dr. D.R. Basiime.

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DEDICATION

To my husband Frederick and my children Ellis and Louisa, without whose encouragement throughout the writing up of the book this work may never have been completed.

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CHAPTER I

INTRODUCTION

Geographical distribution and world status

Sunflower (Helianthus annuus) is a member of the family Compositae which is characterized by the crowding together of individual flowers into heads. They have been grown as major source of oil in the Eastern European countries for several decades. Like maize, sunflowers are a native plant species to the North American continent and are supposed to have evolved in the South Western United States or on the plateaus of Mexico. They were introduced in Europe in the 18th Century and later to the Soviet Union.

Sunflowers constitute the second most important oilseed crop in world production, the first one being soyabeans, and groundnuts taking the third place. It is also the fourth largest source of oil seed protein on the world market (Foreign Agriculture Circular, World Fats and Oils 1975).

World production is much greater in temperate zone countries than in the tropics. Temperate zone production is greatest in Argentina, Bulgaria, Rumania, Yugoslavia, U.S.S.R, and Uruguay, while production of sunflowers in the tropics and subtropics is in Ethiopia, Morocco, Tanzania and Turkey where they are usually grown as a major crop in rotation with maize, sorghum and millet, and in competition with such crops as groundnuts, and the food grain legumes.

The world seed output of sunflower in 1975 was 10.7 million tonnes (Foreign Agriculture Circular, World Fats and Oils 1975); with U.S.S.R. contributing 60% of this; besides an annual production of 700,000 tonnes of valuable by-products.

The main reason for the popularity of sunflower in many parts of the world is its potential to yield a large quantity of top quality oil per unit area, valuable by-products not considered (Krishnamurth et. al., 1974). Under optimum conditions of production, high oil content sunflower varieties are capable of yielding 2 tonnes of seeds within 110 days and in terms of oil, this amounts to 1000 kg of oil per hectare at 9.1 kg/day/ha as compared to 4.2 kg/day/ha for groundnuts (Krishnamurth, 1974). Some late maturing low-oil cultivars may produce high yields varying between 2.0 - 3.0 tonnes (Van Eijnatten 1976).

Importance of Sunflower in Kenya

The sunflower crop was introduced into Kenya in the early 1920's and has been grown on large-scale farms in Western Kenya for many years but on a rather limited scale. Production has spread throughout East Africa from sea level up to 8,000 ft (2,400 m) above sea level.

By 1970, the total acreage under sunflower in Kenya was estimated to be about 20,000 (8404.8ha) (Ravagnan, 1970), most of the acreage being under the local varieties which are low yielding, and not uniform in several agronomic traits for instance, time of maturity, tallness, etc. In the past, the sunflower produced was mainly whole seed for the bird trade.

Extension of sunflower is currently taking place in the small scale farming sector, especially in the marginal areas. This has been through the efforts of the Ministry of Agriculture and the East African Industries Company. An estimated acreage of 900,000 hectares has been surveyed as potential production area for sunflower and it was hoped that by the year 1980, at least 15% of the surveyed area would be under sunflower production.

In the last 10 years oilseeds including sunflowers have been fetching an average of 9.5 million shillings on an annual basis, for the country. Sunflower exports alone fetched between 7 - 8 million shillings in 1974 - 1975 as compared to one million shillings between 1939 - 1951, a clear indication of the growing importance of the crop as a foreign exchange earner. The crop's economic status is bound to grow also considering the present world shortage of edible oils, which should create a keen demand for any edible oil-seeds which Kenya can produce for export, and also the country's own need for crop diversification and self-sufficiency in the much needed edible oil and protein in the local diet.

Locally, the sunflower crop is a possible alternative cash crop for certain areas and with the erection of oil-expelling plants in the country, there is a strong possibility for a small local market in sunflower oil and cattle cake. It may also play a key roll in bee farming for the production of honey.

Botanical description

The sunflower is an erect annual herb that belongs to the genus Helianthus which is composed of nearly 70 species of both annual and perennial habit. Of the annual species only cultivated sunflowers, H. annuus have played an important role in agricultural production. The cultivated sunflowers are mostly single headed, producing heads or discs of aggregated fertile flowers bordered by sterile ray flowers that are lemon to orange in colour. Most varieties range from 1.5 - 3 meters in height. The stems are rough and hairy and bear large pointed leaves that are also rough and hairy, born on short petioles. The discs may vary from 10 - 30cm in diameter depending upon the variety and the plant population.

Flowers are almost completely cross-pollinated by insects but under favourable environmental conditions considerable selfing may occur. The seed is an achene, consisting of an embryo entirely encased in a tough pericarp.

The plant has a tap-root system which is well branched and extends laterally for several meters and makes good use of available moisture in the upper soil profile. The tap-root does not however penetrate and remove water as deep from the soil as many other tap-rooted crops. A characteristic of the plant that gives it its name is the bending of the stem (nutation) so that the head and leaf positions follow the sun during the day-light. This following of the sun ceases in part after pollination when the head remains facing east.

Varieties

Horticultural varieties of sunflower differ in height, in the number of heads, and in the colour, size and oil content of the seeds. Varieties planted for oil production are usually small-seeded with the kernel accounting for about 60% of the weight of the seed. In varieties that are grown for direct human consumption, the seeds are usually large, the kernels do not fill the husks, and constitute about 50% of the weight of the seed.

Using height as a criterion there are four types of varieties; very tall (more than 200cm) tall (170-200cm) semi-dwarf (120-170cm) and dwarf (less than 120cm). The very tall varieties are very late maturing, the hulls constitute a large proportion of the seed and their overall oil yield is low, while the heads are difficult to harvest, dry very slowly, and usually have a high proportion of empty seeds.

The dwarf varieties are generally lower yielding than the taller varieties, their main significance being in the possibility which they offer for mechanical harvesting.

Following recent discovery of Cytoplasmic male sterility and fertility restoration in sunflowers, production of hybrids is now possible. The United States have pioneered in the development of hybrid sunflowers using this method and several hybrid varieties are now available in the U.S. The hybrids offer greater uniformity, high oil-content, higher yield and greater disease resistance than the previous open-pollinated varieties.

Ecological requirements

The sunflowers are best adapted to savannah type of climates and may be damaged by diseases when grown in high rainfall areas. It thrives in the entire range of climates suited to maize, sorghum and millet (Childs, 1948; Gearside, 1975). When the plants are well established they are quite tolerant to a considerable amount of drought, heat, with prompt recovery when rains occur. Sunflowers are harder than maize and will give good yields on soils too poor, and in seasons too dry, wet or cold for good yields of maize (Hill 1948, Acland 1971). Frost tolerance by sunflower is particularly in the seedling stage and this enables this crop to grow where occasional low temperatures seriously damage maize, sorghum and millet.

Sunflowers grow well in areas with 750mm rainfall or more per annum and for best yields it requires reasonable rainfall during the three to four weeks that coincide with flowering and seed fill as this is the most critical period for moisture stress (Gearside 1975, Doorenbos 1975, McAlister et al. 1970, Acland 1971, Singh et al. 1976). Dry weather is necessary during harvesting to avoid rotting of the heads.

Sunflowers do well on a wide range of soils, but prefer deep soils with good water storage capacity. The crop is unexacting and not particular in its soil requirements (Hill 1947) and will thrive in ordinary good soil with a warm sunny and moist climate. The sunflower plant is a gross feeder but does not require special manuring, however, sunflower seed is high in protein and minerals, so it follows that high yields require substantial amounts of fertilizer to correct soil deficiencies. Sunflowers will also not do well on acid soils, water logged land or steep slopes, highly fertilized soils are not suitable as the plants grow too tall with a high incidence of lodging and ripen late.

Unlike the hybrid varieties the older open pollinated varieties have a wider ecological adaptation and perform better under widely diverse conditions than do hybrid varieties. This variability is not entirely negative, for it suggests that hybrids can be developed and regionalized to fit specific ecological conditions.

The Sunflower and its uses

In all areas of production the crop is utilized both for direct consumption as food and for oil and oilseed cake that enters trade in competition with products of other edible oil seed crops. Sunflowers can be utilized for subsistence or as a cash crop. They may contribute to domestic market demands or serve as an export crop (seed oil cake). European countries import about 85% and Asian countries 15% of the crop that enters world trade.

The sunflower seeds can be eaten as salted whole seeds and as roasted nuts (dehulled).. Flour can also be made from the seeds. Whole seeds are used for feeding livestock, poultry and cage birds.

The seed may be processed for oil extraction by using seed with or without hulls. An estimated 90% of the sunflower seed produced is crushed for oil extraction (Arnon, 1972). Commercial processing of a metric ton of seed for oil yields about 400 kgs of oil, 350 kgs of meal and 200 kgs of hulls. The composition on average of these products are presented in table 1 below.

Table 1: Composition of Sunflower Products

	Protein %	Oil %	Carbohydrate %	Mineral matter
Whole seed (with hulls)	20	46	25	4
Naked Kernels	24	55	12	4
Meal (from dehulled seed)	50	4	36	8

Source: Guide for field crops in the Tropics and the subtropics. Part 2 of 2. PN-AAB-952 by Zimmer.

The oil produced is used for cooking, as salad oil and for the manufacture of compound cooking fats and shortening. Because of its colour, high keeping ability and the absence of off-flavours sunflower oil is considered to be most suited for the manufacture of margerine.

The sunflower oil is rich in unsaturated fatty acids and contains physiologically valuable components such as linoleic acid (about 30 - 70%), Vitamin E and phosphatides; (Pan-chenko 1976, Singh 1976, Gearside 1975). A large quantity of this oil is used for confectionery purposes. The linoleic acid contained in the oil gives it therapeutic qualities, and is, as a result, recommended to patients with physiological disorders of the arteries.

The sunflower oil is used in industry as well, for the manufacture of soap and candles. Being a semi-drying oil, it is used in blends with linseed and other drying oils in the making of paints and varnishes. It is also used as a lubricant.

The cake containing hulls after extraction of oil is excellent feed for ruminant livestock and the cake and meal produced by processing dehulled seed is an excellent protein food in human diets. The press cake or meal is reported to contain 40 - 50% protein, Vitamin B complex and about 5% fat (Nagarajan 1974, Panchenko 1976, Blackman 1947). The protein is said to be superior to most vegetable proteins and equal to soyabean protein in terms of digestability and biological value. It is also more nearly balanced in essential amino acids than most other vegetable proteins, its net dietry value being 93% which is as high as the standard egg protein used by nutritionists. Soyabean protein rates 62% and groundnut protein 69%. Because of its high quality and being devoid of any toxic substances, sunflower protein has been used in the preparation of protein rich supplements for pre-school children (Nagarajan et al. 1974, McCleary, 1973).

The sunflower husks are valuable material for preparing ethyl alcohol furfural and yeast. The hulls which constitute 35 - 50% of the seeds may be used as fillers in feed-cakes and meals, as bedding for livestock and poultry litter and in the preparation of polishing abrasives. They can also be used for fertilizer and mulch. Pressed into blocks they can make an excellent fuel. The stalks can be processed for the production of pulp for the paper industry and of cellulose. Since the stalks are relatively rich in nitrogen, calcium and potassium, they can be shredded and incorporated into the soil for the purpose of improving soil fertility and adding soil organic matter.

The dried heads can be ground to provide a fair roughage for farm animals, with up to 9% crude protein and 3% oil (Moberley, 1965). Threshed heads are a source of pectin, which is as good in quality as that obtained from apple pulp (Panchenko, 1976).

The crop can be used as an alternative to maize for silage (Rozycka, 1974), being cut for this purpose at the end of flowering. The leaves have a high nutritive value but the stalks lignify very rapidly and their nutritive value is relatively poor. This silage from sunflower is less palatable and less nutritive than that of maize but the nutritive value of sunflower silage is greatly improved if mixed with silage maize.

Sunflower can be grown as a catch crop, after the main season and is effective at smothering weeds. When used for smothering weeds it should be broadcast at the rate of 45 - 55 lbs per acre (50.5 - 61.3 kgs/ha). It can also serve as a cover crop for clovers.

Weed problems in Sunflower production

A weed is a plant out of place and weed control involves a large portion of the effort required of a farmer to produce a crop. This effort directly affects the cost of production among other things and thus the cost of food. Weeds as a group have much the same requirements for growth as crop plants and are by far better competitors for these requirements. For every pound of weed growth, the soil produces about one pound less of crop.

Several investigators have demonstrated that weed infestations may lower yields of various crops (Blackman and Templeman 1938, Godel 1935 and Staniforth 1953). Weeds bring about yield reductions by competing with crops for moisture, nutrients and light (Pavlychenko 1949). Competition begins early and persists over a major part of the growing season (Blackman and Templeman 1938). As early as 1932, Korsom reported increases in yields of cereals by an average of 25% due to suppression of weeds in the temperate zone. In the tropics and subtropics yield increases due to removal of weed competition are of the order of 100% or even more (Ashby and Pfeiffer 1956).

Weeds also lead to less efficient use of land. Efficiency is reduced since costs are increased through cultivation, hoeing, mowing and spraying. Land values may be reduced, especially by perennial noxious weeds. Crop choice may be limited as some crops will not compete effectively against heavy weed-growth. Harvesting costs may be increased and root and crop damage may result from cultivation. Soil structure may be destroyed by repeated cultivation, especially when wet.

When considering the weed problem one also has to consider the added protection costs from insects and diseases, as weeds may harbour insect and disease organisms that attack crop plants. All types of crop products may be reduced in quality. Weed seeds and onion bulbets in grain and seed, weedy trash in hay and cotton are a few examples. Thus weeds may be responsible for poorer quality of products.

An important factor in weed control is the timing of the weeding operation, because there are critical weed competition periods during which the presence of weeds is particularly harmful to a crop (Nieto, Brando and Gonzalez 1968). By keeping the crop weed free only during the critical period, weeding costs may be greatly reduced. An early control of the weeds in the sunflower crop has been shown to lead to considerable increases in yield (Wilkins and Swallers 1972, Van Eijnatten and Wamburi 1972). It has been reported that the critical period during which the growth of weeds has an important negative influence on the yield falls in the first four weeks (Kovacik 1966, Johnson (1971)

When mechanical weed control is practiced up to three cultivations are necessary, before the crop is able to suppress further weed growth. The first cultivation should be performed when the sunflower plants are emerging and rows have become visible, and the second cultivation when the second pair of true leaves has unfoled (Knizhnikov and Gladyshev, 1965). A weed-free seed-bed is a great help in ensuring that the crop is able to suppress later weed growth.

Post planting cultivations in the sunflower crop can be carried out in several ways. In the widely spaced sunflowers row crop cultivators with hilling discs may be used. The discs should be set in such a way that germinating seedlings will not be covered by soil from the cultivated inter-rows. Early cultivations can also be carried out by cross harrowing of the sunflower rows, and this is best done soon after emergence. In Kenya hand-weeding is the normal practice.

Quite a range of herbicides have been tried for weed eradication in sunflower, both pre and post emergent. The majority are applied after sowing, but before the emergence of the young plants. An example is Alochlor (Lasso) which is applied pre-emergent, and is effective in controlling annual grasses and several broad leaved weeds. Avedex for the control of wild oats and eptam for control of fox tail and broad-leafed weeds (Putt,,1963) have also been used. Prometryne has proved effective against a large number of dicotyledons (Purseglove, 1968). Use of herbicides in sunflower should however be treated with a lot of caution as some herbicides have been known to adversly affect the crop. An example being 2, 4-D. Spray drift of this herbicide will cause considerable damage to the sunflower at distances up to 0.75 km.

Effect of Plant Density on Sunflower yields and plant characteristics

Optimum plant populations per unit area for sunflower are dependant on soil fertility and climatic conditions during the growing period. It has been observed that the characters of the single plant such as head size, seed-weight, stem-diameter etc., improved significantly with decreasing plant density. It has also been observed that the yield per unit area of land is favoured by high plant densities (Turchi 1974, Van Eijnatten 1973, Zubriski and Zimmerman 1974). Oil content also increases with increasing density. At very high plant densities however the percentage of lodged plants increases.

The objectives of this research were therefore,

(1) to determine the most critical weed competition period in Sunflower.

(2) to study the effect of weed competition on dry

matter distribution and final yield of Sunflower.

(3) to study the influence of population density on weed growth and yield of Sunflower.

CHAPTER II

LITERATURE REVIEW

Effect of weeding frequency on dry matter distribution and yield:

Weed infestations have been shown by many investigators to lower crop yields (Blackman and Templeman, 1938; Godel 1935; Pavlychenko, 1949; Staniforth 1953 and Staniforth and Weber 1956, 1957). In recent times the losses caused by weeds have been accurately measured for different crops. In the U.S.A. for example, Wimer and Harland (1925) found that the average yield reduction in unweeded maize plots was 81%, and more recently Denham (1964) quoted reductions ranging from 41% - 86%.

At Kitale, Western Kenya, in two series of trials carried out in 1967 and 1970, unweeded plots of maize gave 33% and 31% less yield respectively than clean weeded ones. Mani et al. (1968) reports that in some crops such as rice, maize, onion and cotton, the yield may be reduced more than 50% due to weed competition. Crops with poor competing ability such as groundnuts and rainy season crops such as maize and cotton suffer more from unchecked weed growth. Abubaker (1978) found that in sugar-cane where no weeding was done loss of yield could be as high as 70%. In India it was found that the losses to the crop vary from 10 - 70% in terms of yield reductions depending on the weed flora and its intensity (Lall, 1977).

It has also been shown that much as there are reductions in yield due to weed competition, critical weed competition periods do exist for various crops (Gurnah 1974, Enyi 1973, Johnson 1972, Oram 1961) and by keeping the crop weed free only during the critical period, weeding costs can be greatly reduced.

According to Bell and Koeppe (1972), competition is the mechanism by which one plant depletes some essential element for plant growth to a level that is limiting to the growth of a second plant sharing that habitat while the critical weed competition period can be defined as that period during the growth of the crop when the presence and competition of weeds is harmful to the crop (Nieto, Brando and Gonzalez 1968; Gurnah 1970).

Gurnah (1974) reports four periods of weed competition in a crop. (1) The pre-early post emergence period, when the seed bed preparation effectively controls weeds; (2) the period from when the effects of seed bed preparation are no longer noticed to that at which the crop itself covers the ground and eliminates weed competition ; (3) the period when the crop completely covers the ground thus eliminating competition from weeds; and (4) the period between crop maturity and harvesting. Most workers define period two as the critical weed competition period (Nieto et al. 1968) but according to Kasasian and Seeyave,(1969) the critical weed competition period includes periods one and two which they estimate to cover the first 25 - 33% of the life of many crops.

The length of the critical weed competition period has been shown to vary with different crops (Hauser, 1971, Nieto et al. 1968; Williams 1971). In trials conducted in 1973 and 1974 using the soyabean cultivar "Hill" it was shown that weeding for the first four weeks adequately controlled weeds in soyabean (Gurnah, 1976). Wetala (1976) also showed that delayed weed control resulted in significantly lower soyabean yields than early weed control mainly due to weed competition during the pod filling stage. Wetala also found that yields from plots which received one early weeding were as high as those from plots hand-weeded twice and suggested that the soyabean crop needed weeding once and if weeded twice, the first weeding should be done within three weeks after planting.

In another set of experiments Wetala (1976) showed that it is feasible to control weeds to a minimum critical level as control of weeds beyond this level does not lead to increased yields. This is assuming that weed control is effected at the correct stage, the correct stage being the critical weed competition period. Earlier work by Staniforth and Weber (1956) had indicated that soyabean growth was depressed appreciably by weeds only when they were present up to and after pod formation. Staniforth (1962) reported soyabean yield reductions due to weed competition to range between 15 - 33% compared with the yield of weed free soyabeans Burnside (1972) reported a reduced stand of soyabean due to weed competition.

Amir and Lifshitz (1976) reported the critical weed competition period for groundnuts to be the first 60 days, while Hauser and Parham (1969) found it to be between the first 3 - 5 weeks. Ishag (1971) working in the Gezira reported that groundnuts must be weeded at least once after 30 days from sowing and that weeding twice at 30 - 60 days was adequate to give maximum yields.

For cotton competition with weeds was reported to be most serious from two to four weeks after crop emergence (Schwerzel and Thomas 1967 - 68) and that a weed free period of at least four weeks was required to maintain maximum yields. In 1971 the same experiments were repeated and the results indicated that cotton need only be weeded between six and eight weeks after emergence. The difference in the length of the critical periods was attributed to weather conditions, the period being shorter during the drier than wetter periods.

Martinez and Nieto (1968) showed that production of maximum yields of spring cotton required a weed free period of 60 days, while winter cotton required a weed free period of 120 days after emergence. In Colombia, Perdomo et. al. (1969) reported that weed control in cotton was only essential between the 20th and 45th days after emergence. Buchanan and Burns (1970) reported that Alabama cotton tolerated from 4 - 6 weeks weed competition without suffering severe yield reductions while weed control beyond eight weeks did not affect yields.

In wheat experiments Reeves (1976) found significant reductions in wheat dry matter production caused by weed infestation to occur within 3 - 6 weeks after emergence. Removal of rye grass (Lolium rigidium) at the two lead stage of wheat significantly increased yields of wheat while removal of the rye grass at late tillering did not increase yields significantly (Smith and Levick, 1974).

For corn it has been reported that most crop loss was caused by weed competition in the early stages of the crop and weeding once when the crop was 10 cm high gave as good yields as weeding 3 times at various heights of the crop (Allan, 1974). Nieto, Brando and Gonzalez (1968) reported experiments that showed that maize and beans are most susceptible to weed competition during the first 30 days of their 100 - 135 days growth cycle, weeds growing after that period having no depressing effect on yields. Staniforth (1957) found the average corn yield reductions due to weed competition to be 5, 10 and 20% for different levels of nitrogen, yield reductions being lower under high fertility. Similar trends had been observed previously (Staniforth 1953). Nieto and Staniforth (1961) also reported similar results but with greater reductions of corn yield due to weed competition.

In an analysis of the effect of weed competition on growth and yeild attributes in sorghum (*Surghum vulgare*) cowpeas (*Vigna unguiculata*) and green grams (*Vigna aureus*) Enyi (1973) showed that all three crops yields were highest when weed removal was effected at 2 weeks and 4 weeks (i.e. Two weedings) after sowing. Remison (1978) found that weed competition in a cowpea crop (*Vigna Unguiculata* (L) Walp) manifests its effects in the very early stages of growth, reducing number of leaves, nodules, delaying flowering and finally reducing yield and yield components.

Experiments in which *Cyperus difformis* L. was removed from rice (*Oryza sativa* L.) by hand at various stages of crop growth demonstrated severe competition between the weed and the crop (Swain et al. 1975). Where high populations of *Cyperus difformis* competed with rice for the whole of the growing season rice yields were reduced by 22% to 43%. Weed removal prior to tillering led in all experiments to rice yields significantly higher than those obtained when weeds were removed after tillering. The results indicated that *Cyperus difformis* commences to compete with rice at an early stage of growth and continues to compete throughout the period during which the potential yield of the crop is determined.

In experiments carried out with sunflower, Johnson (1972) observed that sunflower required to be cultivated at 2 and 4 weeks after sowing. Weeds that emerged after a single cultivation at 2 weeks after sowing competed with sunflowers and gave significantly lower yields than where sunflowers were cultivated at 2 and 4 weeks after sowing. Yields were also significantly reduced by weeds not removed until 6 weeks after sowing. Van Eijnatten (1972) also working on timing of weeding in sunflower at Kabete concluded that weeding once at 4 weeks after emergence of the sunflower was adequate. The Kenya Ministry of Agriculture (Crop Advisory Leaflet No. 272) reported that the growth of the sunflower the first 3 - 4 weeks is slow so weed competition must be controlled within this period, and after the crop is 60 - 70cm high it grows rapidly and tends to smother the weeds.

From the review of literature there is sufficient evidence to show that weed competition does reduce crop yields and that for various crops there are critical weed competition periods during which the crops are particularly susceptible to weed competition. Literature on weed competition and critical weed competition periods in sunflower is however very scarce.

Effect of plant density on dry matter distribution and yield.

Several workers have observed pronounced change in the morphology and performance of various crops as a result of varying the plant population per unit area. Generally yield and total dry weight have been shown to increase with increasing plant population and also that high yields of grain are usually accompanied by high, but not necessarily maximum production of total dry matter (Genter and Camper 1973). Component-part weights have been shown to decrease as plant populations increased (Genter and Camper 1965, Turchi, 1974, Van Eijnatten 1972).

Clement et al. (1929) found that lowering the seedling rate of Marquis spring wheat to half the normal resulted in more heads, but it reduced yield and kernal weight. Percival (1921) working with Swan winter wheat found that increasing the area for a single wheat plant from 6 to 18, 36, 72 and 144 square inches gave progressively lower plot yields. He also showed that weight of seed per head and head number per plant increased with decreased plant population. Pendleton and Dungan (1960) varying planting rates of winter wheats from 3-18 pecks per acre (50.4 - 302.7 kg/ha) obtained the most heads per plant, greatest height, and latest heading date with the lowest seeding rate. Wilson and Swanson (1962) working on the effect of plant spacing on the development of winter wheat observed progressively lower yields as wheat populations were reduced. The adverse effe ts of reduced stand were reflected primarily in decreased head number per unit area and test weight.

While high populations have been shown to favour high yields, it has equally been demonstrated that optimum populations do exist and above optimum populations cause a reduction in yield. Willey and Holliday (1971) suggest that the decrease in grain yield at high populations is probably determined by a decrease in the number of grains per unit area. They also suggest that a decrease in the number of grains per unit area may be attributable more to a lower production of total dry matter by high populations during the later stages of ear development than to an unfavourable partitioning of such dry matter between the ear and the rest of the plant. This lower production of total dry matter was attributed to the crop growth rates of the higher populations having reached their peak and then having declined before the end of the ear development period. Similar results were obtained for barley (Willey and Holliday 1971).

Giesbrecht (1969) using four populations of corn reported a substantial increase in grain yield with increasing population in years when moisture was adequate. In years when moisture was inadequate peak production occured at a much lower density. Giesbrecht also reports that at very high populations yield decreased, probably due to the increased percentage of barren stalks with increasing plant population. Lang et al. (1956) Pendleton (1965) Rutger and Crowder (1967), Colville (1966 and

and Stickler (1964) made similar observations.

According to Alessi and Power (1975) working on the effect of plant spacing on the phenological development of corn, higher populations fixed the greatest percentage of solar energy which was indicated by higher dry matter production. Plant populations with the highest dry matter production also had the highest yields. Alessi and Power (1974) in experiments conducted to determine the effects of plant population and row spacing on dry matter production and grain yield of corn reported an increase in grain yield from 2,680 kg/ha to 3,070: 3,090; 2,960 ; and 2,680 kg/ha with progressive increases in population from 20,000; 30,000; 40,000; 60,000 and 74,000 plants/ha. It was also observed that plants tended to be larger at the lower populations thereby compensating in weight for the greater number of smaller plants at the high planting rates. Brown and Shradder (1959) however reported that wide row spacings and low populations are desirable in drought years since individual plant size is less in wide than in narrow rows and less vegetative development would generally mean more moisture available during grain development.

Stickler and Laude (1960) showed grain sorghum yield to be higher with 78,000 than with 52,000 plants per acre. They also observed that weed control in the sorghum crop was more effective in the narrow than in the wider spacings. With regard to plant population studies in grain sorghums, Sieglinger (1926) has shown that the tillering characteristics of various sorghum genotypes greatly influence their response to spacing. Varieties that tillered profusely produced similar yields when the within-row space varied from 6 - 30 inches. Conversely, genotypes that produced few tillers showed successive yield reductions when plant populations were decreased.

Rutger and Crowder (1967) evaluated three corn hybrids at two locations for 3 years at 50, 88, and 125 thousand plants per hectare. They reported a delay in maturity with increasing population. The amount of dry shelled grain in the silage decreased at higher populations. Total dry matter increased about 6% as the population was raised from 50,000 to 88,000 plants but total.dry matter yield at 125,000 plants was the same as at 88,000 plants per hectare. The dry shelled grain/total dry matter ratio was reported to decrease with increasing populations.

Goldsworthy and Tayler (1970) examined the effect of plant spacing on grain yield of short and tall sorghum in Nigeria and found that yield per plant declined with increase in population, mainly due to a decrease in the number of grains per head. Goldsworthy (1970), using four varieties of sorghum and three plant populations also found that with the exception of one variety, grain yield increased with increasing plant density. In all varieties the dry weight per unit area also increased with plant population.

Weber et al. (1966) working on soyabean reported that those plant population arrangement combinations favouring a rapid attainment of high LAI, i.e. high plant populations and narrow spacings, were those also having the greatest dry weight accumulation. The rate of dry weight accumulation was also shown to be a function of LAI, but only up to a particular LAI. It was further shown that maximum seed yield occurred at less than maximum LAI and at generally lower populations and narrower spacings. Plants produced at highest densities were taller, more sparsely branched, lodged more and set fewer pods and seed than those plants at lower densities. Thus, the seed reduction resulting suggested more severe plant competition at higher plant densities.

Lambert and Lehman (1960) found that seed weight and seeds per pod were not affected appreciably by population change, whereas the number of seeds, pods and branches per plant decreased with increased plant population. Oba et al. (1961) found that lower populations resulted in greater pod set, and an increased dry matter production of leaves and stems of soyabeans.

Felton (1976) also working with soyabeans reports that under conditions of available moisture during the grain filling stage seed weight was not affected by crop density, and that where weeds occur there are distinct advantages in growing soyabeans at higher crop densities, and reducing the interrow spacing is the most effective method of achieving this. It was also reported that seeding soyabean below 19.7 plants per meter of row resulted in reduced yields, a general shortening of plants and production of pods too close to the soil for efficient harvesting. Seeding rates above 39.4 seed per meter of row often resulted in increased plant height, smaller stem diameter, increased lodging and sometimes reduced yield..

Johnson and Harris (1967) in an investigation to study the effects of plant population on soyabean yield and other agronomic characteristics using plant densities varying from 6.6 to 26.2 plants per meter of row found that the highest densities (26.2 plants per meter of row) produced maximum yield. Plant height increased as populations increased through 26.2 plants per meter of row. Weed populations occurred in populations below 13.1 plants per meter of row. Gurnah (1976) found that a plant population of one million plants/ha gave significantly higher yields than lower populations tested for soyabeans, when rainfall is sufficient. Auckland (1970) and Rubaihayo (1969) had previously reported similar results.

McWhorter and Barrentine (1975) reported increased yields and better weed control when soyabean populations were increased from 80,000 to 350,000 plants per hectare. Veeraswamy and Rathnaswamy (1974) using various inter-row spacings found that the closest spacing resulted in the tallest plants and the highest production per unit area. Wide spacing increased number of branches, number of pods and yield per plant.

Williamson (1974) reported increased yields obtained from increased plant population when available moisture was adequate, while plant heights decreased in the soyabean crop.

Delgado and Yermanos (1975) working on yield components of sesame as affected under different population densities found that number of capsules and seed yield per unit area decreased if plant density was increased beyond a certain level. At lower densities more branches were produced. They also showed yield of seed per unit area to be positively and significantly correlated with plant height, number of primary branches, number of capsules per plant, number of seeds per capsule, seed weight, seed yield per plant and number of capsules per unit area, factors that are all influenced by plant density.

Adelana (1976) carried out field trials at 3 locations to study the effect of plant density (10,000, 20,000, 30,000 or 40,000 plants/ha on four tomato cultivars. The highest fruit yield was obtained from the highest plant density.

As for other crops, it has been established by various workers that plant density affects sunflower plant characteristics and yield. Klimov (1968) using the sunflower cultivar Uniimk 8931 grown in rows 60cm apart with plants 25, 30, 35, 40, 45, 60 or 70 cm apart in the row, giving plant populations ranging from 24 to 67 thousand/ha found that the closest 2 spacings gave the highest yields of seed and oil, but that seed size increased at the wider spacings. Length of growing, percentage oil content and percentage husk in the seed were relatively unaffected by plant density, but plant height increased and head diameter decreased at the closer spacings.

Ilisulu (1968) also reported highest yields at the closest spacings and lowest yields for the wider spacings. Galgoczi (1967) reports that close spacing of long stalked sunflower varieties decreased the size of heads and seeds, increased fungal damage and led to a high incidence of empty seeds.

Turchi (1974) working on a spacing trial on sunflower considered four populations; a low plant population 17,774 plants per hectare, two middle plant populations 35,554, 44,444 plants per hectare and a relatively high population as 77,777 plants/ha. He observed that going from the closest to the widest spacing, the characters of the single plant significantly improved, for example the mean height decreased, head diameter and weight of 1,000 seeds improved significantly. Main yield per plant also increased with wider spacing. However in spite of the favourable characters of the single plants at wider spacings, it was observed that when yield was considered in terms of surface area, the closer spacings produced the highest yields.

Weiss (1966) reported the optimum stand density for sunflower to be 10,000 plants/acre. In trials to establish optimum plant densitites for sunflowers in the Jijia-Bahlui depression, the sunflower cultivars UNIIMK 8931 and Smena were grown at populations ranging from 20,000 to 60,000 plants/ha. It was shown that optimum plant densities ranged between 50,000 to 60,000 plants/ha (Dumitrescu and Pinzaru 1966).

CHAPTER III

MATERIALS AND METHODS

Experimental Site

The trials were conducted at Kabete University farm during the second rains of 1979 and the first rains of 1980. The farm is located on Loresho Ridge and is part of the land known as Kirima Kimwe Estate, whose approximate location is latitude 1° 14' 20" S and longitude 36° 44' E to 36° 45' 20" E. The farm lies at an altitude of 1940 metres above sea level.

Climate of the area

Maximum and minimum temperatures:

The mean maximum and minimum temperatures during 1979 and 1980 are presented below:

Year	Maximum	Minimum
1979	22.72°c	12.85
1980	21.34°c	11.49

Solar radiation

Yearly means expressed in langleys/day.

Year	Solar radiation
1979	474.97 langleys
1980	479.62 langleys (Average of 11 months)

Precipitation: see appendix fig. (1) and appendix fig. (2) for the rainfall distribution for the years 1979 and 1980 respectively. Rainfall totals for the previous two years were 1020.2mm for 1977 and 1001.2mm for 1978. The area has two rainfall seasons, generally referred to as the long and short rains with the long rains coming between the months of March to June and the short rains between October to December.

Soils of the University Field Station

Classification and structure: The soils are composed of humic and eutric nitrosols, which have a moderate to strongly developed fine and medium rocky structure.

Texture: They are clays with 70-80% clay.

Reaction: about pH 6

% Carbon: 3-4% in the top soil.

Experimental design

The treatments were examined in a 6 x 3 factorial randomized complete block design, with six levels of weeding frequency and three levels of spacing, giving eighteen treeatments in all. The experiment was replicated four times in plots of size 6 m x 6 m. The field plan is presented in Fig. 1.

Treatments

Weeding frequency

A - No weeding all season

B - Clean weeding all season

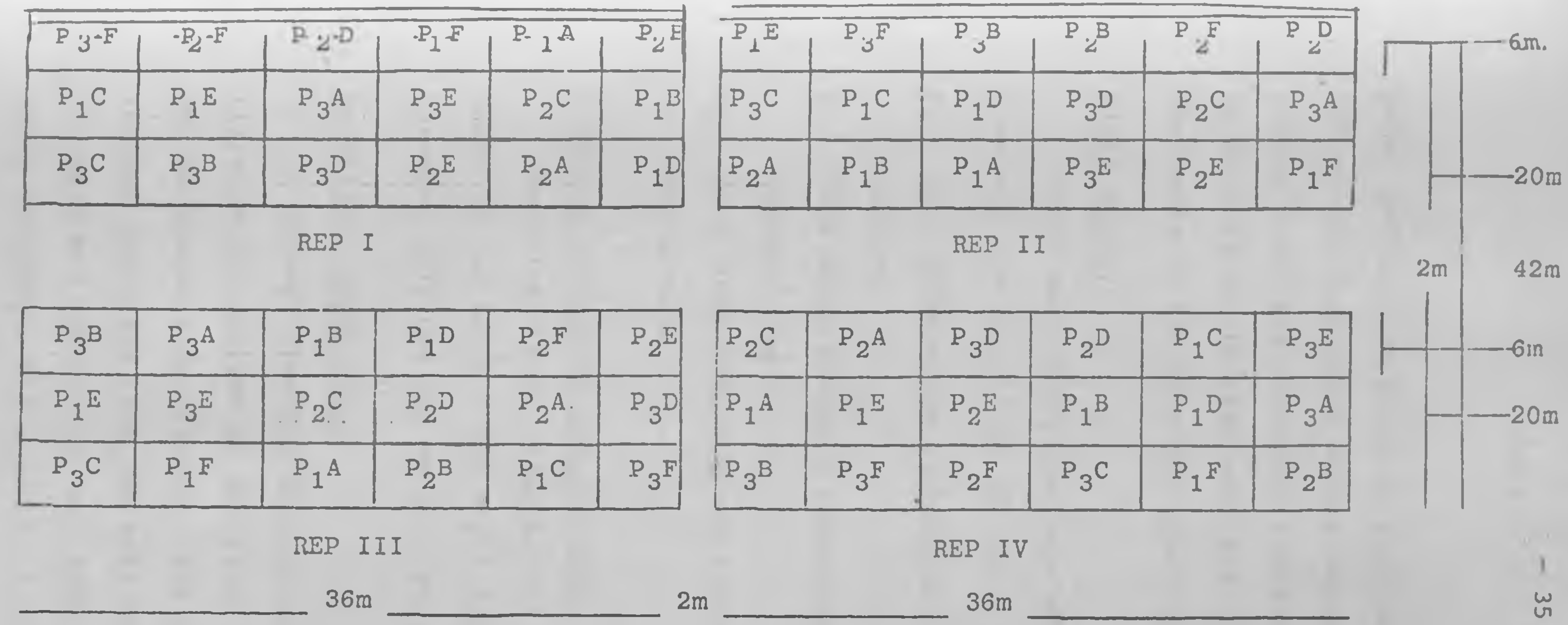
C - Clean weeding up to anthesis and thereafter no weeding.

D - No weeding up to anthesis and thereafter kept weedfree.

E - Single weeding before anthesis, two weeks after emergence.

F - Single weeding after anthesis.

Fig. 1. FIELD PLAN



P_3F	P_2F	P_2D	P_1F	P_1A	P_2E
P_1C	P_1E	P_3A	P_3E	P_2C	P_1B
P_3C	P_3B	P_3D	P_2E	P_2A	P_1D

REP I

P_1E	P_3F	P_3B	P_2B	P_2F	P_2D
P_3C	P_1C	P_1D	P_3D	P_2C	P_3A
P_2A	P_1B	P_1A	P_3E	P_2E	P_1F

REP II

P_3B	P_3A	P_1B	P_1D	P_2F	P_2E
P_1E	P_3E	P_2C	P_2D	P_2A	P_3D
P_3C	P_1F	P_1A	P_2B	P_1C	P_3F

REP III

P_2C	P_2A	P_3D	P_2D	P_1C	P_3E
P_1A	P_1E	P_2E	P_1B	P_1D	P_3A
P_3B	P_3F	P_2F	P_3C	P_1F	P_2B

REP IV

Plant Population

P_1 - 45 x 30 cm (74,000 plants/ha)
P_2 - 60 x 30 cm (55,000 plants/ha)
P_3 - 75 x 30 cm (44,000 plants/ha)

Weeding frequency

A - No weeding
B - Weeding all season
C - Weeding up to anthesis
D - Weeding up to anthesis and weed-free thereafter
E - One weeding, two weeks after emergence
F - One weeding after anthesis

Note: Anthesis or bloom is here defined as the time between 50% of the seed heads having commenced flowering and 50% having completed flowering (Anderson 1975). It can also be defined at the time when 50% of the anthers on 50% of the heads in the plot are shedding pollen.

Plant desity

There were three spacings between the row against a constant spacing within the row.

P_1 - 45 x 30cms giving a population of 74,000 plants per hectare.

P_2 - 60 x 30cms giving a population of 55,000 plants per hectare.

P_3 - 75 x 30cms with a plant population of 41,000 plants per hectare.

Cultural operations and planting

The fields were ploughed and harrowed before the onset of the rains. The first trial was planted on 5th November 1979 and the second trial on 20th April 1980.

Fertilizer application

A blanket dressing of nitrogen and phosphorus fertilizers was applied to all plots at the rates of 40 kgs/ha and 80 kgs/ha respectively. The phosphate was applied in furrows and mixed into the soil before planting. The nitrogen was topdressed four weeks after germination, soon after thinning. The sources of nitrogen and phosphorus used were calcium ammonium nitrate and Tripple supperphosphate respectively.

Variety used

The sunflower variety Issanka was used and three to four seeds were planted per hill, which were later thinned to leave one plant per hill. This variety was selected at INRA-Montpellier (France) from the cultivar VNIIMK 88-83. It is a dwarf variety with a high oil percentage (about 45% in the seed). It is early maturing, with a maturity period of 90-120 days depending on the weather.

Sampling technique

From about the 4th week after germination, a sample of 6 plants across two rows from each plot were harvested for growth analysis, at an interval of two weeks. The plants harvested were partitioned into their various organs; i.e. leaves, petioles, stem, root, basket, florets and seeds. The various organs were then oven dried at a temperature of 75^{o}c for 48 hours at the first two samplings before the plants became bulky and at 100^{o}c for 96-120 hours for the rest of the harvests. The dry weights were then recorded. The fresh weight of the leaves was also taken for the purpose of determining leaf area development at the various sampling dates.

At each sampling weeds too were collected from the area from which the crop plants had been sampled, using a 1m^2 quadrat. This area was roughly equivalent to the area occupied by the 6 plants. The weed species of the plants collected were identified after which the weed samples were also oven dried and dry weights recorded. At each sampling a guard plant along the row was left between the sampled areas.

The following determinations were also done. The leaf area development was measured at the various stages of crop sampling using the punched disc method. Discs were taken from a random sample of 10 leaves weighed and the total area of the discs was worked out. The fresh weight of all the leaves from the sample of 6 plants including the punched leaves was also determined. The leaf area was then worked out on the basis that if a given weight of discs A gms occupied an area B cm^2 then leaves weighing C gm should occupy an area $\frac{B \times C}{A}$ sq. cm. The leaf area so obtained was then expressed in M^2/ha for the various treatments.

- The seed yield at the final harvest.
- The size of the sunflower heads at maturity.
- The weight of 1,000 seeds to determine seed size.

A hand or manual counter device was used to count 1,000 seeds of sunflower randomly taken from a sample of the final harvest. The seeds were then weighed.

The analysis of variance was performed on the data collected and significance of treatment effects is reported at 5% and 1% levels of significance. The L.S.D. test was used to distinguish between treatment effects that were significantly different.

CHAPTER IV

RESULTS AND DISCUSSION

The results are presented in nine parts. Each part is divided into (a) the effect of weeding frequencies, (b) effects of plant population (density). The main parts are: 1. effects of the treatments on leaf blade dry matter, 2. effects of the treatments on stem dry matter, 3. effects of treatments on root dry matter, 4. effect of treatments on basket and seed dry matter, 5. effect of treatments on total dry matter, 6. effect of treatments on leaf area development, 7. the effect of treatments on 1,000 seed weight, 8. effect of treatments on final yield and 9. the effect of plant population on weed growth and kind of weeds in sunflower.

Results considered as not showing anything of interest or significance are omitted. Note also that for all the characters considered in these trials there were no significant interactions between the weeding frequency and plant density treatments.

Except where mentioned the results are based on the effects of the treatments on the individual plant response (refer to Chapter 3, under the treatments section). Detailed results and analysis of variance are given in the Appendix. Relevant LSD's are given for both the 5 percent and 1 percent levels of significance.

Effect of weeding frequencies on leaf blade dry matter. 2nd rains 1979

Table 2 and Figs. 2 and 3 show the results of the effect of weeding frequencies on leaf dry matter both for 1979 and 1980 respectively.

At the beginning of the sampling period (i,e,at 4 weeks) there were no significant differences between the effects of the different weeding frequencies on leaf blade dry matter but differences among the treatment effects began to appear from the 6th week after planting. The treatments fall roughly into two groups, with one group comprising of the control B (weeding all season), C (weeding up to anthesis) and E (one weeding before anthesis) and the second group comprising of treatments A (no weeding all season), F (one weeding after anthesis) and D (no weeding up to anthesis and thereafter weed-free). Throughout the sampling period, there were no significant differences between the effects of treatments falling within the same groups. However there were significant differences between the effects of the treatments in the two groups.

At the 6th week after planting the leaf blade dry matter obtained from treatment C was significantly higher than the leaf blade dry matters obtained for

TABLE 2: Effect of weeding frequency on leaf blade dry matter in gms/plant

Year 1979	Weeding Frequency	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
	A	8.57	53.39	85.18	73.30	52.38		
	B	11.17	63.86	146.38	131.80	101.07		
	C	9.72	63.03	137.75	132.13	107.83		
	D	8.84	50.12	94.85	86.17	73.76		
	E	10.18	65.55	133.48	139.17	108.87		
	F	8.86	48.55	83.53	80.93	61.68		
	S.E.	0.78	4.29	11.10	8.99	9.30		
	L.S.D.-5%	2.25	12.39	32.07	25.99	20.57		
	L.S.D.-1%	-	16.69	43.18	35.00	27.71		
	C.O.V.(%)	28.32	25.99	33.90	29.07	38.25		
Year 1980	A	3.40	20.35	61.84	76.01	95.49	86.47	65.65
	B	4.69	30.99	88.14	105.57	157.35	138.28	127.57
	C	4.43	33.01	83.41	96.77	147.11	144.24	131.85
	D	4.17	18.16	64.82	82.53	100.22	105.63	86.18
	E	4.19	34.31	75.14	112.02	139.03	122.35	114.13
	F	3.97	21.47	55.75	77.05	99.37	90.68	63.68
	S.E.	0.49	2.26	3.13	4.46	6.88	5.44	5.93
	L.S.D.-5%	1.39	6.52	9.03	12.87	19.86	15.70	17.12
	L.S.D.-1%	-	8.77	12.17	17.33	26.74	21.14	23.05
	C.O.V.(%)	40.56	29.63	15.15	16.84	19.35	16.43	20.91

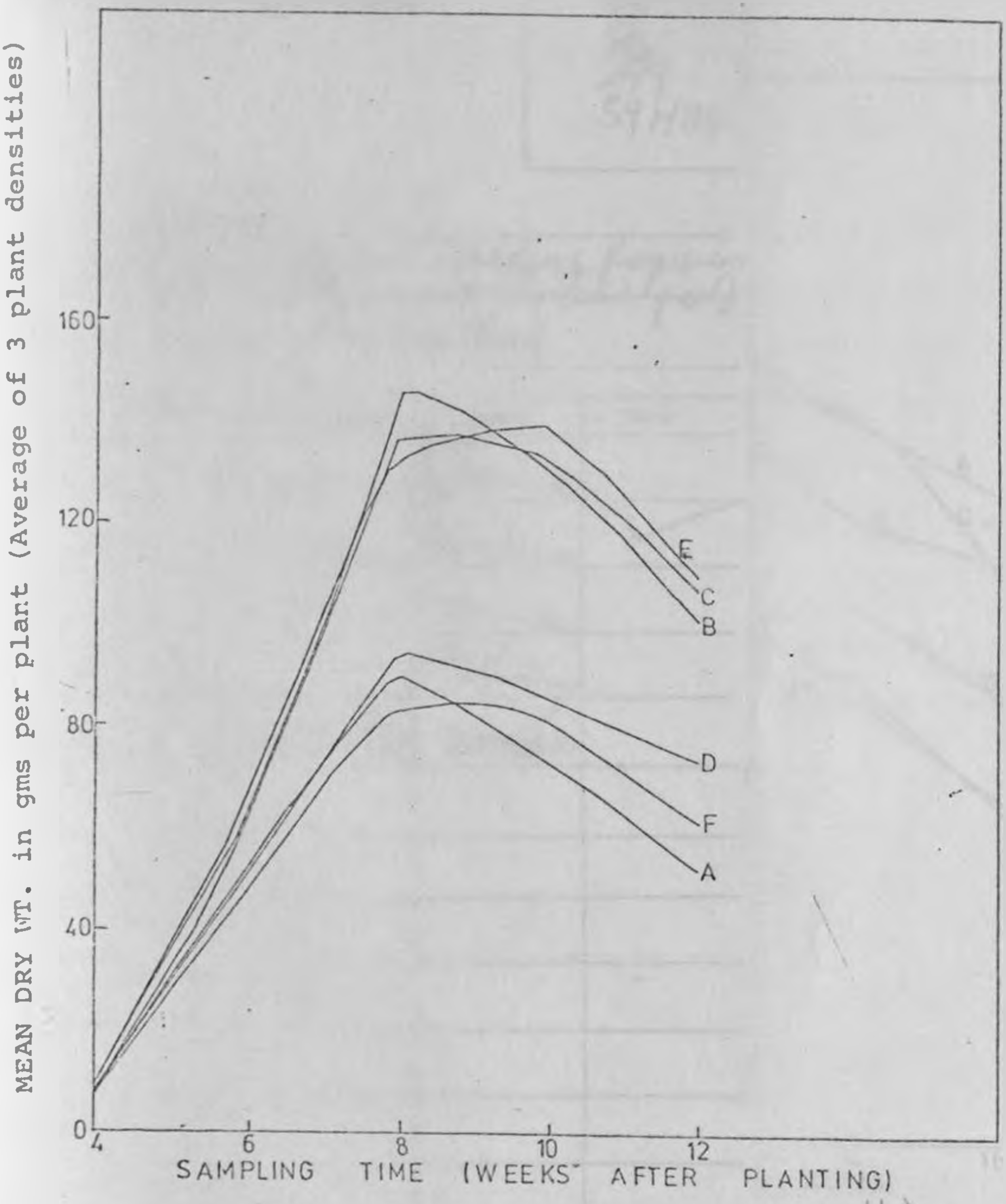


Fig. 2. Effect of weeding frequency on leaf blade dry matter (1979).

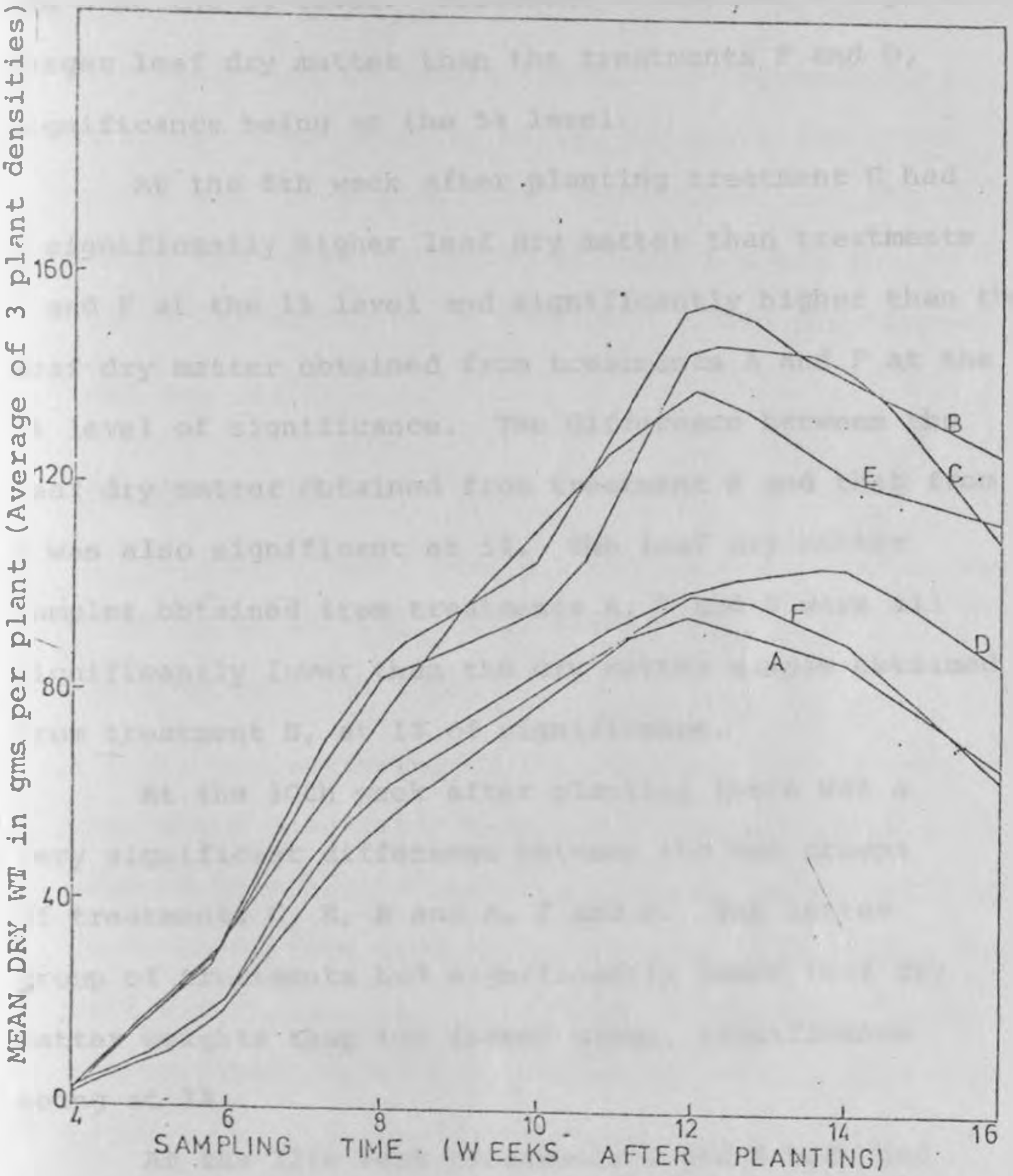


Fig. 3. Effect of weeding frequency on leaf blade dry matter (1980).

treatments F and D at the 5% level of significance. The plants from treatment E also had a significantly higher leaf dry matter than that from treatments F at the 1% level and D at the 5% level. Treatment B also had a significantly larger leaf dry matter than the treatments F and D, significance being at the 5% level.

At the 8th week after planting treatment C had a significantly higher leaf dry matter than treatments A and F at the 1% level and significantly higher than the leaf dry matter obtained from treatments A and F at the 1% level of significance. The difference between the leaf dry matter obtained from treatment E and that from D was also significant at 5%. The leaf dry matter samples obtained from treatments A, F and D were all significantly lower than the dry matter sample obtained from treatment B, at 1% of significance.

At the 10th week after planting there was a very significant difference between the two groups of treatments C, E, B and A, F and D. The latter group of treatments had significantly lower leaf dry matter weights than the former group, significance being at 1%.

At the 12th week treatments C and E both had significantly higher leaf dry matter weights than treatments A, F and D at the 1% level. Differences between the effect of treatment B vs treatment A and F was significant at 1% and the difference between effect of treatment B vs D was significant at 5%.

Fig. 2 shows that leaf dry matter increased linearly for all treatments up to the 8th week after planting and began to decline thereafter. At the peak of leaf dry matter accumulation treatment B had the highest leaf dry matter. At the end of the sampling period treatment A had the lowest dry matter while treatment E had the highest leaf dry matter.

1st rains 1980:

Where as there were 5 sampling times during the short rains of 1979, there were 7 samplings during the long rains of 1980.

At the beginning of the sampling period (4th week after planting) there were no significant differences between the leaf dry matter samples obtained from the various weeding frequencies, but by the 6th week after planting, significant differences among the treatment effects were evident. The differences between the effects of the treatments B, C and E on leaf dry matter and the effects of the treatments D, A and F were significant at the 1% level, with the group B, C and E having the higher leaf dry matter weights.

For the remainder of the sampling period the trend of results obtained was similar to the results obtained at the 6th week after planting until the 16th week. Differences in leaf dry matter obtained for treatments C, B, E and leaf dry matter obtained from for treatments F, A and D were significant at 1% level. There was also a significant difference between the leaf dry weights obtained from treatments C and E at the 5% level, treatment C having the bigger leaf dry matter. The leaf dry matter weights obtained from ~~for~~ treatments F and A were significantly lower than the leaf dry matter weights from treatment D at the 5% level.

Fig. 3 shows that during this season leaf dry matter accumulation reached its peak at the 12th week and began decreasing thereafter, as opposed the 2nd rains crop 1979 where leaf dry matter growth reached its maximum in the 8th week after planting. This means that the 1979 crop had a shorter growing season than the 1980 crop and the difference is probably due to the difference in seasons. The 1979 crop was grown in November during the short or second rains, which is a drier season. The second crop (1980) was grown during the long-rains. Because the short-rain season is a drier period that the long-rain season, it means that the crop had less moisture available for growth, leading to a shorter growth period and earlier maturity, hence the leaf dry matter peak at 8 weeks after planting.

The results have shown that weeding frequency does have an effect on leaf dry matter. The treatments weeded before anthesis C and E and the control B (weeding all season) had significantly higher leaf dry matter weights than those treatments weeded after anthesis F and D and the no weeding control A. Anthesis here was defined as the time between 50% of the seed heads having commenced flowering and 50% having completed flowering (Anderson, 1975). In the first crop anthesis was attained around the 7th week after planting and in the second crop around the 9th week after planting.

The results also show that in both seasons, the differences between the weeding treatment effects did not become significant until the 6th week after planting. Since there were no significant differences between the effects of treatments C and E and the effect of treatment B on leaf dry matter, it would seem that weeding all season was not necessary.

According to available literature most crops are most susceptible to weed competition during the very early part of the crop's life. This period, often referred to as the critical weed competition period is reported to cover the first 25 - 33 percent of the crop's life (Kasasian and Seeyave, 1969; Allan, 1974; Gurnah, 1976; Van Eijnatten, 1972). This being the case, it would be expected that removal of weeds from a sunflower crop early in the life of the crop should be more advantageous than removing them later. This would explain the better performance of plants from treatments C and E over the other treatments. It is also reported that beyond the critical weed competition period, any weeds arising do not affect the performance of the crop (Kasasian and Seeyave, 1969; Gurnah, 1976) as beyond the critical period the crop plants have formed a sufficient canopy to cover the ground and limit further weed growth and are also more competitive against weeds. This would explain why weeding all season (treatment B) did not have a significantly higher leaf blade dry matter than treatments C and E.

Since there was no significant difference between leaf dry matter obtained from treatment C and E this probably means that the critical weed competition period lies between these two weeding times i.e. betwwen the first two weeks after emergence and anthesis. Johnson (1972) also reported that sunflowers required to be cultivated at 2 and 4 weeks after sowing and that yields were significantly reduced by weeds not removed until 6 weeks after sowing. Van Eijnatten (1972) reported that weeding sunflower once at 4 weeks after emergence was adequate. The results obtained are therefore in agreement with available literature.

Since anthesis was reached at different times by the two crops it would also seem that the duration of critical weed competition period of the sunflower also depends on the season and varies within the period established by the results depending on the weather condition. Schwerzel and Thomas (1967-8) reported differing weed critical periods for cotton which were attributed to the weather conditions, being shorter during the drier than wetter periods.

The results further suggest that delayed removal of weeds, in this case until after anthesis was as bad as not not weeding at all, since the effects of treatments D and F were not significantly different from the effect of treatment A which was not weeded all season. The reason must be that damage was already done by the time of weed removal.

Effect of plant density on leaf blade dry matter 2nd rains 1979:

The results of the effects of plant density on leaf dry matter are presented in Table 3 and figures 4 and 5 for 1979 and 1980 crops respectively.

Leaf blade dry matter increased as the plant density decreased from 74,000 plants to 44,000 plants per hectare (i.e. from P_1 to P_3). From the 6th week after planting highly significant differences between the effect of plant density P_3 and the effect of plant density P_1 on leaf blade dry matter were recorded at the various sampling times. Between the 6th and 10th weeks, after planting, significant differences between the effects of treatments P_1 and P_2 were also recorded. There were no significant differences between the effects of treatments P_2 and P_3 on leaf blade dry matter throughout the sampling period.

<u>1st rains 1980:</u>

There were no significant differences among the various plant density effects on leaf dry matter until the 8th week after planting, when differences at 1% level of significance were observed between all the plant density comparisons. From Table 3 and figs. 4 and 5 it can be seen that leaf blade dry matter increased as plant density decreased from P_1 to P_3, so that P_3 had the highest leaf blade dry matter.

The results have indicated that plant density affects leaf blade dry matter development. The results have shown that on the basis of individual plant development (in this case the sum total of 6 plants) leaf dry matter increased with decreasing plant density (Table 3 and Figs.4 and 5). The reason for this could be that as the plant density decreases the number of plants per unit area decreases, resulting in less and less competition between individual plants for water, nutrients and space. With decreased competition and therefore increased nutrients upon which to draw, the plants should grow bigger with a proportionate increase in the size of the

TABLE 3: Effect of plant density on leaf blade dry matter(gms/plant)

Year	Plant density	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
1979	P_1	9.36	47.95	94.33	86.69	68.77	-	-
	P_2	9.91	61.29	116.82	108.38	83.81	-	-
	P_3	9.38	63.07	129.27	126.68	100.22	-	-
	S.E.	0.55	3.03	7.85	6.36	6.58	-	-
	L.S.D.-5%	1.59	8.76	22.67	18.37	18.99	-	-
	L.S.D.-1%	-	11.80	30.54	24.72	25.30	-	-
	C.O.V. (%)	-	25.99	33.90	29.07	38.25	-	-
1980	P_1	3.56	23.87	58.49	69.88	99.04	87.99	81.64
	P_2	4.53	27.52	69.73	91.67	123.45	112.95	92.91
	P_3	4.33	27.76	86.34	113.43	146.79	142.89	119.98
	S.E.	0.34	1.60	2.21	3.15	4.86	3.84	4.19
	L.S.D.-5%	0.98	4.61	6.39	9.10	14.04	11.10	12.10
	L.S.D.-1%	-	-	8.60	12.25	18.91	14.95	16.30
	C.O.V. (%)	40.56	29.63	15.15	16.84	19.35	16.43	20.91

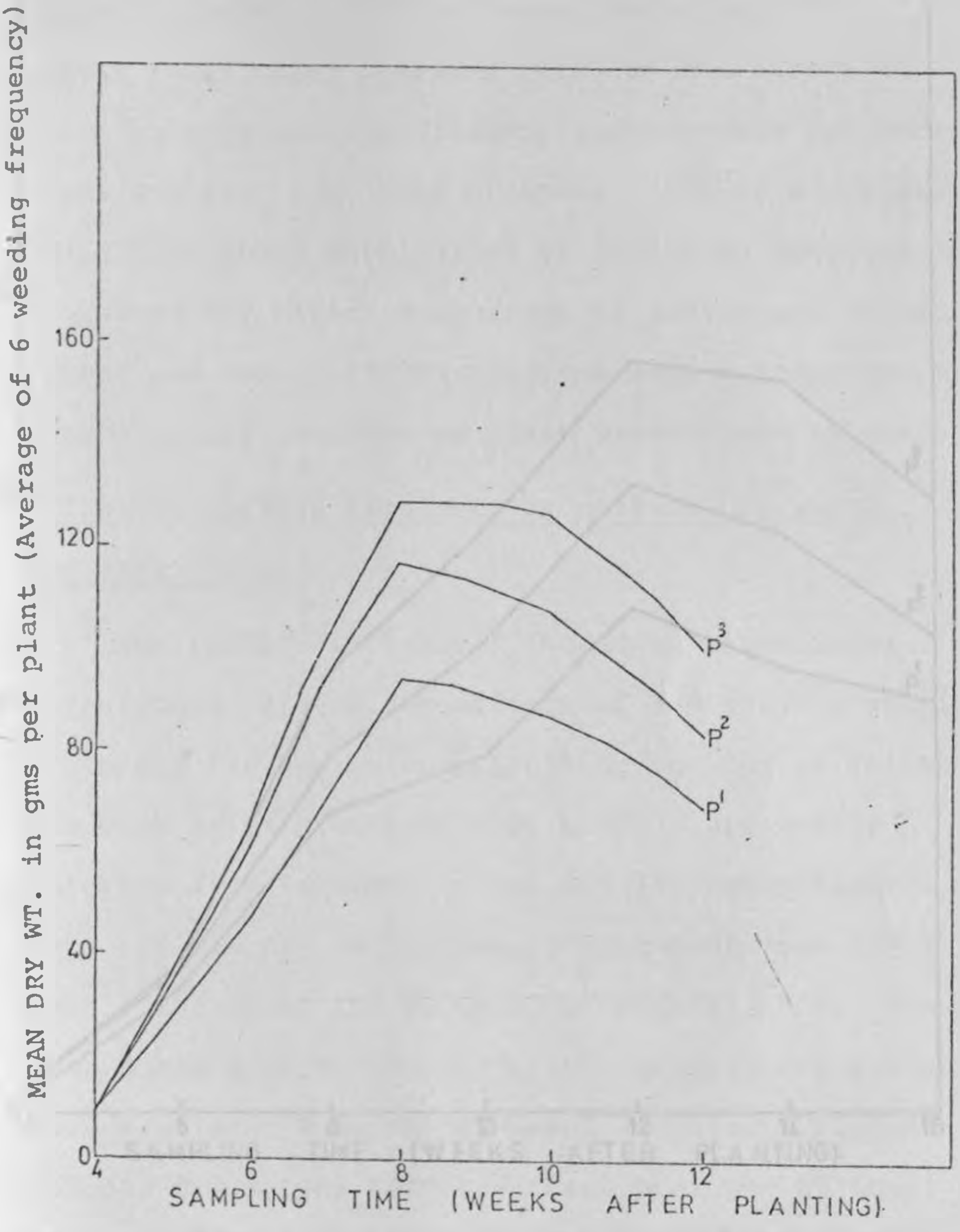


Fig. 4. Effect of plant density on leaf dry matter (1979).

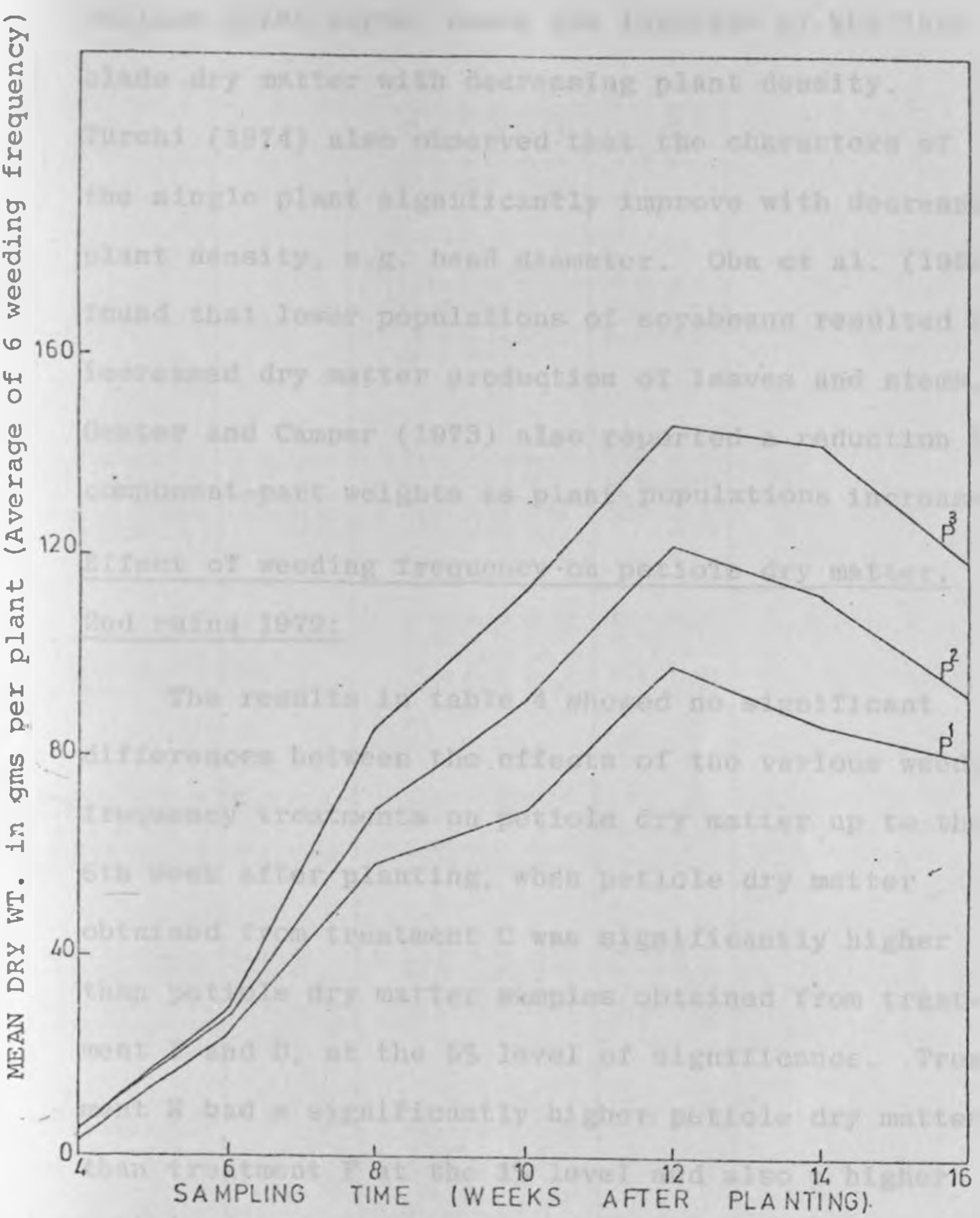


Fig. 5. Effect of plant density on leaf dry matter (1980).

various plant parts, hence the increase of the leaf blade dry matter with decreasing plant density. Turchi (1974) also observed that the characters of the single plant significantly improve with decreasing plant density, e.g. head diameter. Oba et al. (1961) found that lower populations of soyabeans resulted in increased dry matter production of leaves and stems. Genter and Camper (1973) also reported a reduction in component-part weights as plant populations increased.

Effect of weeding frequency on petiole dry matter. 2nd rains 1979:

The results in table 4 showed no significant differences between the effects of the various weeding frequency treatments on petiole dry matter up to the 6th week after planting, when petiole dry matter obtained from treatment C was significantly higher than petiole dry matter samples obtained from treatment F and D, at the 5% level of significance. Treatment E had a significantly higher petiole dry matter than treatment F at the 1% level and also a higher petiole dry matter than treatment D at the 5% level of significance. The difference between the effect of B and that of F was significant at 1% and the difference between the effect of treatment B and the effect of treatment D was significant at 5%, with treatment B having the higher petiole dry matter in both cases.

TABLE 4: - Effect of weeding frequency on petiole dry matter/gms/plant)

Year	Weeding Frequency	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
1979	A	1.16	14.16	29.55	20.10	14.56	-	-
	B	1.56	17.05	49.29	38,17	29.72	-	-
	C	1.31	16.61	47.47	38.95	31.63	-	-
	D	1.18	13.06	31.58	22.67	20.76	-	-
	E	1.34	17.31	50.57	42.44	33.41	-	-
	F	1.19	12.58	28.74	21.54	16.31	-	-
	S.E.	0.13	1.09	4.22	2.68	3.25	-	-
	L.S.D. -5%	0.38	3.16	12.18	7.75	9.39	-	-
	L.S.D. -1%	0.51	4.26	16.39	10.44	12.65		
	C.O.V. (%)	35.35	25.05	36.95	30.33	46.18		
1980	A	0.33	4.10	17.85	24.73	31.50	25.77	19.86
	B	0.48	7.40	23.31	34.57	47.56	44.66	33.49
	C	0.43	8.18	24.32	32.63	43.88	46.17	43.79
	D	0.38	3.51	17.51	25.74	30.23	32.13	25.15
	E	0.39	9.31	23.16	36.16	47.19	38.97	35.25
	F	0.51	5.28	15.22	23.83	31.95	27.97	19.51
	S.E.	0.07	0.77	1.03	1.89	2.63	2.o3	1.89
	L.S.D. -5%	0.20	2.21	2.96	5.44	7.60	5.89	5.46
	L.S.D. -1%	0.28	2.98	3.99	7.32	10.23	7.89	7.36
	C.O.V. (%)	58.00	42.27	17.55	22.03	23.53	19.57	22.20

At the 8th and 10th weeks after planting all treatment comparisons between the two groups of treatments B, C, and E and A, F and D were significant at the 1% level, the B, C and E group of treatments having the higher petiole dry matter.

At the 12th week petiole dry matter samples obtained from treatment A, F and D were significantly lower than the samples obtained from treatments C and E at 1%. The effect of B on petiole dry matter was significantly higher than the effects of treatments A and F at the 1% level of significance.

1st rains 1980:

Significant differences between weeding frequency effects on petiole dry matter were observed from the 6th week after planting. At this stage the petiole dry matter sample weights from treatments E and C were significantly more than the petiole dry matter samples from treatments A, F and D, significance being at 1%. Petiole dry matter obtained from treatment B was also significantly higher than that obtained from D and A at the 1% level of significance.

Between the 8th and the 12th week after planting, differences between the petiole dry matter samples from treatments C, B and E and the samples from treatments A, F and D were significant at 1% with the former group having the higher petiole dry matter.

At the 14th week similar results were obtained as for weeks 8-12, and in addition the effect of treatment C on petiole dry matter was significantly greater than the effect of treatment E at the 5% level. Petiole dry matter obtained from treatment D exceeded that obtained from treatment A and was significant at 5%.

At the 16th week after planting the petiole dry matter obtained from treatment C was significantly more than the petiole dry matter from the rest of the weeding frequency treatments, at 1%. Treatments E and B effects on petiole dry matter were also significantly higher than the effects of treatments A, F and D at the 1% level. The difference between petiole dry matter obtained from treatment D and that obtained from treatment F was also significant at 5% and the difference between D and A was almost significant at 5%, treatment D having the higher petiole dry matter in both comparisons.

As was observed for leaf dry matter, petiole dry matter from the 1979 crop begins to decline from the 8th week while in the 1980 crop the decline does not begin until the 12 th week. The possible reason for the difference has already been mentioned in the section under leaf blade, mainly variations in the seasons.

Again the difference between treatments weeded before and those weeded after anthesis is brought out.

Treatments weeded before anthesis and the weeding all season control had significantly higher petiole dry matter measurements than the treatments weeded after anthesis and the no weeding all season control, thus suggesting that removal of weeds before anthesis favours petiole dry matter development as opposed to removing weeds after anthesis. The reason for the possible difference between the two groups of treatments has been mentioned already under the leaf-blade section; i.e. that in the case of the treatments weeded before anthesis weeds were removed just before or at a time when weed competition is most detrimental to the development of a crop, whereas in treatments weeded after anthesis, the damage was already done by the time weeding operations were initiated.

Effect of plant density on petiole dry matter. 2nd rains 1979.

The results in table 5 show that petiole dry matter increased when plant density decreased from 74,000 plants per hectare (P_1) to 44,000 plants per hectare (P_3). Petiole dry matter was not significantly affected by the various plant densities until the 6th week after planting, when the differences between the petiole dry matter samples obtained from plant densities P_1 and P_3 was significant at the 1% level, plant density P_3 having the higher dry matter measurement. Plant density P_2 also had a significantly higher petiole

TABLE 5: Effect of plant density on petiole dry matter (gm/plant)

Year	Plant	SAMPLING TIME IN WEEKS AFTER PLANTING						
1979	density	4	6	8	10	12	14	16
	P_1	1.22	12.69	32.08	24.57	19.43	-	-
	P_2	1.38	16.35	40.76	30.47	24.08	-	-
	P_3	1.26	16.34	45.77	35.65	29.69	-	-
	S.E.	0.09	0.77	2.98	1.89	2.30		
	L.S.D.-5%	0.27	2.23	8.61	5.47	6.64		
	L.S.D.-1%	0.36	3.01	11.59	7.37	8.94		
	C.O.V.(%)	35.35	25.05	36.95	30.33	46.18		
Year 1980	P_1	0.45	5.27	15.49	21.95	29.71	25.35	23.68
	P_2	0.34	6.49	19.53	28.66	38.75	35.94	29.29
	P_3	0.47	7.12	25.67	38.22	47.69	45.10	35.55
	S.E.	0.05	0.54	0.72	1.33	1.86	1.43	1.34
	L.S.D.-5%	0.14	1.57	2.09	3.84	5.37	4.14	3.86
	L.S.D.-1%	0.19	-	2.82	5.18	7.23	5.58	5.20
	C.O.V.(%)	58.00	42.47	17.55	22.03	23.53	19.57	22.20

dry matter weight than plant density P_1 at the 1% level of significance during the 6th week, and at 5% level during the 8th and 10th week. P_1 and P_2 treatment effects were not significantly different by the 12th week. No significant differences between the effects of P_2 and P_3 were recorded throughout the sampling period.

1st rains 1980

Plant density effect on petiole dry matter became significantly different among treatments from the 6th week and remained significant up to the end of the sampling period. At the 6th week after planting the difference between P_3 and P_1 effects on petiole dry matter was significant at 5%, with the treatment P_3 having the higher petiole dry matter. Beyond the 6th week after planting the differences between the effects of P_3 and P_1 were significant at the 1% level. Treatment P_2 also had a higher petiole dry matter than treatment P_1, and the difference was significant at the 1% level. Unlike in the 1979 crop, differences between the effect of P_3 and the effect of P_2 were also significant at the 1% level.

The results have shown that petiole dry matter decreases with increasing population. In the 1979 crop differences between the highest and the lowest plant density were more pronounced than differences between plant densities that were close to each other. In the second crop differences between the whole range of plant densities tested were outstandingly significant. The difference in the level of significance among the treatment effects could be attributed to the differences in the growing seasons and the amount of moisture that was available to the different crops and its effects on the growth of the crops.

Effect of weeding frequency on stem dry matter.

2nd rains 1979

The results in table 6 and Fig. 6 show that there was no significant weeding frequency effect on stem dry matter until about the 8th week after planting, when the effect of treatment B on stem dry matter was significantly higher than the effects of treatments A and F at the 1% level and higher than the effect of D at the 5% level of significance. Treatment E effect was significantly higher than the effect of treatment A at 1% of significance and higher than the effect of treatments F and D at the 5% level. Treatment C effect was also significantly higher than the effects of treatments A and F at the 5% level.

At the 10th week after planting, treatment E had a significantly higher stem dry matter than treatments F, A and D at the 1% level of significance. The stem dry matter obtained from treatment C was significantly higher than the stem dry matter obtained from A and F

TABLE 6: Effect of weeding frequency on stem dry matter. (gms/plant)

Year	Weeding Frequency	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
Year 1979	A	6.73	48.14	175.27	166.84	150.90		
	B	7.25	51.80	254.64	234.13	233.46		
	C	6.97	47.71	234.92	240.74	228.23		
	D	7.07	47.13	192.94	186.35	182.09		
	E	7.02	55.02	246.61	261.79	260.64		
	F	6.89	42.44	178.33	165.68	158.05		
	S.E.	0.32	4.58	18.12	15.31	20.73		
	L.S.D. -5%	0.92	13.21	52.27	44.17	59.81		
	L.S.D. -1%	1.25	17.79	70.39	59.48	80.54		
	C.O.V. (%)	15.89	32.54	29.32	25.31	35.47		
Year 1980	A	0.86	9.53	65.81	136.54	181.29	200.05	204.24
	B	1.32	12.00	106.89	186.01	282.56	296.60	274.04
	C	1.11	18.08	89.47	170.24	278.71	309.93	304.93
	D	1.08	7.70	67.26	128.69	170.68	214.42	215.38
	E	1.09	20.69	104.05	205.35	266.50	279.92	270.05
	F	1.04	10.16	53.46	136.86	169.42	190.06	185.16
	S.E.	0.15	1.45	6.64	9.94	11.87	11.62	9.80
	L.S.D. -5%	0.44	4.18	19.17	28.66	34.25	33.52	28.28
	L.S.D. -1%	0.61	5.64	25.82	38.60	46.12	45.14	38.08
	C.O.V. (%)	48.99	36.01	28.34	21.41	18.27	16.28	13.91

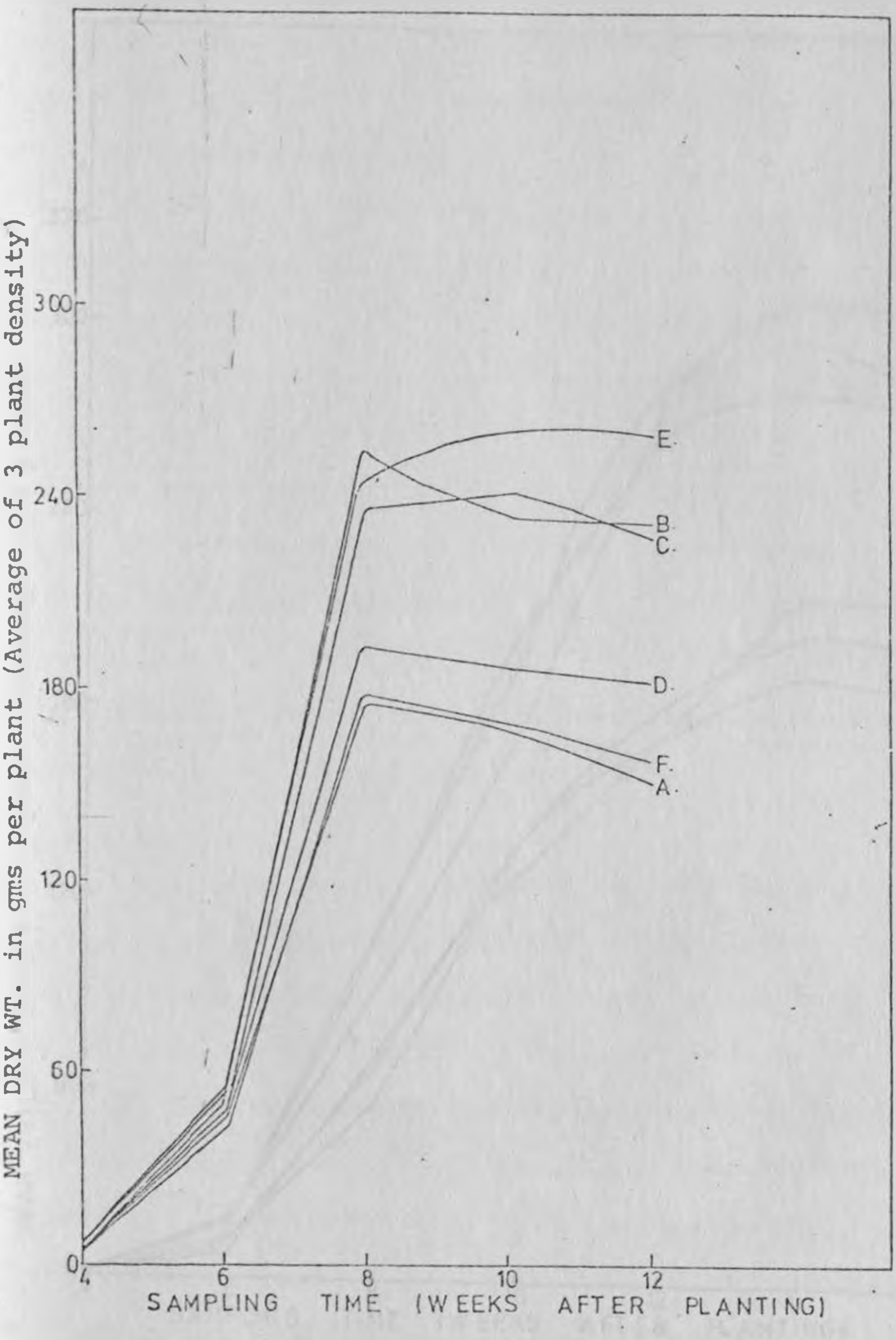


Fig. 6. Effect of weeding frequency on stem dry matter (1979).

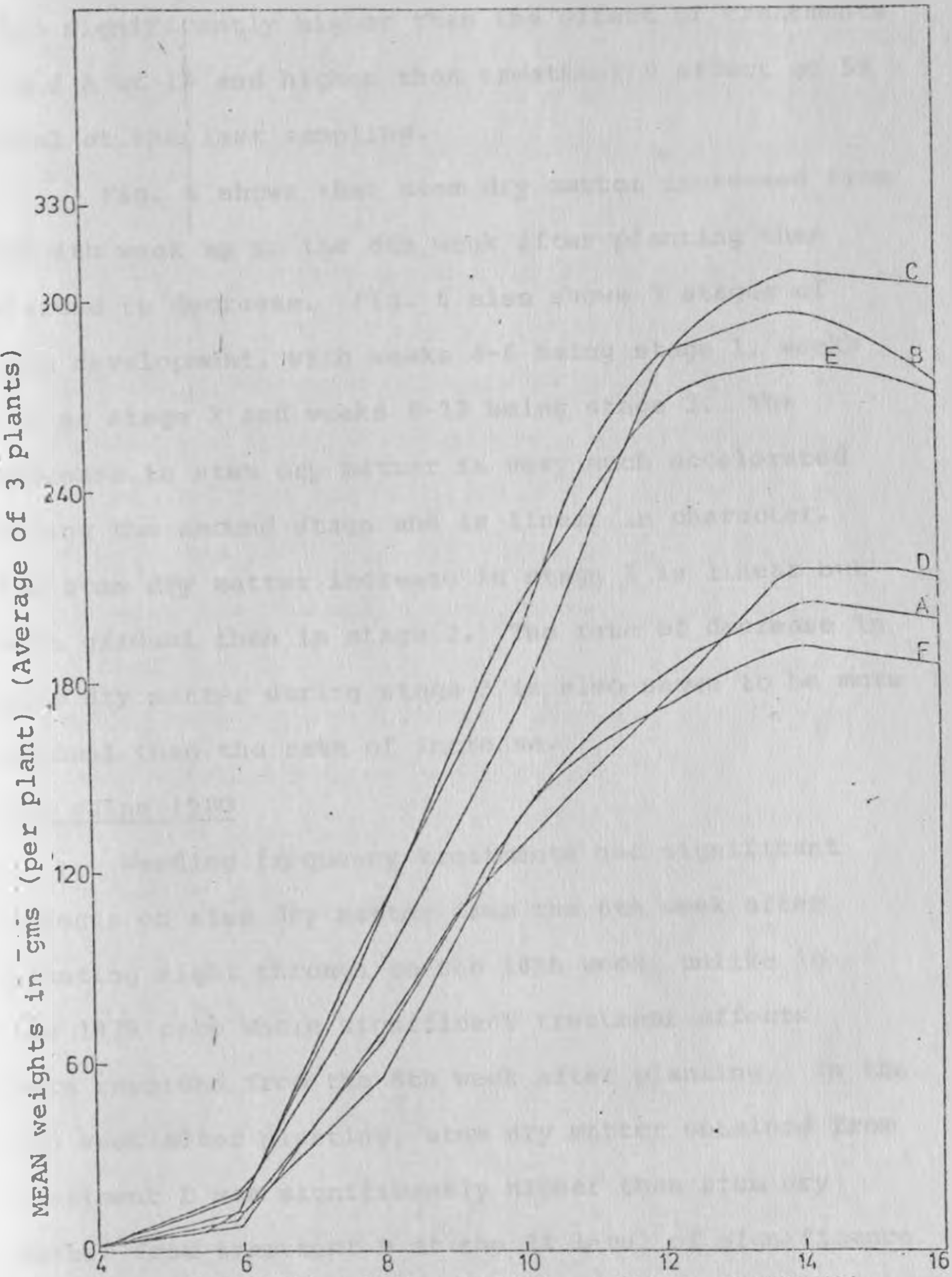


Fig. 7. Effect of weeding frequency on stem dry matter (1980).

at 1% and higher than the effect of D at the 5% level of significance. Treatment B effect on stem dry matter was also significantly higher than the effect of treatments F and A at 1% and higher than treatment D effect at 5% level at the last sampling.

Fig. 6 shows that stem dry matter increased from the 4th week up to the 8th week after planting then started to decrease. Fig. 6 also shows 3 stages of stem development, with weeks 4-6 being stage 1, weeks 6-8 as stage 2 and weeks 8-12 being stage 3. The increase in stem dry matter is very much accelerated during the second stage and is linear in character. The stem dry matter increase in stage 1 is linear but more gradual than in stage 2. The rate of decrease in stem dry matter during stage 3 is also shown to be more gradual than the rate of increase.

1st rains 1980

Weeding frequency treatments had significant effects on stem dry matter from the 6th week after planting right through to the 16th week, unlike in the 1979 crop where significant treatment effects were recorded from the 8th week after planting. In the 6th week after planting, stem dry matter obtained from treatment E was significantly higher than stem dry matter from treatment B at the 1% level of significance. Throughout the sampling period lower stem dry matter measurements were recorded from treatments A, F and D than for treatments B, C and E and the difference was significant at the 1% level.

Fig. 7 shows that the decline in stem dry matter does not begin until the 14th week after planting, showing that this crop had a longer growth period than the 1979 crop.

The same trend among treatments as was observed for leaf and petiole dry matter is again observed in that the group of treatments A, F and D in which weeding was delayed had significantly lower stem dry matter than the treatments B, C and E in which weeding was performed early in the life of the crops. The only difference is that where significant differences in stem dry matter occurred, they were observed two weeks earlier in the second crop than in the first crop, and the decline did not begin until the 14th week after planting.

The possible reasons for the differences between the two groups of treatments has already been mentioned in the section under leaf blade dry matter. According to available literature weed damage in most crops occurs early in the growth cycle (Gurnah, 1976; Allan, 1974; Kasasian and Seeyave, 1969). Since the treatments weeded early, E and C had significantly higher stem dry matter measurements than treatments F and D which were weeded later the results would seem to support earlier findings.

Stem dry matter samples obtained from treatment B were not significantly different from the stem dry matter samples obtained from treatments E and C in both crops which again points to the fact that keeping the crop weed free throughout the season (treatment B) is not necessary either because after the critical weed competition period the crop covers the ground and suppresses weed growth or is able to compete effectively with any weed growth occurring beyond the critical period or both. There was also no significant difference between the results obtained from treatment A (no weeding all season) and the results obtained from treatments F and D which were weeded after anthesis, showing that weed damage had already been done. This brings us to the question of a critical weed competition period (Gurnah 1974) which according to Kasasian and Seeyave (1969) covers the first 25-33% of the life of many crops.

The results obtained therefore suggest that for the sunflower crop the critical weed competition period i.e. that period during the growth of the crop when the presence and competition of weeds is harmful to the crop (Nieto _et al._, 1968; Gurnah 1974) is before anthesis. Since treatment E (one weeding at two weeks after emergence) had more or less similar results to treatments C and the control B, it would appear that for the treatment E, the weeding operation was performed either just before or during the critical weed competition. This would therefore place the critical weed competition period for sunflower between the periods when treatments E and C (weeding up to anthesis) were performed. This would be from 2 weeks after emergence to anthesis.

Since the two crops reached anthesis at different times (around the 7th week for the 1979 crop and around the 9th week for the 1980 crop) it would seem that the length of the critical weed competition period is also dependent on the season. Johnson (1972) reported that sunflowers required to be weeded at 2 and 4 weeks after sowing while Van Eijnatten (1972) reported that one weeding at 4 weeks after emergence was adequate. Schwerzel and Thomas (1967-68) reported differing critical weed competition periods for cotton which they attribute to weather conditions, the critical periods being shorter during the drier than wetter seasons. Nieto, Brando and Gonzalez (1968) in their experiments on maize and beans observed that these crops were most susceptible to weed competition during the first 30 days at their 100-125 days growth cycle, weeds growing after that period having no depressing effect on yields. This fact would explain why the control weeding all season (B) did not have a significantly different effect from the treatments C and E.

Effect of plant density on stem dry matter

2nd rains 1979

Table 7 shows that there were no significant plant density treatment effects on stem dry matter until the 6th week after planting, when significant differences between treatments P_3 and P_1 at the 5% level were observed. Between weeks 6-8 significant differences between P_2 and P_1 at the 5% level were also recorded. The effects of treatments P_3 and P_2 on stem dry matter were not significantly different throughout the sampling period.

Fig. 8 shows that stem dry matter increased as plant density was decreased from P_1 to P_3, so that P_3 had the highest stem dry matter.

1st rains 1980

Table 7 and Fig. 9 show that stem dry matter increased as plant density decreased from P_1 (74,000 plants per hectare) to P_3 (44,000 plants per hectare). Stem dry matter samples obtained from P_3 were significantly higher than stem dry matter samples from populations 1 and 2 at the 1% level between the period 6th - 16th week after planting.

Differences between P_2 and P_1 effects were significant at the 5% level between the 6th-9th weeks, and thereafter differences between the effects of the two plant densities were significant at the 1% level.

TABLE 7: Effect of plant density on stem dry matter/gm/plant)

Year	Plant Density	SAMPLING TIME IN WEEKS AFTER PLANTING						
1979		4	6	8	10	12	14	16
	P_1	6.83	41.16	182.56	186.08	175.74	-	-
	P_2	7.23	52.63	224.22	213.82	198.27	-	-
	P_3	6.89	52.32	234.58	227.87	232.68		
	S.E.	0.22	3.24	12.80	10.82	14.67	-	-
	L.S.D. -5%	0.65	9.34	36.96	31.23	42.29	-	-
	L.S.D. -1%	0.88	-	49.77	-	-	-	-
	C.O.V. (%)	15.89	32.54	29.32	25.31	35.47	-	-
Year 1980	P_1	0.89	10.16	61.61	117.37	181.62	204.39	213.63
	P_2	1.15	13.50	77.24	160.49	229.45	246.61	242.11
	P_3	1.22	18.15	104.61	203.97	263.50	289.99	275.65
	S.E.	0.11	1.02	4.69	7.02	8.38	8.21	6.92
	L.S.D. -5%	0.31	2.96	13.56	20.27	24.22	23.70	19.99
	L.S.D. -1%	0.41	3.99	18.26	27.29	32.61	31.92	26.93
	C.O.V. (%)	48.99	36.01	28.34	21.41	18.27	16.28	13.91

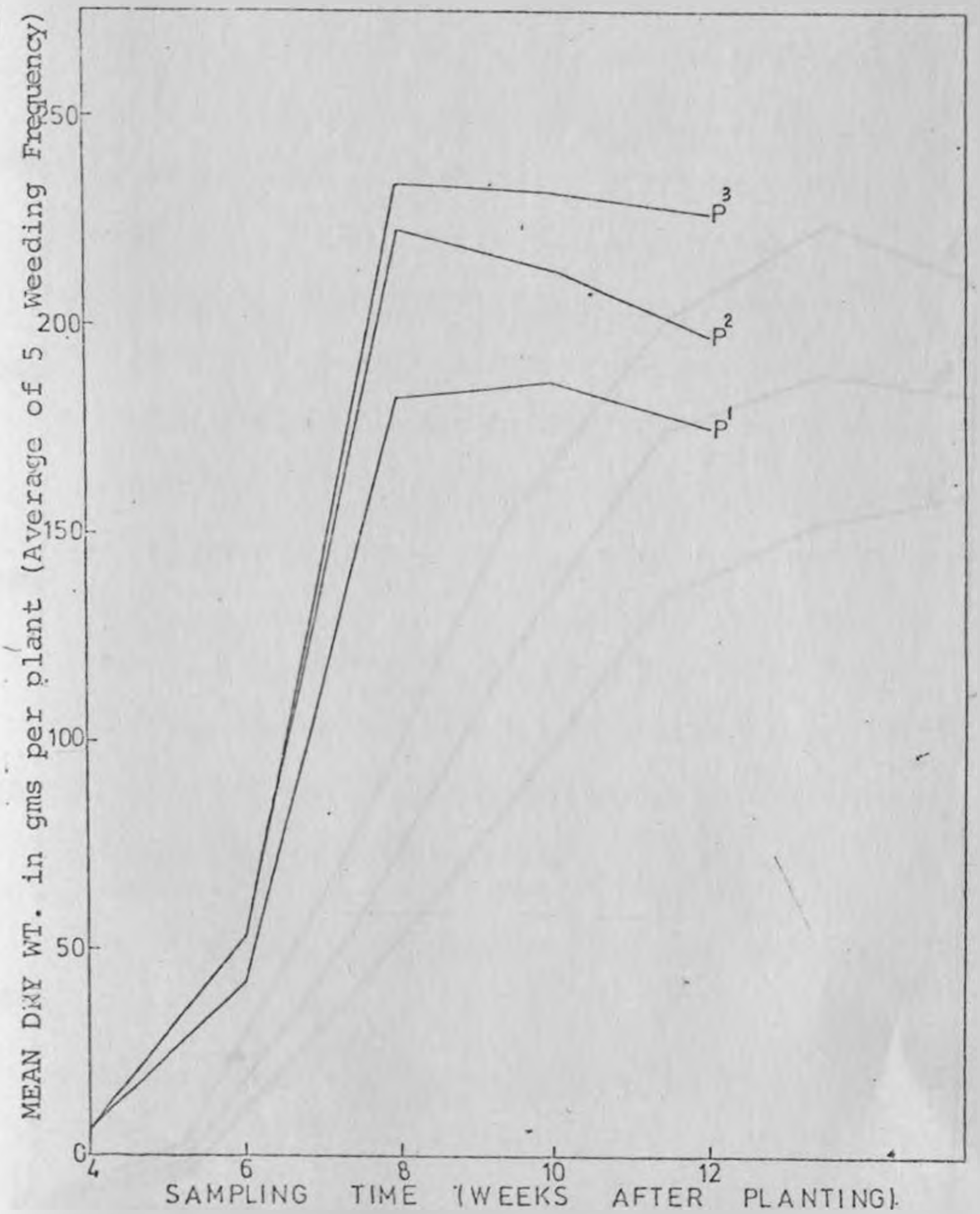


Fig. 8. Effect of plant density on stem dry matter (1979).

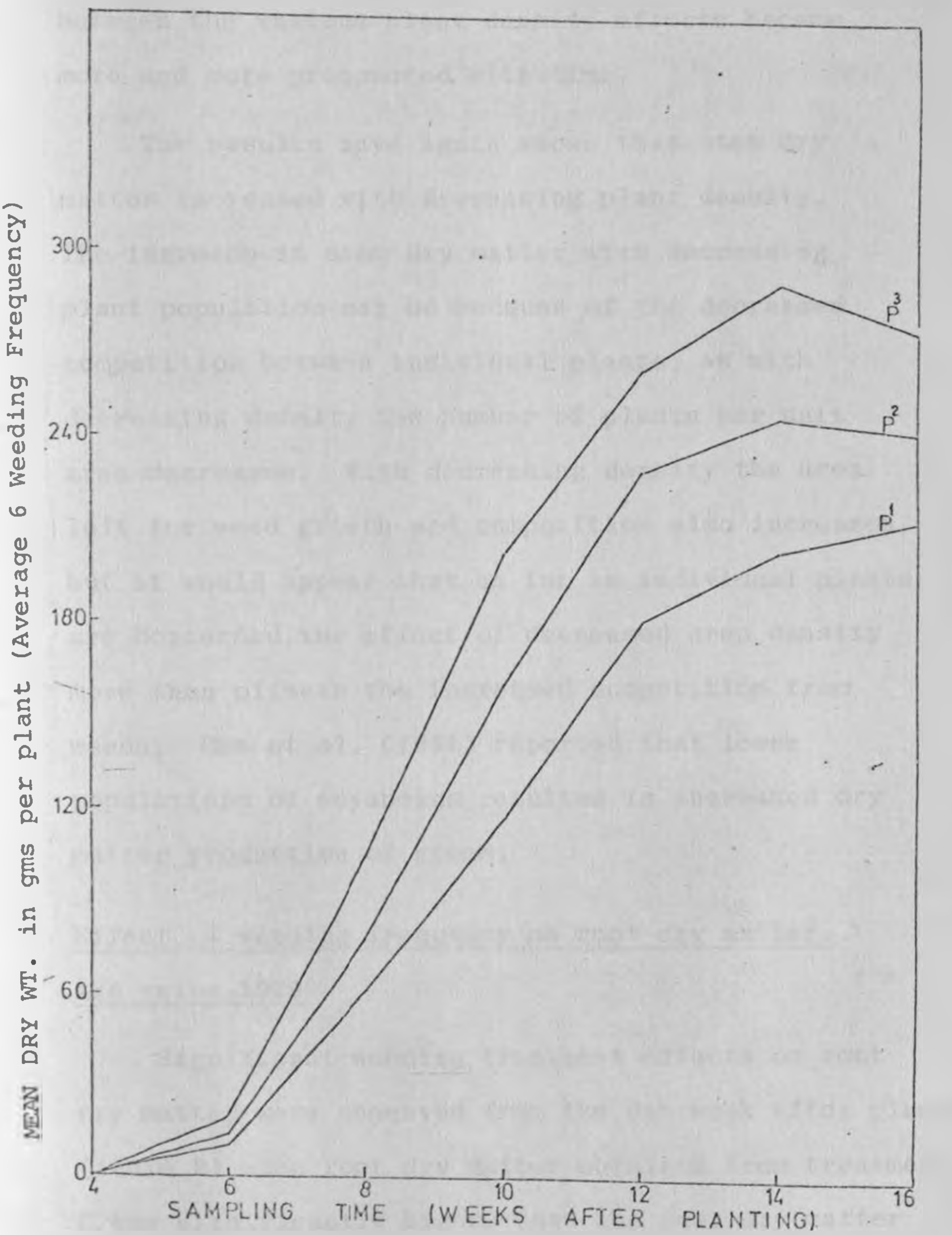


Fig. 9. Effect of plant density on stem dry matter (1980).

It was also observed that the differences between the various plant density effects became more and more pronounced with time.

The results have again shown that stem dry matter increased with decreasing plant density. The increase in stem dry matter with decreasing plant population may be because of the decreased competition between individual plants, as with decreasing density the number of plants per unit area decreases. With decreasing density the area left for weed growth and competition also increases, but it would appear that as far as individual plants are concerned the effect of decreased crop density more than offsets the increased competition from weeds. Oba et al. (1961) reported that lower populations of soyabeans resulted in increased dry matter production of stems.

Effect of weeding frequency on root dry matter. 2nd rains 1979

Significant weeding treatment effects on root dry matter were observed from the 6th week after planting (table 8) when root dry matter obtained from treatment C was significantly higher than the root dry matter obtained from treatments A and F, at the 5% level. Treatment E also had a significantly higher root dry matter than treatment F at the 5% level and the diff-

TABLE 8: Effect of weeding frequency on root dry matter.(gms/plant).

Year	Weeding Frequency	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
Year 1979	A	1.77	17.40	58.17	56.42	52.21	-	-
	B	2.11	21.56	107.69	122.35	110.07	-	-
	C	1.95	22.33	102.71	116.82	122.53	-	-
	D	1.85	18.63	67.06	71.60	69.68	-	-
	E	2.02	22.11	90.72	147.51	107.21	-	-
	F	1.83	16.23	58.17	65.36	59.41	-	-
	S.E.	0.19	1.68	11.03	12.41	14.00	-	-
	L.S.D. -5%	0.55	4.87	31.80	35.80	40.39	-	-
	L.S.D. -1%	-	-	42.82	48.21	54.39	-	-
	C.O.V. (%)	34.59	29.64	46.37	44.41	55.78	-	-
Year 1980	A	0.67	7.44	29.67	52.56	76.28	59.94	47.76
	B	1.02	14.95	50.05	99.74	121.19	132.37	73.68
	C	0.94	15.50	43.27	71.33	112.04	130.88	97.15
	D	0.89	6.02	28.43	56.28	77.34	65.61	55.71
	E	0.92	14.85	42.35	102.32	117.78	126.26	79.57
	F	0.91	8.40	22.49	63.94	80.21	102.03	50.22
	S.E.	0.13	1.03	2.74	5.09	7.75	8.16	5.15
	L.S.D. -5%	0.38	2.97	7.90	14.69	22.36	23.54	14.86
	L.S.D. -1%	0.52	4.00	10.64	19.78	30.11	31.71	20.01
	C.O.V. (%)	51.49	31.86	26.29	23.69	27.52	21.39	26.46

erence between the effects of treatments B and F on root dry matter was also significant at 5%, treatment B having the higher root dry matter.

At the 8th week after planting, treatments B and C had significantly higher root dry matter than treatment F at the 1% level.and also significantly higher root dry matter than treatments D and A at the 5% level of significance. Root dry matter obtained from treatment E was also significantly higher than that obtained from treatment F at the 5% level.

At the 10th week after planting, the effects of treatments E and B were significantly higher than the effects of treatments A, F and D at the 1% level of significance. Differences between the effect of C on root dry matter and that of E and F were also significant at 1%, and the difference between C and D was significant at 5%.

At the 12th week after planting differences between the effect of treatment C and the effects of treatments A and F were significant at 1%, and the difference C vs. D was also significant at 5%. Root dry matter obtained from treatment B was significantly higher than root dry matter obtained from treatment A at the 1% level, and also higher than root dry matter obtained from treatments F and D at the 5% level. The difference between treatment E effect and treatment A effect was significant at 1% and the difference between

E effect and F effect was significant at 5%. Root dry matter from treatment E was higher than that from treatment D but not significantly different.

Fig. 10 shows that with the exception of treatment A, root dry matter from all the other treatments continued to increase up to the 10th week after planting, unlike the leaves, petiole and stem dry matter which reached the peak of their development at the 8th week after planting, for the 1979 crop.

1st rains 1980

Table 8 shows that the effects of the various weeding frequencies became significantly different from the 6th week after planting, when the root dry matter samples obtained from treatments C, B and E were significantly higher than those from treatments A, D and F at the 1% level of significance. There were no significant differences between the effects of treatments A, F and D on root dry matter throughout the sampling period. Treatments C, B and E effects on root dry matter were also not significantly different, except at the 10th week when the effects of treatments B and E were significantly higher than the effect of C at 1% level and at the 14th week when treatment C effect was significantly higher than treatment B effect at 1% level and also higher than treatment E effect at the 5% level of significance.

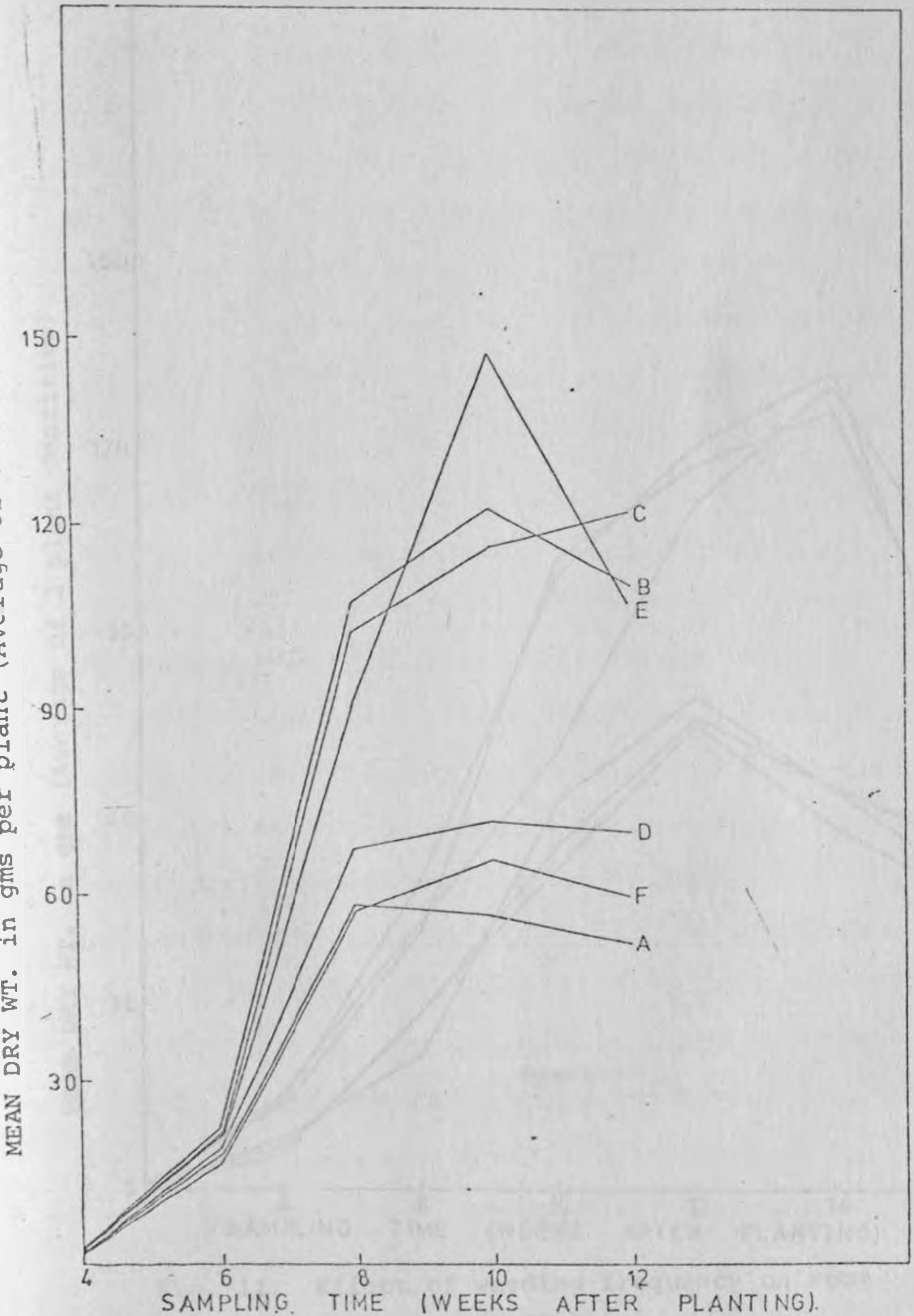


Fig. 10. Effect of weeding frequency on root dry (1979).

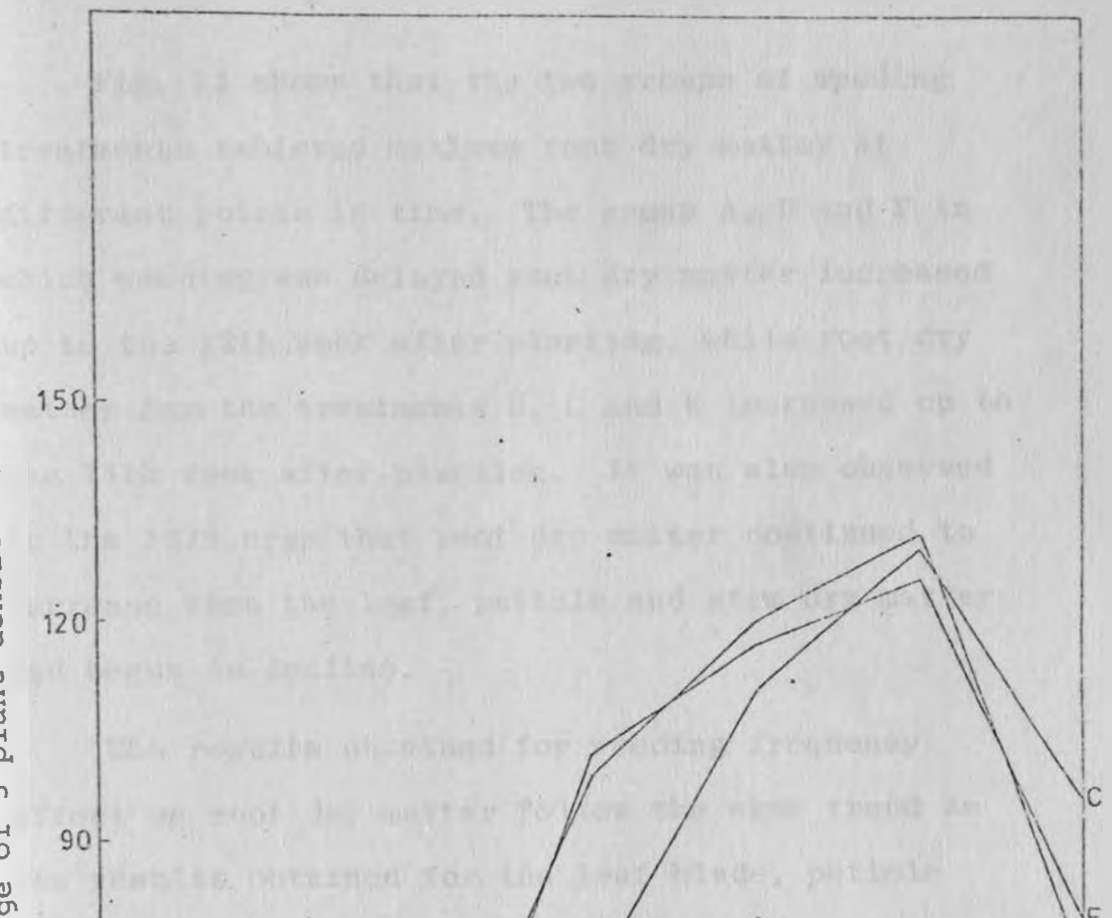


Fig. 11. Effect of weeding frequency on root dry matter (1979).

Fig. 11 shows that the two groups of weeding treatments achieved maximum root dry matter at different points in time. The group A, D and F in which weeding was delayed root dry matter increased up to the 12th week after planting, while root dry matter from the treatments B, C and E increased up to the 14th week after planting. It was also observed in the 1979 crop that root dry matter continued to increase when the leaf, petiole and stem dry matter had begun to decline.

The results obtained for weeding frequency effect on root dry matter follow the same trend as the results obtained for the leaf blade, petiole and stem dry matter in that in both seasons the treatments weeded before anthesis (C and E and the control B) had consistently higher root dry matter than the treatments weeded after anthesis (D and F and the control A). The reasons for the difference in treatment effects has already been discussed under the leaf blade and stem sections, mainly that treatments weeded before anthesis had weeds removed either just before or during that critical period when weed competition is most deleterious to crop growth and development, while the treatments weeded after anthesis had already suffered heavily by the time weeds were removed.

Except during the 10th and 14th weeks after planting there were no significant differences between the effects of B, C and E and the difference recorded during the mentioned sampling times was probably due to experimental error. It has been suggested that the fact that treatment B did not obtain a significantly different effect on root dry matter than treatments C and E suggests that no advantage is gained by weeding all season because after a given period the crop develops a sufficient canopy to cover the ground and suppress weed growth and the crop is capable of competing effectively with weeds that may occur beyond that period. Several workers have found this to be the case for various crops (Allan, 1974; Gurnah, 1976, Hauser and Parham 1969).

Figs. 10 and 11 show that while there was no significant difference between the effects of treatments C and E, treatment C attained a higher root dry matter than treatment E in both seasons, at harvest. Since these two treatments performed as well as treatment B and far better than treatments A, D and F the results show quite definitely that early weeding is necessary. One of the objectives of this study was to determine the critical weed competition period in sunflower and the results have indicated that it probably lies somewhere between the periods when treatments E and C were weeded i.e. between two weeks after emergence and anthesis.

The results would seem to be in agreement with available literature (Van Eijnatten 1972; Johnson 1972) which reports the critical weed competition period to be within the first 4-6 weeks of the sunflower crop.

In the 1980 crop the two groups of treatments have been shown to reach maximum root dry matter development at different times, with treatments A, D and F reaching their peaks two weeks earlier than treatments B, C and E. Perhaps weed competition exerts stress on crop development similar to stress due to low moisture conditions since weeds not only compete with the crops for available moisture but also increase the surface area over which moisture is lost from the soil. The stress so created would lead presumably to a shorter growth period and therefore earlier maturity as would be the case in relatively dry conditions, hence the earlier peak in root dry matter development for treatments A, F and D since they were subjected to weed competition over an extended period.

Effect of plant density on root dry matter.

2nd rains 1979

At 4 and 6 weeks after planting (Table 9) there was an increase in root dry matter from P_1 to P_2 then a fall in root dry matter when the population decreased to P_3. Significant plant density

TABLE 9: Effect of plant density on root dry matter(gms/plant)

Year	Plant Density	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
Year 1979	P_1	1.86	16.70	59.01	76.81	72.61	-	-
	P_2	2.07	21.31	88.95	94.66	78.36	-	-
	P_3	1.83	21.11	98.86	118.57	109.58	-	-
	S.E.	0.14	1.19	7.80	8.78	9.91	-	-
	L.S.D. -5%	0.39	3.44	22.49	25.31	28.56	-	-
	L.S.D. -1%	-	-	30.28	34.09	38.46	-	-
	C.O.V. (%)	34.59	29.64	46.37	44.41	55.78	-	-
Year 1980	P_1	0.72	8.34	24.75	50.72	62.11	78.61	52.32
	P_2	1.02	11.25	34.95	69.09	94.50	97.90	64.46
	P_3	0.94	14.00	48.42	103.28	135.80	132.04	85.27
	S.E.	0.09	0.73	1.93	3.60	5.47	5.76	3.64
	L.S.D. -5%	0.27	2.10	5.59	10.39	15.81	16.65	10.51
	L.S.D. -1%	0.36	2.83	7.52	13.99	21.29	22.42	14.15
	C.O.V. (%)	51.49	31.86	26.29	23.69	27.52	21.39	26.46

effects on root dry matter were observed from the 6th week, when root dry matter from plant populations 2 and 3 were significantly higher than that from population 1 at the 5% level of significance. At the 8th week after planting root dry matter from populations 3 and 2 were significantly higher than that from population 1 at the 1% and 5% levels respectively.

At the 10th week the difference between root dry matter from P_3 and that from P_1 was significant at the 1% level. At week 12 the effect of population 3 on root dry matter was significantly higher than the effects of populations 1 and 2 at the 5% level. There were no significant differences between the effect of population 3 and the effect of population 2 on root dry matter except at the 12th week.

Table 9 and Fig. 12 show that root dry matter continued to increase for all treatments up to the 10th week, unlike the leaf, petiole and stem dry matters which were shown to increase up to the 8th week, beyond which they started decreasing.

1st rains 1980

Table 9 and Fig. 13 show that root dry matter increased as plant density decreased from P_1 (74,000 plants per hectare) to P_3 (44,000 plants per hectare). Plant density effect on root dry matter was highly significant from the 6th week up to the end of the

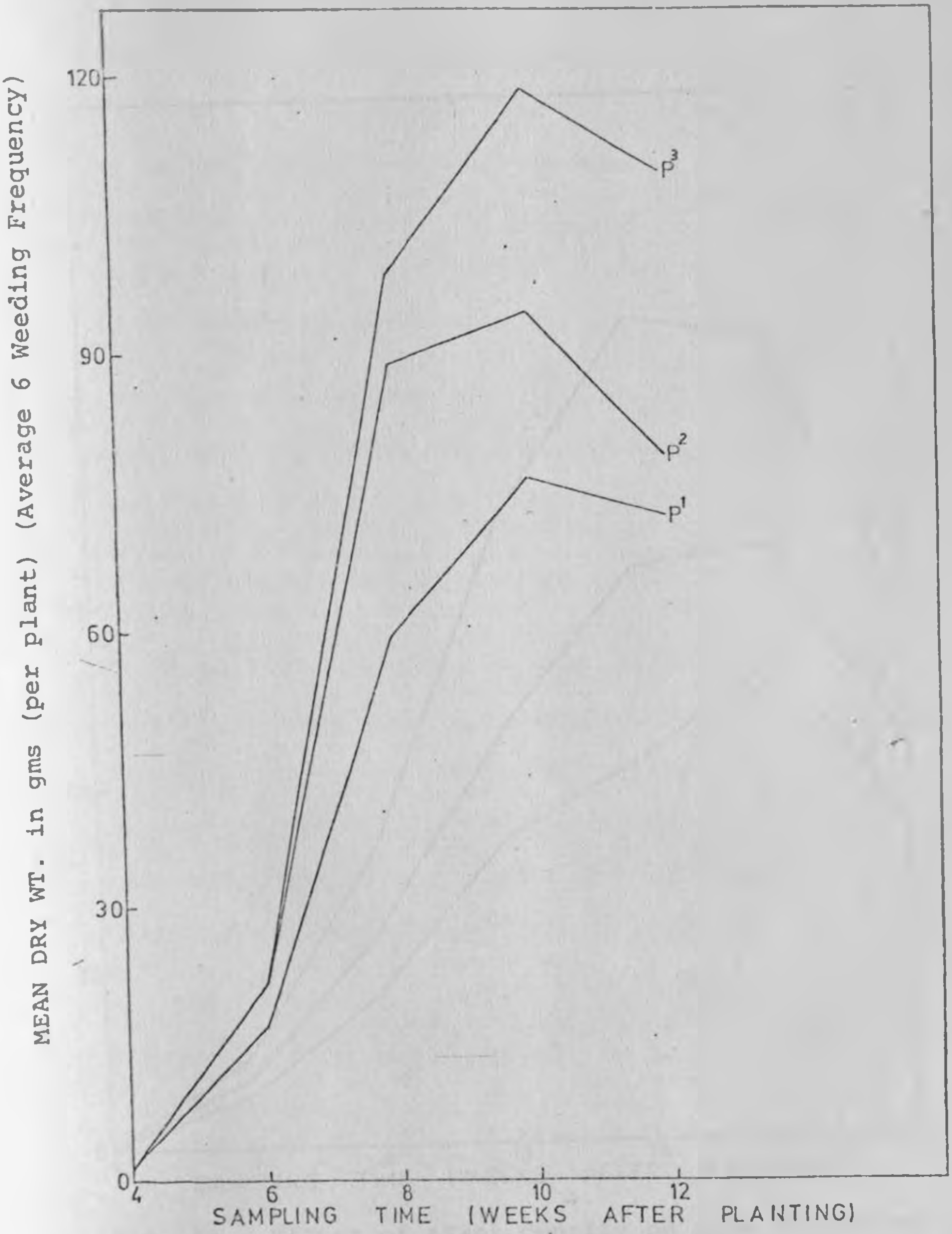


Fig. 12. Effect of plant density on root dry matter (1979).

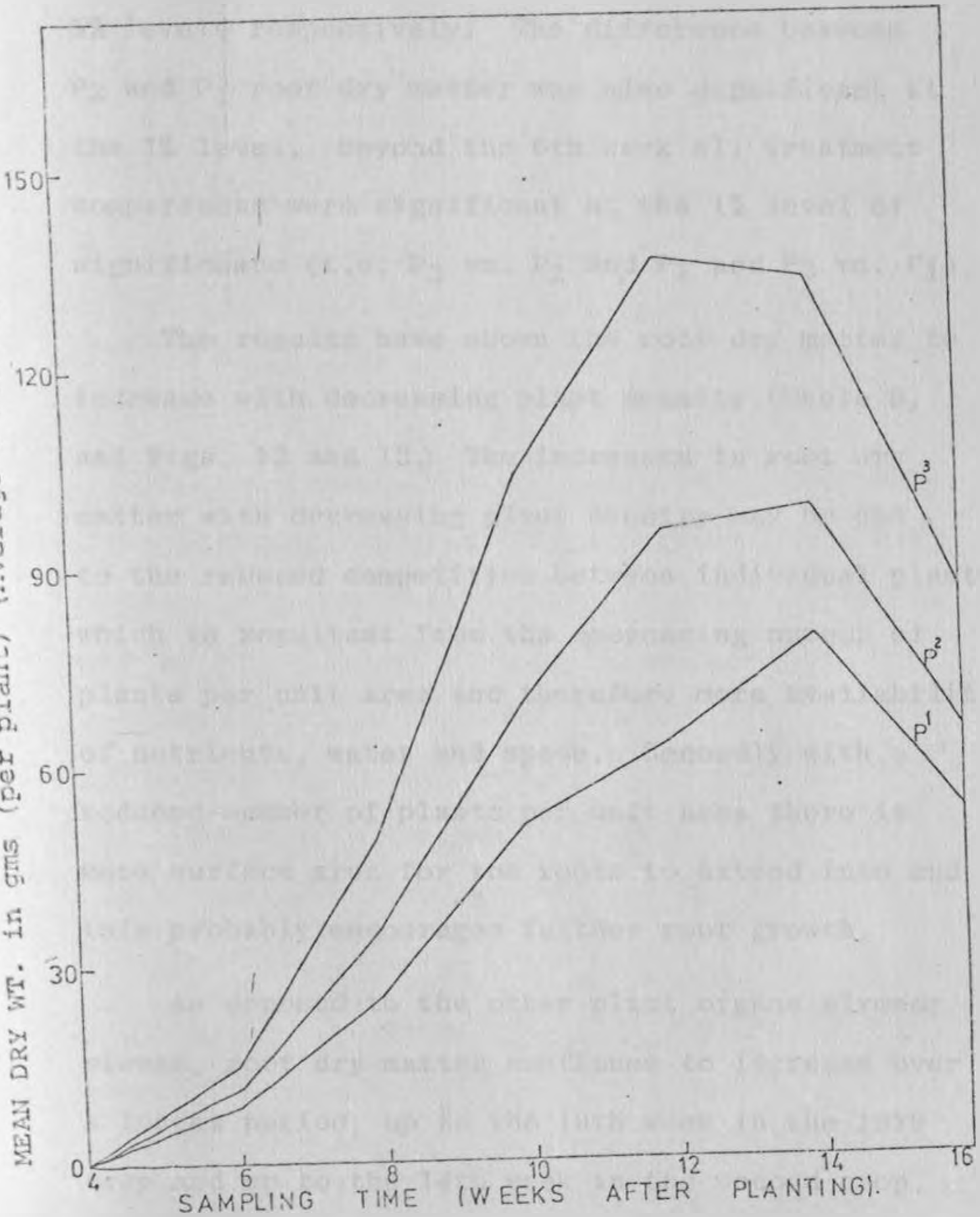


Fig. 13. Effect of plant density on root dry matter (1980).

sampling period. At the 6th week after planting root dry matter from P_3 was significantly higher than root dry matter from P_1 and P_2 at the 1% and 5% levels respectively. The difference between P_2 and P_1 root dry matter was also significant at the 1% level. Beyond the 6th week all treatment comparisons were significant at the 1% level of significance (i.e. P_3 vs. P_2 and P_1 and P_2 vs. P_1).

The results have shown the root dry matter to increase with decreasing plant density (Table 9, and Figs. 12 and 13.) The increases in root dry matter with decreasing plant density may be due to the reduced competition between individual plants which is resultant from the decreasing number of plants per unit area and therefore more availability of nutrients, water and space. Secondly with a reduced number of plants per unit area there is more surface area for the roots to extend into and this probably encourages further root growth.

As opposed to the other plant organs already viewed, root dry matter continues to increase over a longer period; up to the 10th week in the 1979 crop and up to the 14th week in the second crop. The reason for this trend in root dry matter may be that while the flow of photosynthates to the leaves, petioles and stems declined and before the full formation of the seeds, whatever photosynthetic material was manufactured was partitioned between the roots, basket and the developing seeds, hence the continued increase of the root dry matter. This is a possibility considering that sunflower seeds develop in stages even within a single head. It is therefore possible that at a given stage the amount of photosynthates is far above that which can be stored in form of seeds and basket, so that some is diverted to the root system.

Effect of weeding frequency on basket dry matter. 2nd rains 1979

Basket formation started during the 5th week after planting, and significant weeding time effects on this character were not recorded until the 10th week after planting, when basket dry matter from treatment E was significantly higher than the basket dry matter from treatments A, F and D at 1% (Table 10). The basket dry matter from treatment E was significantly higher than that from treatment C at the 5% level.

At the 12th week after planting differences between the basket dry matter from treatment E was significantly higher than that from treatments A and F at 1% level of significance and the basket dry matter from treatments E versus that from treatment D was significantly higher at 5%. The basket dry matter from treatment B was significantly higher than the basket dry matter from treatment A at the

TABLE 10: Effect of weeding frequency on basket dry matter (gms/plant)

Year	Weeding	SAMPLING TIME IN WEEKS AFTER PLANTING						
1979	Frequency	4	6	8	10	12	14	16
	A	-	2.26	30.54	102.89	97.53	-	-
	B	-	2.98	40.18	128.22	137.32	-	-
	C	-	2.69	36.87	117.00	149.34	-	-
	D	-	2.56	33.67	102.92	126.86	-	-
	E	-	2.01	37.23	158.78	167.28	-	-
	F	-	2.18	33.50	104.28	116.81	-	-
	S.E.	-	0.50	3.55	11.95	12.88	-	-
	L.S.D.-5%	-	1.45	10.24	34.46	37.16	-	-
	L.S.D.-1%	-	-	-	46.41	50.04	-	-
	C.O.V.(%)	-	-	34.77	34.73	33.64	-	-
Year 1980	A	-	0.42	10.53	24.19	69.90	122.49	112.06
	B	-	0.56	17.08	37.35	110.20	199.89	169.61
	C	-	0.73	15.02	33.25	107.89	206.72	195.94
	D	-	0.28	9.33	20.43	63.59	139.54	143.73
	E	-	0.75	14.66	39.47	106.43	186.63	166.00
	F	-	0.29	9.50	26.80	78.44	117.30	136.17
	S.E.	-	0.11	1.17	2.11	5.70	17.72	10.51
	L.S.D.-5%	-	0.31	3.37	6.07	16.47	51.10	30.34
	L.S.D.-1%	-	0.42	4.54	8.18	22.18	68.82	40.86
	C.O.V.(%)	-	-	31.88	24.08	22.09	37.82	23.65

5% level, and the basket dry matter from treatment C was also significantly higher than the dry matter from treatment A at the 1% level of significance.

It has already been mentioned that heading started about the 5th week after planting and by the 6th week had spread over all the plots. It was observed that heading started in the treatment plots that had not been weeded, i.e. treatments F, D and A.

Table 10 and Fig. 14 show that by the end of the sampling period, basket dry matter was still increasing for all treatments except for treatment A which was not weeded all season. Basket dry matter from the unweeded control started declining from the 10th week after planting.

1st rains 1980

Head formation also started during the 5th week after planting in this season and basket dry matter reached its peak formation at the 14th week after planting and started declining thereafter (Fig. 15).

At the 6th week basket dry matter obtained from treatments E and C were significantly higher than the basket dry matter obtained from treatment A at the 5% level. The basket dry matter from treatment E was significantly higher than the basket dry matter from treatments D and F at the 1% level of significance.

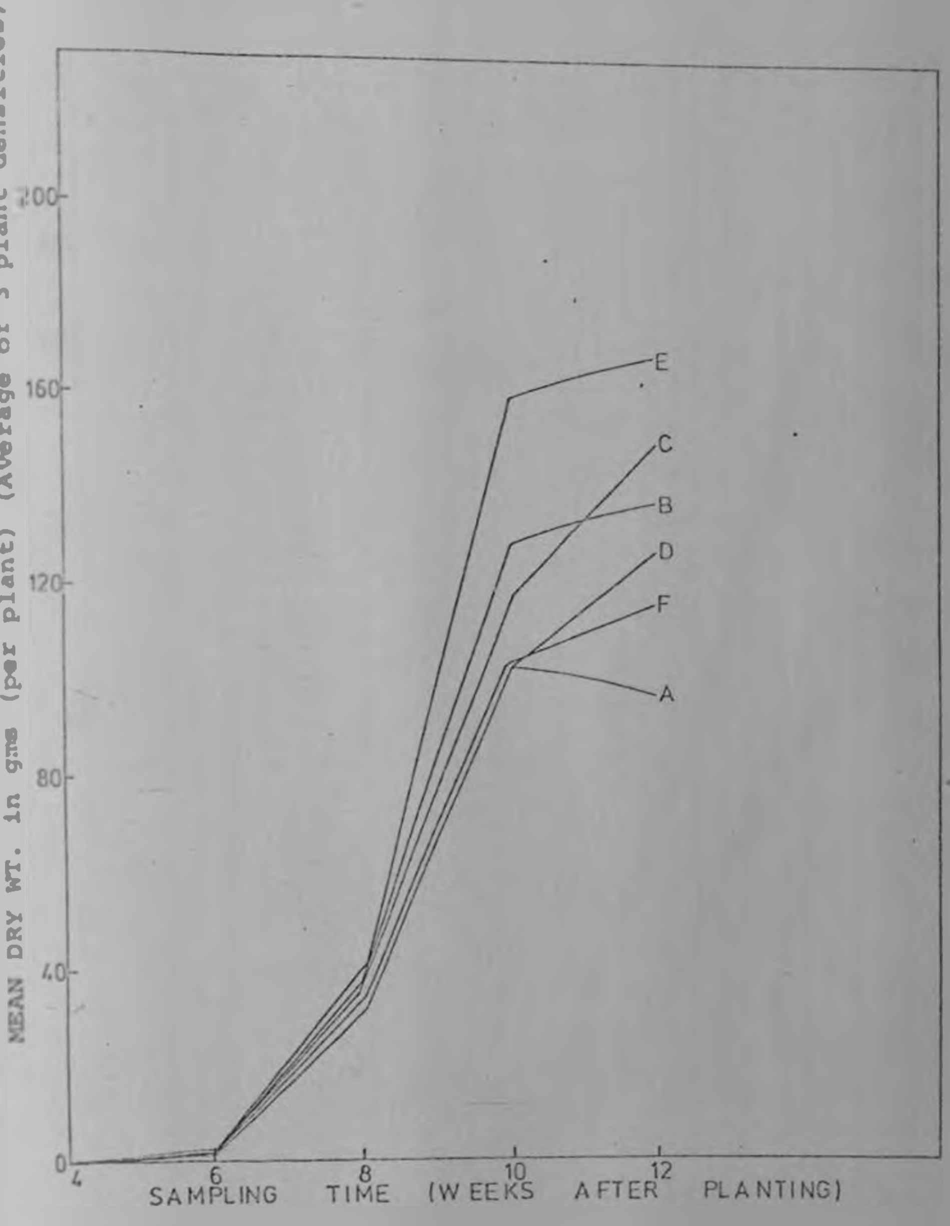


Fig. 14. Effect of weeding frequency on basket dry matter (1979).

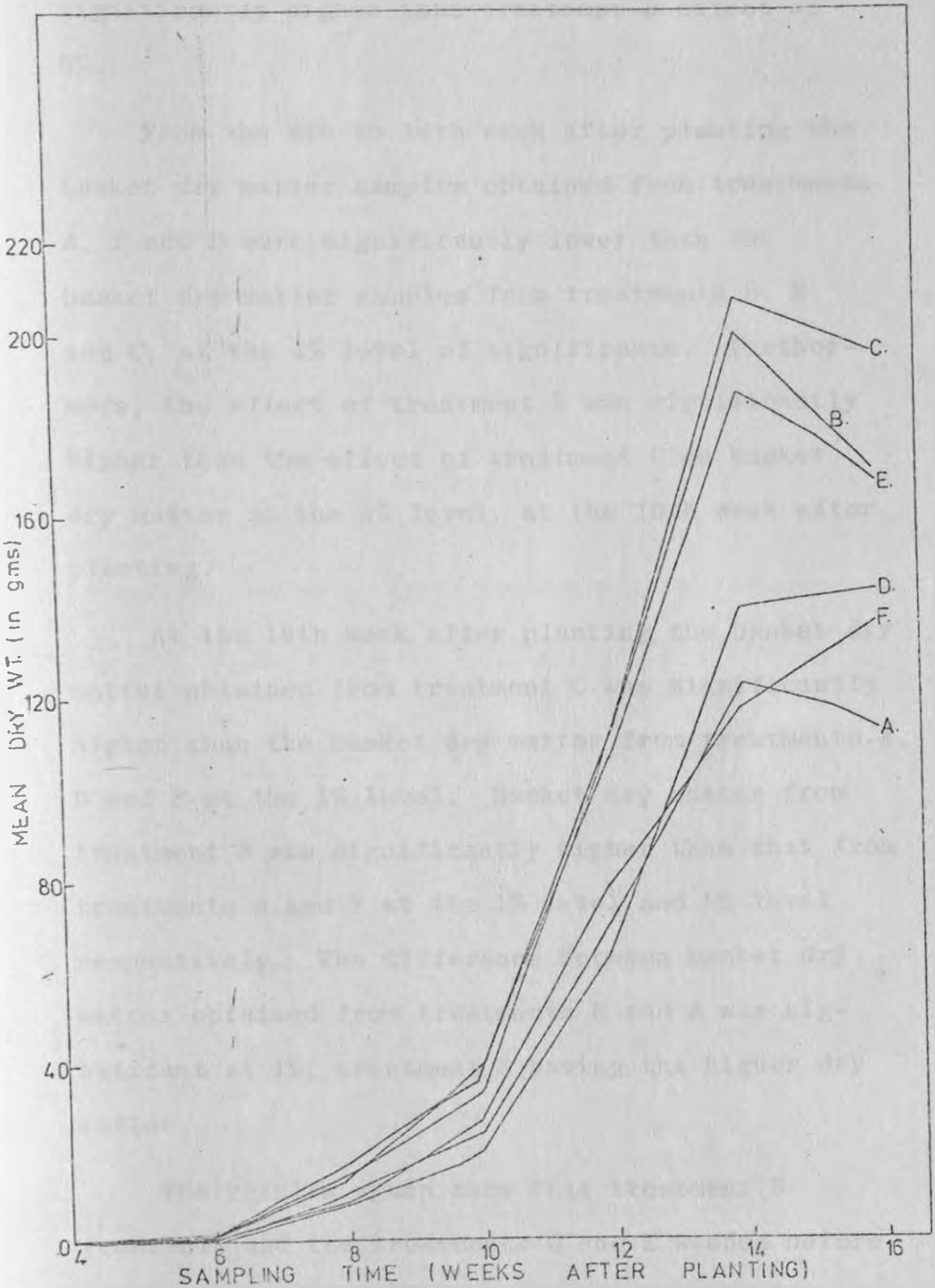


Fig. 15. Effect of weeding frequency on basket dry matter (1980).

And treatment C effect on basket dry matter was significantly higher than treatment D effect at 5%.

From the 8th to 14th week after planting the basket dry matter samples obtained from treatments A, F and D were significantly lower than the basket dry matter samples from treatments B, E and C, at the 1% level of significance. Furthermore, the effect of treatment E was significantly higher than the effect of treatment C on basket dry matter at the 5% level, at the 10th week after planting.

At the 16th week after planting the basket dry matter obtained from treatment C was significantly higher than the basket dry matter from treatments A, D and F at the 1% level. Basket dry matter from treatment B was significantly higher than that from treatments A and F at the 1% level and 5% level respectively. The difference between basket dry matter obtained from treatments E and A was significant at 1%, treatment E having the higher dry matter.

The results again show that treatment B (control) and the treatments C and E weeded before anthesis had higher basket dry matter than the treatment A (control) and treatments D and F, which were weeded after anthesis. There were no significant differences between those treatments weeded before anthesis and the control weeding all season (B). This would tend to suggest that weeding all season is not necessary because after anthesis the crop plants can favourably compete with weeds without any significant drop in basket dry matter. Secondly, beyond anthesis the crop should have formed sufficient canopy to cover the ground and thus limit weed growth and therefore weed competition.

The reason why treatments C and E performed as well as treatment B and better than treatments A, D and F is probably because for treatments C and E weeds were eliminated either before or during that period when the crop was most susceptible to weed competition. Available literature suggests that the critical weed competition period is early in the life of the crop and covers the first 25-33 percent of the life of many crops (Kasasian and Seeyave, 1969; Allan, 1974; Gurnan 1976; Van Eijnatten 1972). This being the case, it would be expected that removal of weeds from a sunflower crop early in the life of the crop should be more advantageous than removing them later. The results obtained from treatments weeded before anthesis are therefore in agreement with the literature available.

Although there were no significant differences between the basket dry matter obtained from treatment C and that from treatment E, treatment E had a higher basket dry matter than treatment C in 1979 and in 1980 treatment C had a higher basket dry matter than treatment E. This probably means that during the short rains or drier season one weeding soon after emergency (in this case 2 weeks) is sufficient while during a wetter season it is necessary to weed up to anthesis. This would therefore mean that depending on the weather conditions, the period when the sunflower crop is most susceptible to weed competition lies between 2 weeks after emergence and anthesis. This is in agreement with the separate pieces of work of Johnson (1972) and Van Eijnatten (1972) who reported the critical weed competition period in sunflower to be within the first 4 - 6 weeks of the crop's life. Later weedings did not increase basket dry matter and this was also observed by Gurnah (1976) in a soyabean crop.

The results also show that there were no significant differences between the basket dry matter obtained from treatment A (no weeding all season) and that from treatments D, and F, in which weeding was delayed until after anthesis. The reason must be that these treatments had already suffered irreparable damage due to weed competition.

Effect of plant density on basket dry matter.

2nd rains 1979

Significant differences between the effects of the different plant densities on the basket dry weight were not observed until the 8th week after planting (Table 11). At this stage, the basket dry matter obtained from population 3 was significantly higher than that obtained from population 1, at the 5% level of significance. At the 10th week the difference between the effects of populations 3 and 1 was still significant at the 5% level and so was the difference between the effects of populations 1 and 2. At the 12th week after planting the difference between the basket dry matter from P_3 and that from P_2 and P_1 was significant at 5% and 1% respectively. Fig. 16 shows that at the time of the final sampling (i.e. at 12th week) basket dry matter was still increasing.

1st rains 1980

Table 11 and Fig. 17 show as in the 1979 crop, that basket dry matter increased as plant density decreased from P_1 to P_3. Basket dry matter is also shown to increase up to the 14th week after planting then begins to decrease except with P_1. Unlike in the 1979 crop, significant differences between plant density effects were observed as from the 6th week after planting, when

TABLE 11: Effect of plant density on basket dry matter (gm/plant)

Year	Plant	SAMPLING TIME IN WEEKS AFTER PLANTING						
1979	Density	4	6	8	10	12	14	16
	P1	-	1.93	30.56	95.42	109.91	-	-
	P2	-	2.41	35.83	122.13	127.65	-	-
	P3	-	3.00	39.60	139.49	160.01	-	-
	S.E.	-	0.35	2.51	8.45	9.12	-	-
	L.S.D. - 5%	-	1.02	7.24	24.37	26.28	-	-
	" - 1%	-	-	-		35.39	-	-
	C.O.V. (%)	-	-	34.77	34.73	33.64	-	-
Year 1980	P1	-	0.28	8.52	21.38	66.33	123.54	134.05
	P2	-	0.43	11.76	28.43	87.34	161.86	157.84
	P3	-	0.80	17.78	40.93	114.55	200.88	169.87
	S.E	-	0.08	0.83	1.49	4.03	12.51	7.43
	L.S.D. - 5%	-	0.22	2.39	4.29	11.65	36.13	21.46
	" - 1%	-	0.30	3.21	5.78	15.68	48.66	28.90
	C.O.V. (%)	-	-	31.38	24.08	22.09	37.82	23.65

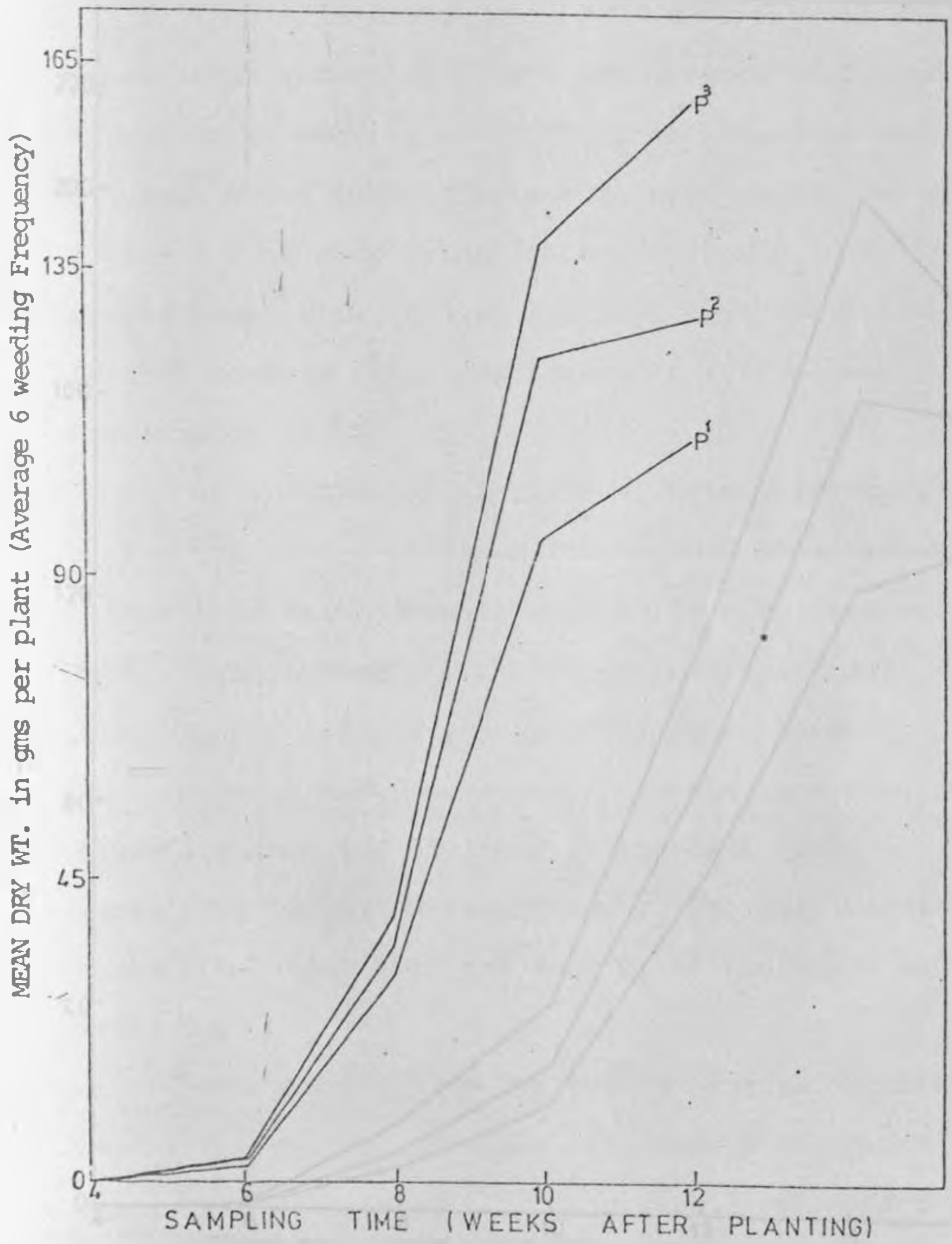


Fig. 16. Effect of plant density on basket dry matter (1979).

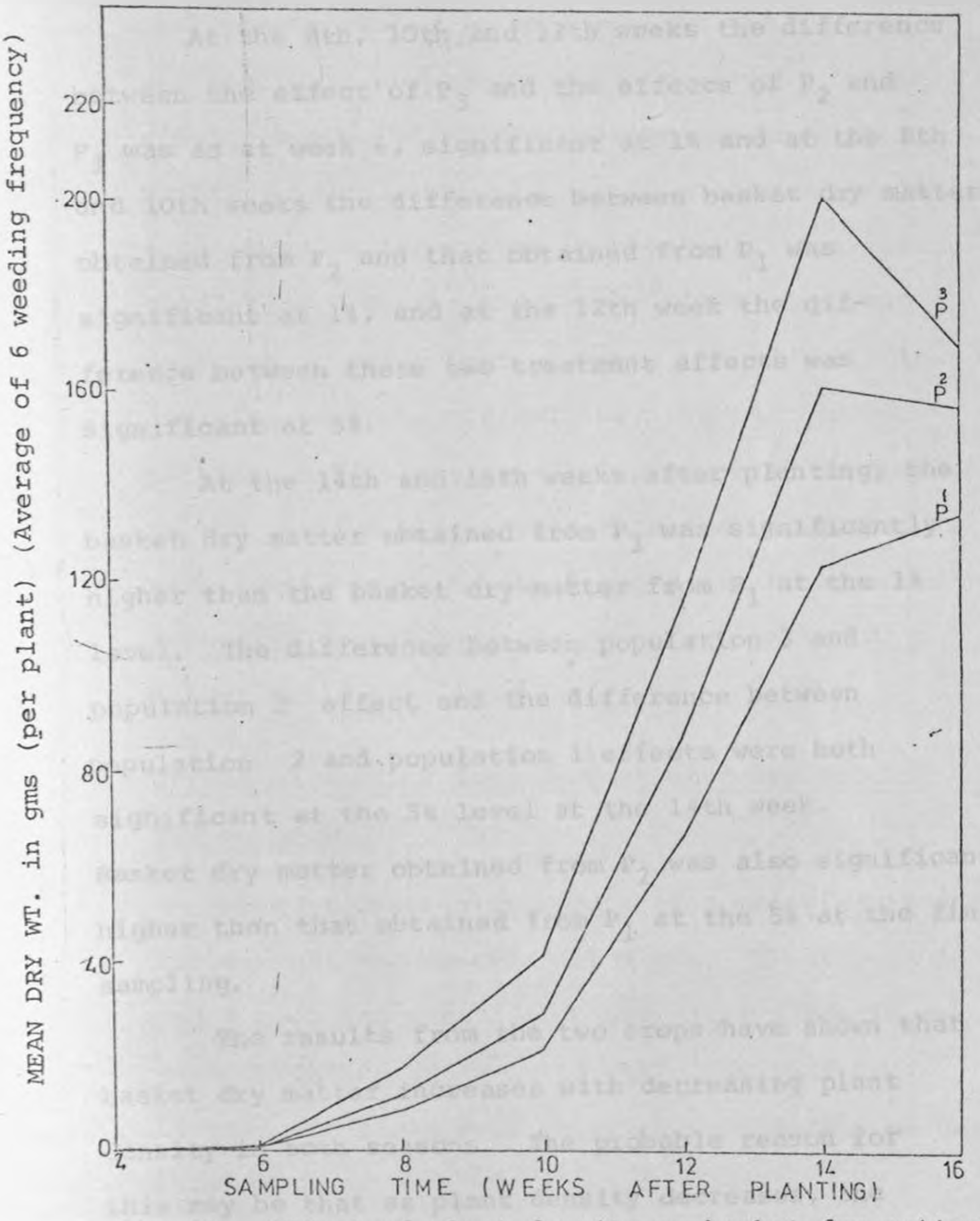


Fig. 17. Effect of plant density on basket dry matter (1980).

basket dry matter from P_3 was significantly higher than the basket dry matter from P_2 and P_1 at the 1% level of significance.

At the 8th, 10th and 12th weeks the difference between the effect of P_3 and the effects of P_2 and P_1 was as at week 6, significant at 1% and at the 8th and 10th weeks the difference between basket dry matter obtained from P_2 and that obtained from P_1 was significant at 1%, and at the 12th week the difference between these two treatment effects was significant at 5%.

At the 14th and 16th weeks after planting, the basket dry matter obtained from P_3 was significantly higher than the basket dry matter from P_1 at the 1% level. The difference between population 3 and population 2 effect and the difference between population 2 and population 1 effects were both significant at the 5% level at the 14th week. Basket dry matter obtained from P_2 was also significantly higher than that obtained from P_1 at the 5% at the final sampling.

The results from the two crops have shown that basket dry matter increases with decreasing plant density in both seasons. The probable reason for this may be that as plant density decreases, the number of plant per unit area also decreases. This would lead to bigger plants with larger plant parts, hence the higher basket dry matter from lower plant densities. These results agree with the report from Alessi and Power's work (1974) who found that plants tended to be larger at the low populations, thereby compensating in weight for the greater number of smaller plants at the high planting rates. The same workers also reported a decrease in ear weight of wheat with increased population. Genter and Camper (1973) reported a decrease in ear weight of maize hybrids with increasing population densities. Turchi (1972) working in Kitale on sunflower reported improvement of the various plant parts when individual plants were considered. It would therefore be expected that with decreasing plant density, basket dry matter would also increase.

Effect of weeding frequency on seed dry matter. 2nd rains 1979

Seed formation started around the 7th-8th week but was not spread over all plots. Treatments A and F each had only 1 plot out of 12 plots in which seed formation had started while the rest had between 4-5 plots each in which seed formation had started.

At the 10th week after planting (Table 12) seed dry matter from treatment E was significantly higher than seed dry matter from treatments A and D at the 1% level and also higher than that from

TABLE 12: Effect of weeding frequency on seed dry matter (gm/plant)

Weeding Frequency	2nd rains 1979		1st rains 1980		
	SAMPLING TIME IN WEEKS AFTER PLANTING				
	10	12	12	14	16
A	52.42	91.99	12.63	71.29	119.54
B	72.53	168.62	40.39	140.10	186.54
C	72.91	160.02	44.38	146.16	226.26
D	51.83	132.89	28.83	89.34	122.01
E	91.37	163.28	39.64	144.92	190.48
F	59.52	129.11	20.44	71.14	120.85
S.E.	8.43	11.34	2.22	3.04	8.58
L.S.D.-5%	24.31	32.71	6.39	20.95	24.74
L.S.D.-1%	32.73	44.06	8.61	28.21	33.31
C.O.V.(%)	43.67	27.84	23.56	22.74	18.44

F at the 5% level of significance. At the 12th week, treatment B had significantly more seed dry matter than treatment A at the 1% level and more seed dry matter than treatments D and F at the 5% level. Seed dry matter from treatment E was also higher than that from treatment A at the 1% level and higher than seed dry matter from treatments D and F at 5%. The difference between the effect of treatment C and the effect of treatment A was significant at 1%. Treatment D effect was also significantly higher than treatment A and F effects on seed dry matter at the 5% level.

Table 12 shows that by the 12th week seed dry matter was still increasing for all treatments.

1st rains 1980

Seed formation began around 9 - 10th weeks after planting. Weeding frequency treatments had a highly significant effect on seed dry weight (P= 0.01). At the 12th week, seed dry matter samples from treatments B, C and E were significantly higher than seed dry matter samples from treatments A, D and F at the 1% level of significance. Treatment D also had significantly higher dry matter than treatments A and F at the 5% level.

At the 14th week treatments B, C and E had significantly higher seed dry matter than treatments A, D and F at the 1% level. And at the 16th week, seed dry matter obtained from treatment C was significantly higher than seed dry matter samples from treatments A, B, D and E and F at 1%. Treatments B and E also had significantly higher seed dry matter weights than treatments A, D and F at the 1% level of significance.

Table 12 shows that by the 16th week seed dry matter was still increasing. Treatment C had the highest seed dry matter weight throughout the sampling period.

Seed formation occured earlier in the first experiment than in the second. It has already been suggested that the first trial having been conducted during the short rains had less moisture available for growth than the second crop and that this might have resulted in a shorter growing period with resultant earlier maturity.

It has been shown that for seed dry matter as for the other plant organs, treatments weeded before anthesis i.e. C and E, and the control B (weeded all through the season) had significantly higher seed dry matter than treatments which suffered weed competition until after anthesis, i.e. D and F and the no weeding all season control

A, thus suggesting that early weeding of sunflower is necessary. Except during the 16th week (1980) when treatment C significantly excelled over all the other treatments, there were no significant differences between the effects of the treatments C and E and the effect of treatment B, again suggesting that weeding throughout the season is not necessary.

Most workers have reported that weed competition in most crops does most damage to the crop very early in the crop life. This period when weed competition is critical has been reported to cover the first 23-33 percent of the life of the plants. (Kasasian and Seeyave, 1969; Allan, 1974; Gurnah, 1976). Since treatments C and E were weeded early and obtained higher seed dry matter than treatments weeded later, it can be assumed that these treatments performed well because they were free of weeds during the critical weed competition period. Other researchers have also indicated that weeding beyond the critical weed competition period does not result in increased yields (Gurnah, 1976; Allan, 1974). This would explain why the control B weed free all through the season did not perform significantly better than treatments C and E. Beyond the critical period the crop is not only more competitive but will have formed a sufficient canopy to cover the ground and suppress further weed growth thus making further weeding unncessary. Further weedings also disturb the root system and this probably has a negative influence on the crop's performance, a likely possibility in sunflower, considering that the sunflower root system is close to the soil surface and does not penetrate deep into the soil. Frequent weeding also leads to higher evaporation losses of moisture from the soil, thus lowering the amount of soil moisture that is available for crop use.

According to the results the critical weed competition period lies between the first two weeks after emergence and anthesis. The 1979 results showed no significant differences between seed dry matter obtained from C and that obtained from E but the 1980 results showed that seed dry matter obtained from treatment C was significantly higher than the seed dry matter obtained from treatment E. It has already been mentioned that 1979 crop was planted during a relatively drier season compared to the 1980 crop. The results suggest therefore that during a dry season one weeding at two weeks after emergence is sufficient while during the wetter season the crop should be weeded right up to anthesis. This suggests that the critical weed competition period varies depending on the season. This is supported by experimental work on cotton by Schwerzel and Thomas (1967-68, 1971) who observed differing lengths of the critical weed competition period, which they attributed to weather conditions, the period being shorter during the drier than wetter periods.

Effect of plant density on seed dry matter.

2nd rains 1979

Table 13 shows that seed dry weight increased as plant density decreased. At the 10th week after planting, seed dry matter obtained from population 3 was significantly higher than seed dry matter from population 1 at the 1% level. The difference between the results obtained from population 2 and those from population 1 was significant at the 5% level. At the 12th week after planting the seed dry matter from population 3 was significantly higher than the seed dry matter from populations 1 and 2 at 1%.

1st rains 1980

As plant density decreased from P_1 to P_3, seed dry matter increased. Throughout the sampling period the seed dry matter obtained from P_3 was significantly higher than that obtained from P_2 and that from P_1 at the 1% level. Differences between P_2 and P_1 effects on seed dry matter were also

TABLE 13: Effect of plant density on seed dry matter (gms/plant)

Plant density	1979		1980		
	SAMPLING TIME IN WEEKS AFTER PLANTING				
	10	12	12	14	16
P_1	50.08	116.31	20.55	87.58	128.47
P_2	71.36	136.59	31.07	108.48	156.64
P_3	78.85	170.05	46.03	135.42	197.52
S.E.	5.96	8.03	1.57	2.15	6.06
L.S.D.-5%	17.19	23.13	4.52	14.81	17.49
L.S.D.-1%	23.15	31.15	6.09	19.95	23.56
C.O.V.(%)	43.67	27.84	23.56	22.74	18.44

significant at the same level.

The results have indicated that seed dry matter increased as the plant density decreased from P_1 to P_3. Willey and Holliday (1971) in plant population and shading studies in barley reported a decrease in grain yield at high populations which was found to be associated with a comparable decrease in the number of grains per unit area. It was suggested that the decrease in grain number may be due to a lower production of total dry matter during ear development. This lower production of total dry matter was attributed to the crop growth rates of the higher populations having reached their peak and then having declined before end of the ear development period.

At the low populations plants tend to be larger (Alessi and Power, 1974) thereby compensating in weight for the greater number of smaller plants at the higher planting rates. With increased plant size it would be expected that other plant characteristics would increase proportionately, hence the higher seed dry matter from P_3 than P_2 and P_1. Turchi (1972) working with sunflower also reported improvement on the individual plant organs as plant density decreased.

Effect of weeding frequency on total dry matter.

Table 14 and Figs. 18 and 19 show the effect of weeding frequency on total dry matter.

2nd rains 1979

From the beginning of the sampling period, weeding frequency treatment effects on total dry matter were significant. At four weeks after planting total dry matter from treatment B was significantly higher than total dry matter from treatment A at the 1% level of significance and also significantly higher than those from treatments D and F at the 5% level of significance.

At the 6th week after planting total dry matter from treatment E was significantly higher than the total dry matter from treatment F at the 1% level and also significantly higher than the total dry matter from treatments D and A at 5%. The total dry matter from treatments B and C were also significantly higher than that from treatment F at 5% level of significance.

From the 8th week to the 12th week after planting, the effects of treatments B, C, E (i.e. the treatments weeded before anthesis) were significantly higher than the effects of treatments A, F and D on total dry matter at the 1% level of significance. There were no significant differences between the effects of treatment B,

TABLE 14: Effect of weeding frequency on total dry matter(Kgs/ha)

	Weeding frequency	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
2nd rains 1979	A	171.93	1253.79	3914.30	4877.32	4550.06		
	B	218.31	1479.67	6060.92	7156.43	7553.34		
	C	193.17	1461.39	5678.27	7069.20	7949.82		
	D	181.74	1251.89	4216.08	5153.51	5887.15		
	E	196.99	1521.40	5546.86	8228.16	7999.40		
	F	182.53	1150.39	3846.55	4891.96	5209.14		
	S.E.	12.24	89.57	325.44	385.64	443.05		
	L.S.D.-5%	34.78	254.44	919.41	1095.46	1258.55		
	L.S.D.-1%	46.36	339.09	1222.81	1460.98	1677.23		
	C.O.V.(%)	22.21	22.90	23.08	21.42	23.49		
1st rains 1980	A	50.55	376.40	1677.47	2959.07	4794.14	5454.26	5503.60
	B	75.97	681.03	2660.00	4310.88	7480.48	9201.69	8381.59
	C	70.16	718.61	2374.76	3828.73	7181.32	9462.58	9727.92
	D	64.85	335.95	1735.18	2934.04	4521.74	6214.61	6234.98
	E	66.14	741.82	2273.26	4694.17	7009.09	8612.66	8352.56
	F	68.54	425.39	1355.73	2928.40	4688.36	5770.53	5558.51
	S.E.	7.64	29.41	68.20	133.96	173.81	155.46	168.53
	L.S.D.-5%	21.69	83.55	193.73	380.54	493.72	441.62	478.74
	L.S.D.-1%	28.90	111.35	258.18	507.13	657.96	588.53	638.00
	C.O.V.(%)	40.00	18.62	11.72	12.84	10.11	7.22	7.99

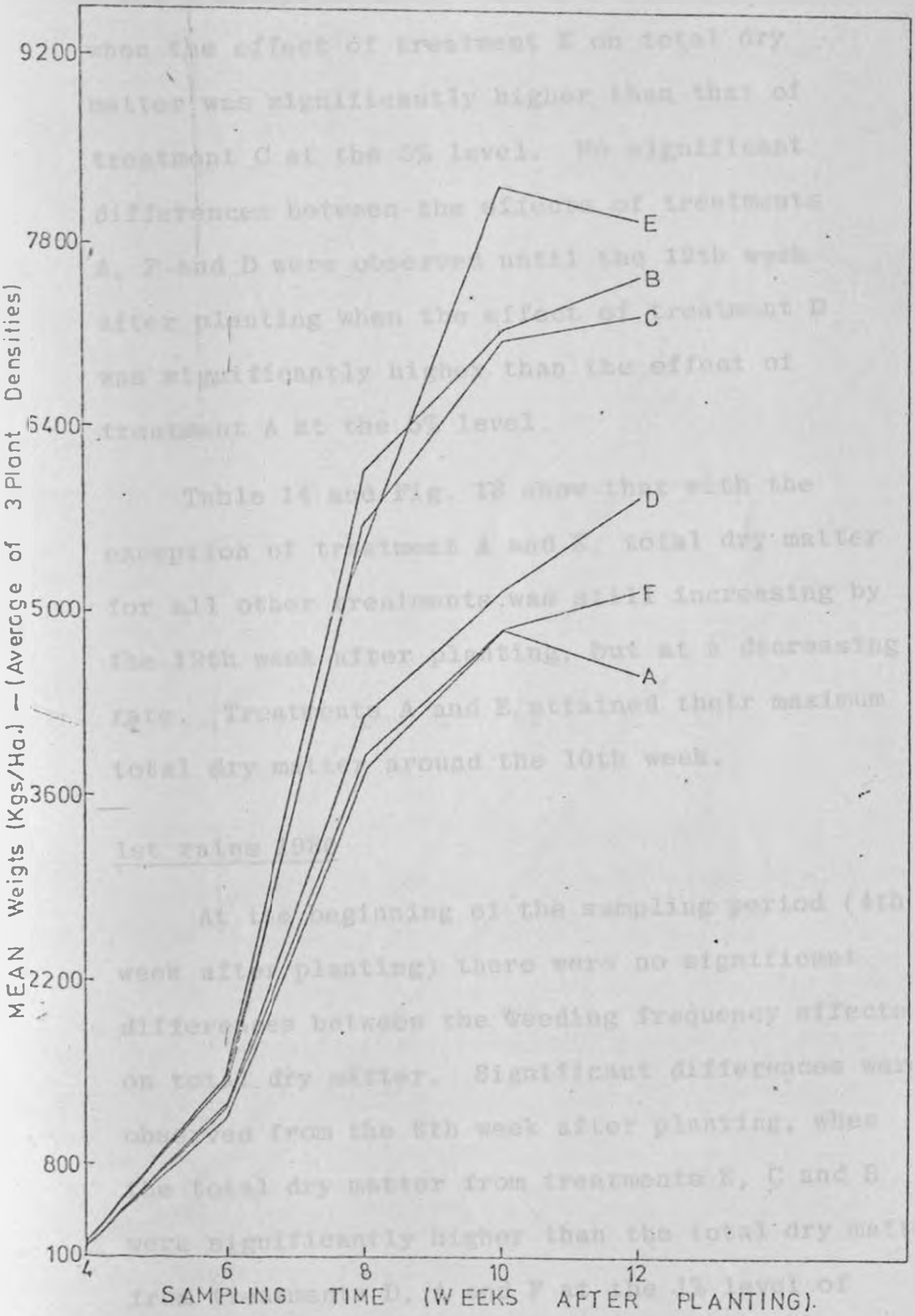


Fig. 18. Effect of weeding frequency on total dry matter (1979).

C and E except at the 10th week after planting when the effect of treatment E on total dry matter was significantly higher than that of treatment C at the 5% level. No significant differences between the effects of treatments A, F and D were observed until the 12th week after planting when the effect of treatment D was significantly higher than the effect of treatment A at the 5% level.

Table 14 and Fig. 18 show that with the exception of treatment A and E, total dry matter for all other treatments was still increasing by the 12th week after planting, but at a decreasing rate. Treatments A and E attained their maximum total dry matter around the 10th week.

1st rains 1980

At the beginning of the sampling period (4th week after planting) there were no significant differences between the weeding frequency effects on total dry matter. Significant differences were observed from the 6th week after planting, when the total dry matter from treatments E, C and B were significantly higher than the total dry matter from treatments D, A and F at the 1% level of significance. The difference between the effect of treatment F and that of treatment D on total dry matter was also significant at the 5% level.

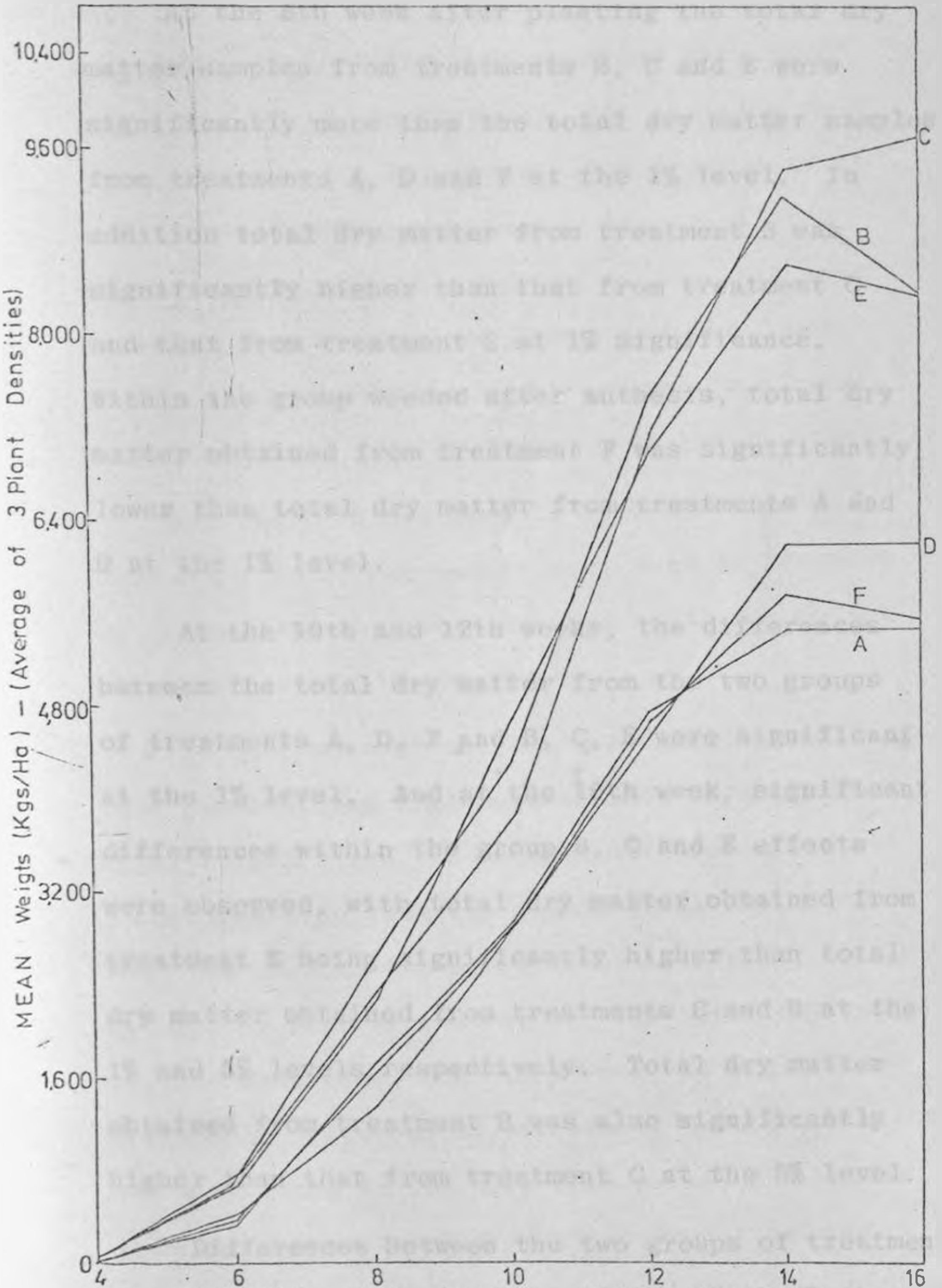


Fig. 19. Effect of weeding frequency on total dry matter (1980).

At the 8th week after planting the total dry matter samples from treatments B, C and E were significantly more than the total dry matter samples from treatments A, D and F at the 1% level. In addition total dry matter from treatment B was significantly higher than that from treatment C and that from treatment E at 1% significance. Within the group weeded after anthesis, total dry matter obtained from treatment F was significantly lower than total dry matter from treatments A and D at the 1% level.

At the 10th and 12th weeks, the differences between the total dry matter from the two groups of treatments A, D, F and B, C, E were significant at the 1% level. And at the 10th week, significant differences within the group B, C and E effects were observed, with total dry matter obtained from treatment E being significantly higher than total dry matter obtained from treatments C and B at the 1% and 5% levels respectively. Total dry matter obtained from treatment B was also significantly higher than that from treatment C at the 5% level.

Differences between the two groups of treatment effects remained significant at the 1% level through the 14th to 16th weeks after planting, the group B, C and E having the higher total dry matter measurements. The total dry matter obtained from treatment D over these two sampling periods was significantly higher than that obtained from treatments A and F at the 1% level. At the 14th week after planting the dry matter from treatments B and C were significantly higher than that from treatment E at the 1% level and at the 16th week total dry matter obtained from treatment C was significantly more than that obtained from treatment B and that from treatment E at the 1% level.

The table 14 and Fig. 19 show that in the 1980 crop, total dry matter continued to increase up to the 14th week when maximum total dry matter was attained by all treatments.

As was observed for the individual plant part results, the treatments weeded before anthesis i.e. C and E and the weeding all season control B obtained significantly higher total dry matter than the treatments weeded after anthesis i.e. F and D and the no weeding control A. The total dry matter results have shown that there were no significant differences between the effects of treatments within the same group in the 1979 crop except during the 10th week, when total dry matter from treatment E was significantly higher than that from treatment C and at the 12th week when total dry matter from treatment D was significantly higher than that from treatment A, both differences being significant at the 5% level. In the 1980 crop significant differences between the total dry matter from treatments within the same group were observed in the two groups during the 14th-16th weeks.

From the total dry matter point of view the results are in favour of early weeding of the sunflower crop. The results also suggest that weeding all through the season is not necessary, since the control B did not perform significantly better than the other treatments. Fig. 18 shows that by the end of the sampling period treatment E had the highest total dry matter and had also attained maximum total dry matter development at the 10th week while for the rest of the treatments with the exception of treatment A, total dry matter was still increasing. For the 1980 crop treatment C had the highest total dry matter which was significantly higher than the total dry matter samples obtained from treatments B and E, at the 1% level.

Several workers have reported that weed infestation in most crops does the most damage early in the crop's life (Gurnah, 1976; Staniforth and Weber 1956; Reeves 1976). Gurnah (1974) reported four periods of weed competition, with period one being the pre-early post emergence period, when the seed bed preparation effectively controls weeds; and period two being that from when the effects of seed bed preparation are no longer noticed to that at which the crop itself covers the ground and eliminates weed competition. According to Nieto et al., (1968) period two is the critical weed competition period but according to Kasasian and Seeyave (1969) the critical weed competition period includes both periods one and two and is estimated to cover the first 25-33% of the life of many crops.

Since treatments E (weeded once two weeks after emergence) and treatment C (weeded up to anthesis) performed better than treatments weeded after anthesis, it can be assumed that their better performance is due to the fact that in the case of treatment C and E there was no weed competition during that critical period when weed competition is deleterious to the performance of the crop. The results therefore suggest that the critical weed competition period in sunflower probably lies between two weeks after emergence and anthesis. This would be in agreement with the results obtained by Johnson (1972) who observed that sunflowers required to be cultivated at 2 and 4 weeks after sowing, and also in agreement with Van Eijnatten and Wamburi (1972) who reported that weeding at 4 weeks after emergence of the sunflower was adequate.

The 1979 results show that by the end of the sampling period treatment E had a higher total dry matter than treatment C although the difference was not significant. In the 1980 crop treatment C had obtained higher total dry matter than treatment E and the difference was significant at 1%. It should be pointed out here again that the 2nd rains 1979 was a relatively dry season compared to the 1st rains 1980. The results seem to suggest that during a drier season one weeding at two weeks after emergence is adequate while during a wetter period it is necessary to weed up to anthesis. Thus suggesting that depending on the weather conditions, the length of the critical period will vary within the period that has been indicated by the results. Schwerzel and Thomas (1967-68; 1971) reported varying lengths of the critical weed competition period in cotton which they attributed to weather conditions, the period being shorter during the drier than wetter periods.

It has also been reported that weeds occurring beyond the critical weed competition period do not have a depressing effect on the performance of the crop (Wetala, 1976; Smith and Levick, 1974; Nieto, Brando and Gonzalez 1968). This would explain why the weeding all season control did not perform better than treatments C and E as would have been expected. Beyond the critical period the crop plants can compete more favourably with the weeds and by this stage the crop canopy is sufficient to suppress weed growth.

Effect of plant density on total dry matter based on individual plants. 2nd rains 1979.

Table 15 shows that at four weeks after planting the effects of the various plant populations on individual plant total dry matter were not significantly different, and total dry matter was observed to increase up to population 2 and to decrease below this population. From the 6th week to the 12th week individual plant total dry matter increased as the plant density decreased from 74,000 plants per hectare to 44,000 plants per hectare (Fig.20).

Between the 6th to the 10th week the individual plant total dry matter obtained from plant densities P_3 and P_2 was significantly higher than that from P_1 at the 1% level of significance. And at the 10th week the difference between total dry matter from P_3 and that from P_2 was significant at 5%. By the final sampling individual plant total dry matter was still increasing with P_3 having a significantly higher total dry matter than populations 1 and 2 at the 1% level of significance.

TABLE 15: The effect of plant density on total dry matter,gms/plant

2nd rains 1979	Plant density	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
	P_1	19.29	120.44	427.63	549.02	583.77	-	-
	P_2	20.59	153.19	541.79	674.15	672.86	-	-
	P_3	19.38	155.79	585.37	765.28	828.62	-	-
	S.E.	0.79	6.37	26.38	28.30	37.11	-	-
	L.S.D.-5%	2.25	18.12	75.05	80.51	105.58	-	-
	L.S.D.-1%	3.00	24.15	100.02	107.29	140.72	-	-
	C.O.V.(%)	19.64	21.81	24.94	20.92	26.16	-	-
1st rains 1980	P_1	5.51	48.98	168.87	294.84	485.81	631.32	653.44
	P_2	6.86	58.69	213.22	399.16	637.62	790.19	766.36
	P_3	7.24	66.35	282.82	529.33	792.12	978.41	906.73
	S.E.	0.47	2.02	4.91	9.54	14.00	11.78	11.57
	L.S.D.-5%	1.78	5.72	13.91	27.00	39.53	33.27	32.67
	L.S.D.-1%	-	7.62	18.50	35.92	52.58	44.24	43.45
	C.O.V.(%)	35.46	17.10	10.87	11.47	10.72	7.20	7.29

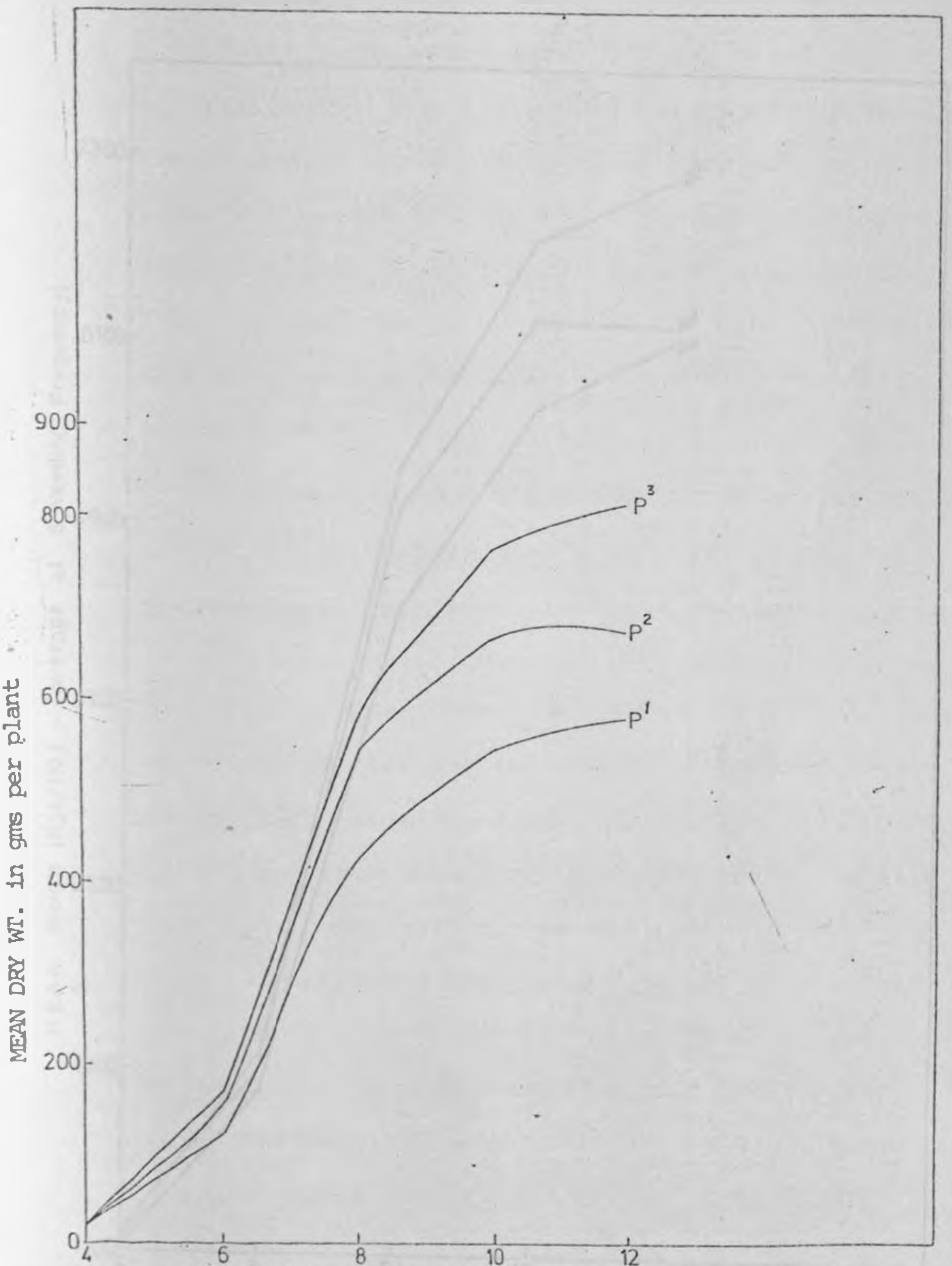


Fig. 20. Effect of plant density on total dry matter (1979)

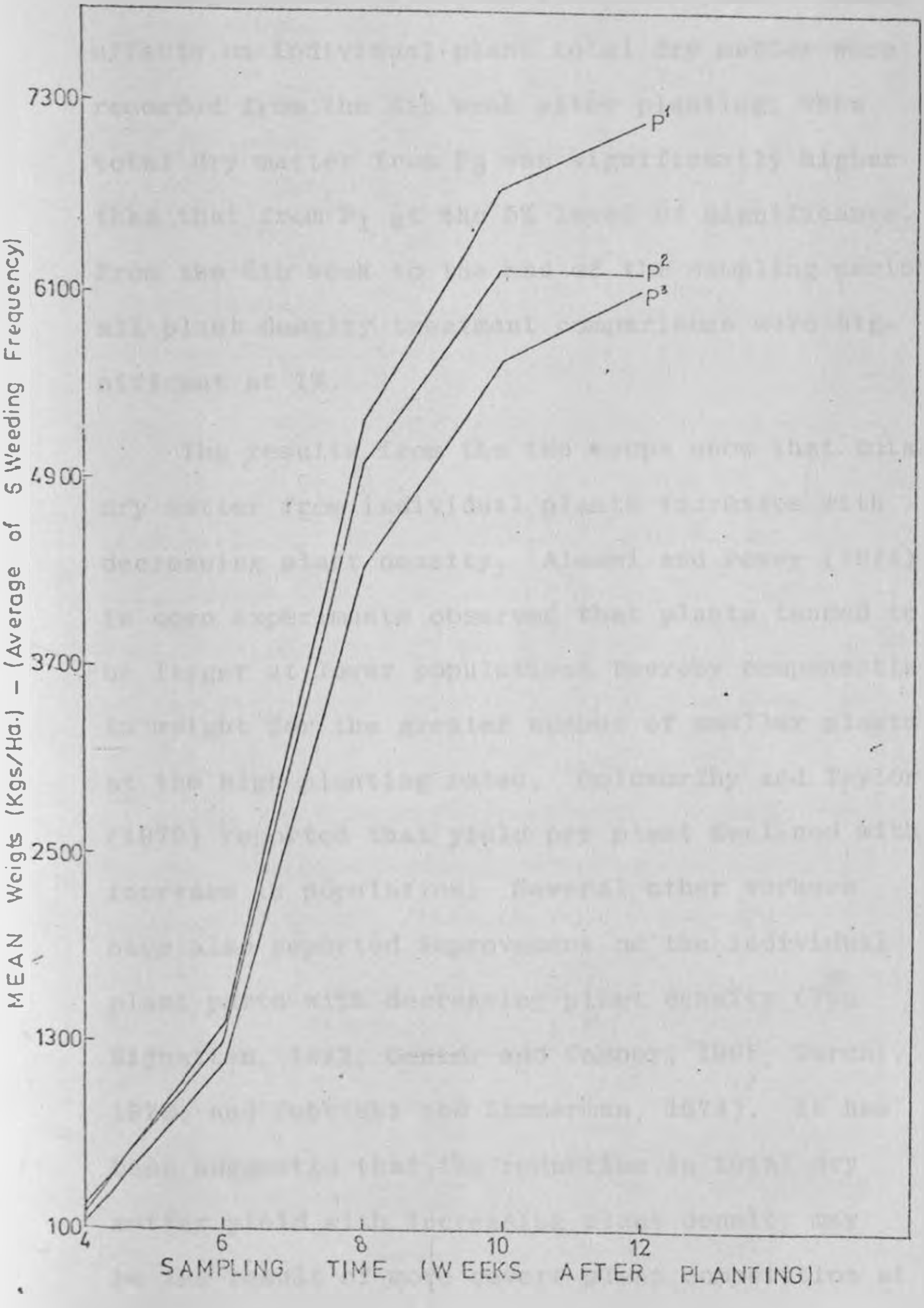


Fig. 21. Effect of plant density on total dry matter (kgs/ha) 1979.

1st rains 1980

Significant differences between plant density effects on individual plant total dry matter were recorded from the 4th week after planting, when total dry matter from P_3 was significantly higher than that from P_1 at the 5% level of significance. From the 6th week to the end of the sampling period all plant density treatment comparisons were significant at 1%.

The results from the two crops show that total dry matter from individual plants increases with decreasing plant density. Alessi and Power (1974) in corn experiments observed that plants tended to be larger at lower populations thereby compensating in weight for the greater number of smaller plants at the high planting rates. Goldworthy and Taylor (1970) reported that yield per plant declined with increase in population. Several other workers have also reported improvement of the individual plant parts with decreasing plant density (Van Eijnatten, 1972; Genter and Camper, 1965; Turchi, 1972; and Zubriski and Zimmerman, 1974). It has been suggested that the reduction in total dry matter yield with increasing plant density may be the result of more severe plant competition at the higher plant densities (Weber et al., 1966).

Effect of plant density on total dry matter, per unit area.

2nd rains 1979

From the 4th-6th weeks after planting the total dry matter obtained from plant density 1 was significantly higher than the total dry matter from plant densities 2 and 3, at the 1% level of significance. At the 8th week the total dry matter from plant density 1 on total dry matter was significantly higher than the total dry matter from plant densities 2 and 3 at the 5% and 1% levels respectively. At the 10th week the difference between the total dry matter obtained from P_1 and that obtained from P_3 was significant at 5%, and at the 12th week, the total dry matter obtained from P_2 and that from P_3 at the 5% level. It should be noted that the significance of the differences between the plant density effects decreases with time.

Fig. 21 shows that total dry matter expressed on an area basis increases with increasing plant density as opposed to total dry matter productivity based on single plants which has been shown to increase with decreasing plant density (Fig. 20).

1st rains 1980

Table 16 shows that total dry matter increased with increasing plant population as for the 1979

TABLE 16: Effect of plant density on total dry matter - Kgs/ha.

2nd rains 1979	Plant density	SAMPLING TIME IN WEEKS AFTER PLANTING						
		4	6	8	10	12	14	16
	P_1	238.01	1486.32	5276.89	6774.93	7203.71	-	-
	P_2	190.74	1418.50	5017.05	6242.66	6230.63	-	-
	P_3	143.58	1154.45	4337.55	5670.70	6140.10	-	-
	S.E.	12.24	63.24	229.80	272.31	312.92	-	-
	L.S.D.-5%	24.59	179.91	653.69	774.61	889.93	-	-
	L.S.D.-1%	32.77	239.77	871.16	1032.30	1185.98	-	-
	C.O.V.(%)	22.21	22.90	23.08	21.42	23.49	-	-
1st rains 1980	P_1	84.72	604.74	2084.84	3639.94	6183.67	8067.11	7794.12
	P_2	72.58	543.39	1974.25	3616.74	4348.14	7095.93	5673.07
	P_3	40.80	491.46	1979.11	3570.98	4399.52	6716.53	5648.55
	S.E.	5.39	20.77	48.15	94.59	122.73	119.00	109.78
	L.S.D.-5%	15.34	59.08	136.98	269.08	349.11	338.52	312.27
	L.S.D.-1%	20.44	78.73	182.56	358.60	465.25	451.13	416.15
	C.O.V.(%)	40.00	186.2	11.72	12.84	10.11	7.94	7.22

crop, so that P_1 had the highest total dry matter. Table 16 also shows that maximum total dry matter accumulation was attained during the 14th week beyond which total dry matter started decreasing for all treatments.

At the 4th week after planting, total dry matter from P_1 was significantly higher than the total dry matter from P_3 and P_2 at the 1% level of significance. At the 6th week P_1 had a significantly higher total dry matter than P_2 and P_3 at the 5% levels respectively.

From the 12th week to the end of the sampling period, plant density 1 had a significantly higher total dry matter than the other plant densities at the 1% level of significance.

The results from both crops have shown that total dry matter expressed on an area basis increases with increasing plant density. Alessi and Power (1975) in corn experiments reported that higher populations fixed the greatest percentage of solar energy which was indicated by higher dry matter production. Goldsworthy (1970) had obtained similar results working with sunflower varieties. Veeraswamy and Rathnaswamy (1974) reported the highest production per unit area from higher densities.

At the higher plant densities although the plant size is smaller, the number of plants per unit area compensates for the larger size of plant at the lower densities. Another reason for the higher total dry matter at the higher densities is that at the higher densities there is less area left for weed growth and because of the higher number of plants a sufficient canopy is sooner achieved than at the lower densities, thus suppressing weed competition more effectively. Johnson and Harris (1967) reported weed growth at lower densities, and Felton (1976) reported similar results. McWhorter and Barrentine (1975) also reported better weed control when soyabean populations were increased from 80,000 to 350,000 plants per hectare.

Effect of weeding frequency on leaf area. 2nd rains 1979

The analysis of variance showed no significant effects of the various weeding frequencies on leaf area at the beginning of the sampling period up to the 6th week after planting. At the 8th and 10th weeks however, weeding frequency treatments B, C and E had significantly higher leaf areas than the weeding frequency treatments A, D and F, at the 1% level of significance.

At the 12th week, leaf area from treatment C was significantly higher than the leaf area from

TABLE 17: The effect of weeding frequency on leaf area in m^2/ha.

	Weeding Frequency	SAMPLING TIME IN WEEKS AFTER PLANTING.						
		4	6	8	10	12	14	16
2nd rains 1979	A	2172.84	8756.68	12860.08	8031.38	6768.52	-	-
	B	2480.96	10805.04	24230.46	15531.89	10611.63	-	-
	C	2241.26	11258.23	24089.46	15988.69	13476.34	-	-
	D	1965.53	11726.85	15088.99	9574.07	9344.14	-	-
	E	2120.37	11276.75	20903.29	15654.32	12897.64	-	-
	F	1918.72	10289.61	12207.31	9706.79	7303.51	-	-
	S.E.	160.96	1303.20	1736.17	1515.81	1276.27	-	-
	L.S.D.-5%	482.81	3701.90	4931.81	4305.83	3625.41	-	-
	L.S.D.-1%	643.43	4933.41	6572.48	5733.25	4831.47	-	-
	C.O.V.(%)	27.35	42.20	32.95	42.25	43.87	-	-
1st rains 1980	A	951.59	4919.24	13399.90	15957.82	17521.61	12347.74	6877.05
	B	1325.72	6862.91	17743.52	20729.94	29964.51	22452.17	13325.62
	C	1210.96	6823.71	17200.31	22534.98	26253.60	23092.60	15011.31
	D	1152.16	4068.11	14957.20	16477.88	17338.48	16897.64	10498.45
	E	1182.26	6575.36	17474.80	25190.33	25243.88	20959.88	12746.39
	F	1163.32	4450.21	11490.85	16578.70	19325.62	13721.19	7127.57
	S.E.	106.05	350.18	792.76	1268.74	978.85	1103.24	747.00
	L.S.D.-5%	301.26	994.73	2251.93	3604.00	2780.56	3133.89	2121.96
	L.S.D.-1%	401.48	1325.66	3001.08	4802.95	3705.57	4176.44	2827.88
	C.O.V.(%)	31.50	21.57	17.83	22.42	14.98	20.92	8.11

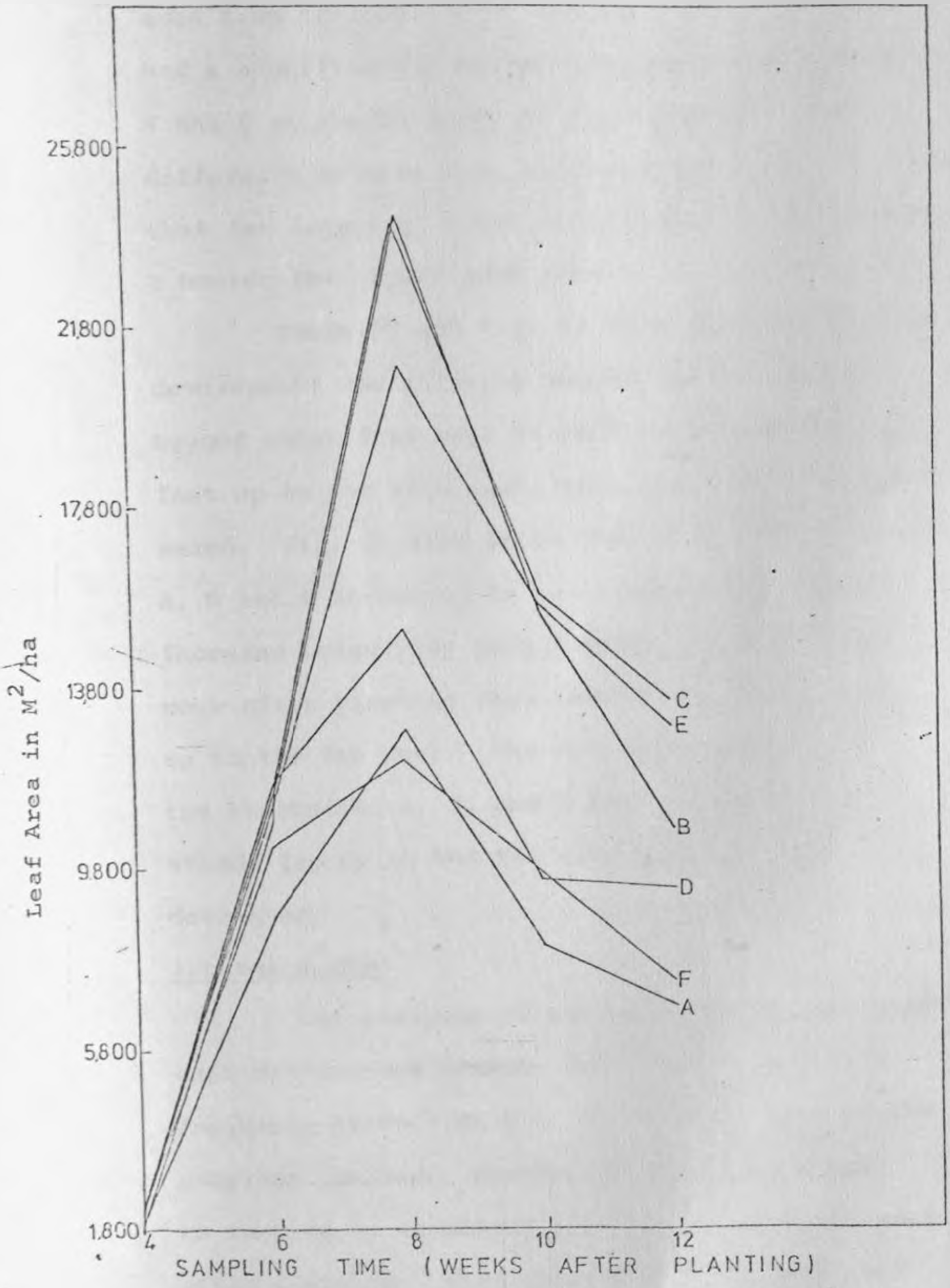


Fig. 22. Effect of weeding frequency on L.A. (M^2/ha) (1979).

treatments A and F at the 1% level. Leaf area from treatment C was significantly higher than leaf area from treatment D at the 5% level. Treatment E had a significantly higher leaf area than treatments A and F at the 1% level of significance. The difference between L.A. obtained for treatment B and that for treatment A was significant at 5%, treatment B having the higher leaf area.

Table 17 and Fig. 22 show that maximum L.A. development was attained around the 8th week, beyond which leaf area started declining quite fast up to the 10th week, when the rate of decrease eased. Fig. 22 also shows that L.A. from treatments A, D and F increased in two stages, the rate of increase being very fast between the 4th - 6th week after planting then increasing less rapidly up to the 8th week. The L.A. development for the treatments B, C, and E however is in one steady lap up to the 8th week after which L.A. decreased.

1st rains 1980

The analysis of variance showed no significant differences between the various weeding frequency effects on L.A. at the beginning of the sampling period. However, differences began to show among treatment effects from the 6th week after planting. From the 6th week to 16th week the L.A.'s obtained from treatments B, C and E were significantly higher than the leaf areas from treatments F, D and A, at the 1% level of significance. Except at the 12th week when treatment B had a significantly higher leaf area than treatments E and C at the 1% level, there were no significant differences between the effects of treatments B, C and E on leaf area development.

At the 12th and 14th weeks after planting treatment D had a significantly higher leaf area than treatments A and F, and the differences (D vs. A and D vs. F) were significant at the 1% and 5% levels respectively. At the 16th week treatment D had a significantly higher L.A. than treatments A and F at the 1% level.

Table 17 and Fig. 23 also show that with the exception of treatment E, L.A. from all the other weeding frequency treatments continued to increase up to the 12th week beyond which it began to decrease. Between the 10th and 12th week the L.A. from treatment E remained constant. At the peak of leaf area development treatment B had the highest leaf area while treatments A and F had the lowest.

The results have shown that the control B (weeding all season) and the treatments C and E, both weeded before anthesis developed more leaf

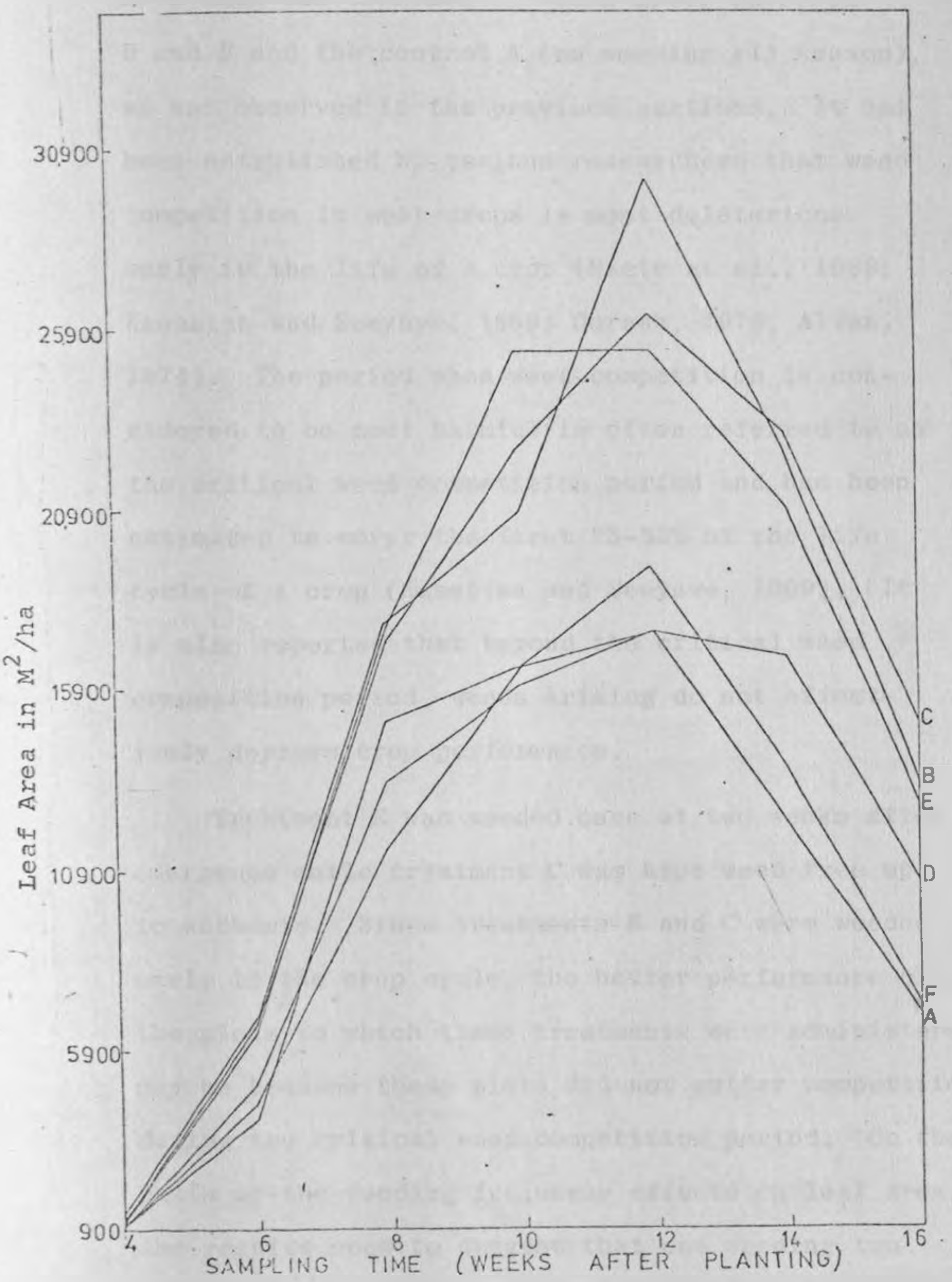


Fig. 23. Effect of weeding frequency on L.A. (M^2/ha) 1980.

area than the treatments weeded after anthesis D and F and the control A (no weeding all season), as was observed in the previous sections. It has been established by various researchers that weed competition in most crops is most deleterious early in the life of a crop (Nieto et al., 1968; Kasasian and Seeyave, 1969; Gurnah, 1976; Allan, 1974). The period when weed competition is considered to be most harmful is often referred to as the critical weed competition period and has been estimated to cover the first 25-33% of the life cycle of a crop (Kasasian and Seeyave, 1969). It is also reported that beyond the critical weed competition period, weeds arising do not effectively depress crop performance.

Treatment E was weeded once at two weeks after emergence while treatment C was kept weed-free up to anthesis. Since treatments E and C were weeded early in the crop cycle, the better performance of the plots to which these treatments were administered may be because these plots did not suffer competition during the critical weed competition period. On the basis of the weeding frequency effects on leaf area, the results seem to suggest that one weeding two weeks after emergence is sufficient since there were no significant differences between the L.A. measurements obtained from treatment E and the L.A. measurements for treatment C. This may be because in plots that received treatment E the weeds were removed either before or during the critical weed competition period. This would seem to suggest that the critical weed competition period in sunflower lies between two weeks after emergence and anthesis. This would be in agreement with results obtained by Johnson (1972) who reported that sunflowers required to be weeded at 2 and 4 weeks after sowing and that weeds not removed until 6 weeks after sowing had a depressing influence on the performance of the crop. Van Eijnatten and Wamburi (1972) concluded that weeding once at 4 weeks after emergence of the sunflower was adequate.

The overall results also show no significant differences between the results obtained for treatment B (the weeding all season control) and the results obtained from treatments C and E. This would seem to suggest that weeding all through the season is not necessary. It has already been mentioned that weeds occuring beyond the critical weed competition period do not do any significant harm to the crop because beyond the critical period the crop is able to compete more effectively with the weeds. This would explain why weeding all season did not yield significantly higher than the rest of the treatments as would have been expected. After a given period the crop develops a sufficient canopy to suppress weed growth thus making further weedings unnecessary.

The results also show no significant differences between the performance of treatments weeded after anthesis (D and F) and the control A (no weeding all season) in the 1979 crop. In the 1980 crop however treatment D had significantly higher leaf area than treatments A and F from the 12th week to the end of the sampling period. Treatment D was kept weed-free after anthesis while treatment F was weeded only once after anthesis. This suggests that delayed weeding is not beneficial as the damage will have been done. And while keeping the crop free of weeds after anthesis in a wet season like during the 1st rains 1980 may improve the performance of the crop the overall results fall far short of what could have been achieved by early weeding.

Effect of plant density on leaf area.

2nd rains 1979

Table 18 shows that the effect of plant density on leaf area during the 2nd rains 1979 was significant only up to the 6th week after planting, beyond which there were no significant differences among the various plant-density treatment effects on leaf area. At the 4th week after planting leaf area from population 1 was

TABLE 18: The effect of plant density on leaf area development in m^2/ha.

2nd rains 1979	Plant density	SAMPLING TIME IN WEEKS AFTER PLANTING.						
		4	6	8	10	12	14	16
	P_1	2746.91	13281.89	18688.27	12674.90	11044.24	-	-
	P_2	2110.34	10725.31	19729.91	12118.06	9502.32	-	-
	P_3	1592.59	8049.38	16271.61	12450.62	9654.32	-	-
	S.E.	120.01	920.22	1225.95	1070.35	901.20	-	-
	L.S.D.-5%	341.39	2617.64	3487.32	3044.68	2563.55	-	-
	L.S.D.-1%	454.97	3488.45	4647.44	4057.55	3416.37	-	-
	C.O.V.(%)	27.35	42.20	32.95	42.25	43.87	-	-
1st rains 1980	P_1	1546.40	6486.73	15910.96	21236.11	23768.01	17849.80	11254.11
	P_2	1167.05	5648.53	15025.72	19094.91	21935.19	18842.59	10819.44
	P_3	780.56	4714.51	15196.61	18403.81	22120.38	18001.55	10719.65
	S.E.	74.88	247.27	559.78	895.88	691.19	779.02	527.48
	L.S.D.-5%	213.02	703.38	1592.35	2548.41	1966.16	2215.99	1500.45
	L.S.D.-1%	283.89	937.38	2122.08	3396.20	2620.24	2953.19	1999.61
	C.O.V.(%)	31.51	21.57	17.83	22.42	14.98	20.92	8.11

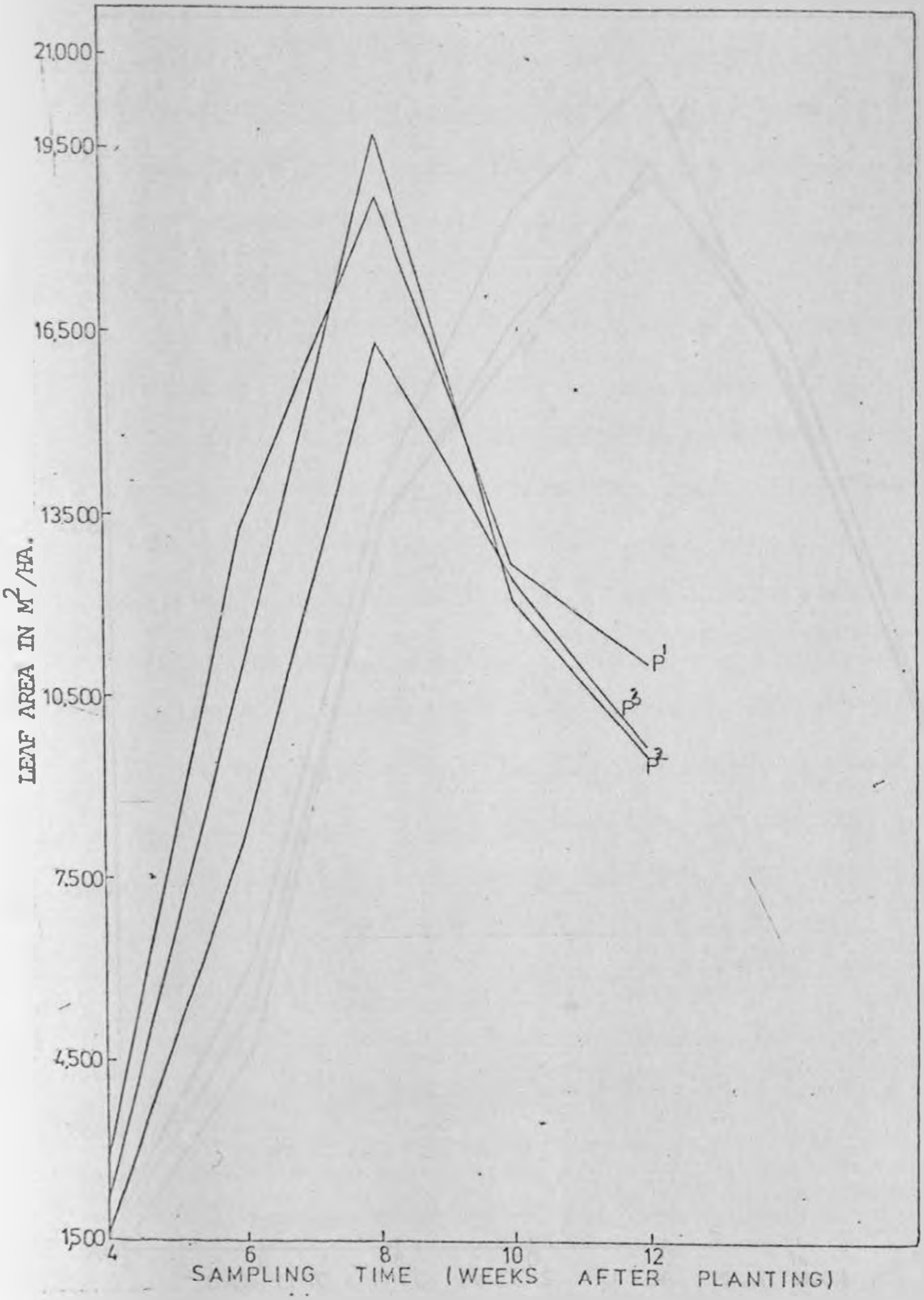


Fig. 24. Effect of plant density on L.A. (1979).

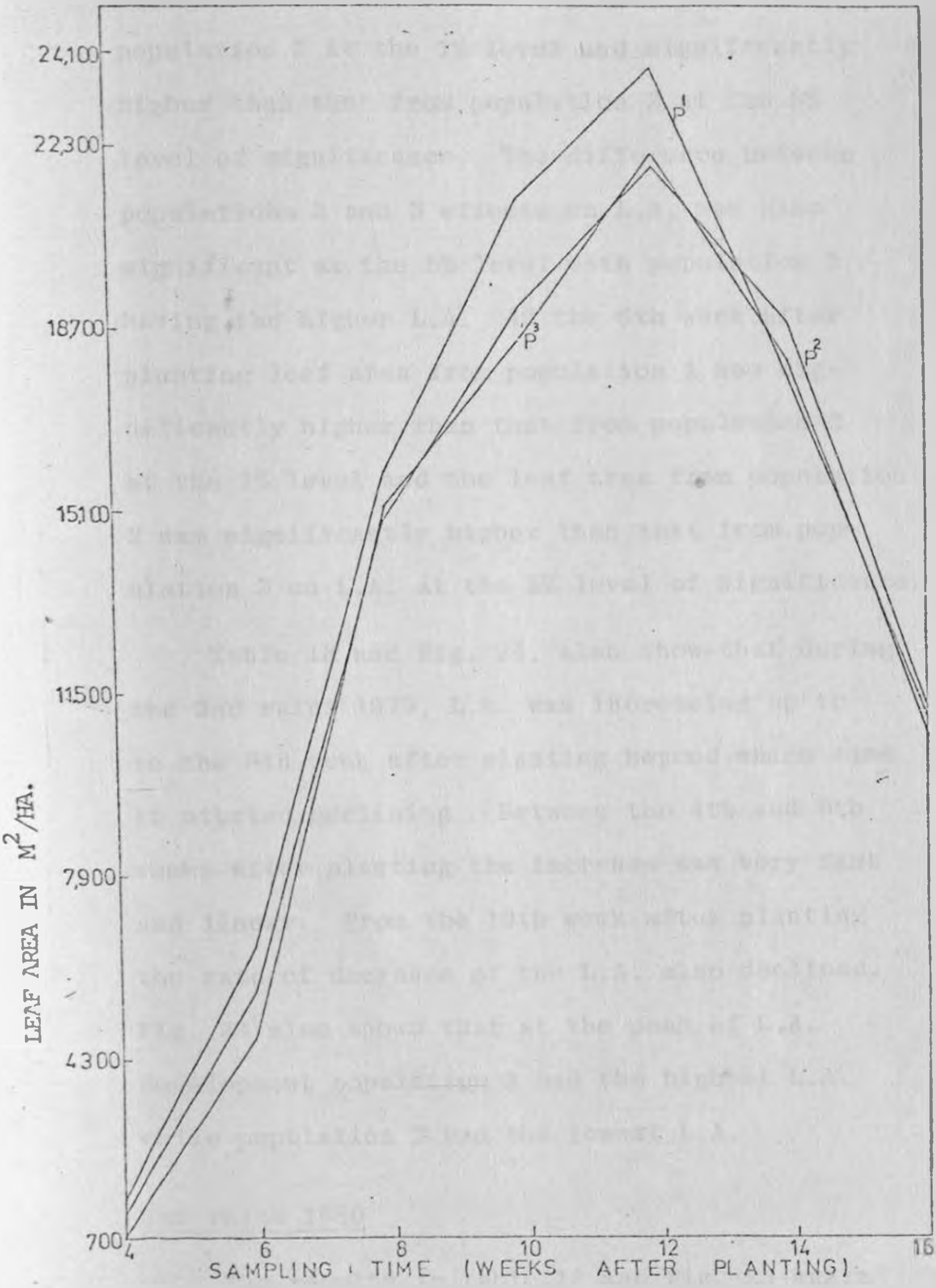


Fig. 25. Effect of plant density on L.A.(1980)

significantly higher than the leaf area from population 3 at the 1% level and significantly higher than that from population 2 at the 5% level of significance. The difference between populations 2 and 3 effects on L.A. was also significant at the 5% level with population 2 having the higher L.A. At the 6th week after planting leaf area from population 1 was significantly higher than that from population 3 at the 1% level and the leaf area from population 2 was significantly higher than that from population 3 on L.A. at the 5% level of significance.

Table 18 and Fig. 24, also show that during the 2nd rains 1979, L.A. was increasing up to to the 8th week after planting beyond which time it started declining. Between the 4th and 8th weeks after planting the increase was very fast and linear. From the 10th week after planting the rate of decrease of the L.A. also declined. Fig. 24 also shows that at the peak of L.A. development population 2 had the highest L.A. while population 3 had the lowest L.A.

1st rains 1980

The results in table 18 and Fig. 25 again show significant differences among the plant-density treatment effects only up to the 6th week after planting. From then to the end of the sampling period no significant differences among plant-density treatment effects were detected. At the 4th week after planting the various plant density treatment comparisons were significant at the 1% level. And at the 6th week after planting' population 1 had a significantly higher L.A. than population 3 at the 1% level and a higher L.A. than population 2 at the 5% level. Population 2 also had a significantly higher leaf area than population 3 at the 5% level.

Table 18 and Fig. 25 also show that L.A. development reached its maximum for all plant density treatments around the 12th week after planting then started declining. Fig. 25 also shows that at the peak of leaf area development population 1 had the highest leaf area while the leaf areas for the other two populations were very close.

The results for leaf area from both seasons are fairly uniform and seem to indicate that plant-density influenced leaf-area development only in the first few weeks after planting, beyond which time the various plant-density treatments had no significant effect on leaf area development. The probable reason for no significant differences between the plant-density treatments may be that the plant-densities were too close to have significantly different effects on L.A. Weber et al., (1966)

TABLE 19: Effect of weeding frequency on head diameter in cms.

Measurements taken at the final harvest.

Weeding Frequency	2nd rains 1979	1st rains 1980
A	13.24	14.03
B	15.52	15.92
C	15.33	17.39
D	14.01	15.19
E	14.99	16.60
F	14.78	14.49
S.E.	0.55	0.30
L.S.D. - 5%	1.30	0.86
L.S.D. - 1%	1.73	1.15
C.O.V.(%)	10.83	6.81

reported L.A. accumulation to be greatest at the highest plant density in soyabean population experiments. Further they also reported that for L.A. there were no significant differences among population treatments until more advanced stages of crop development. Alessi and Power (1975) also reported that highest L.A. was obtained for the highest population of corn.

Effect of weeding frequency on head diameters.

2nd rains 1979

Table 19 shows that treatment B had the largest size of head and treatment A the smallest. Treatments B, C and E had significantly larger heads than treatment A at the 1% level of significance. Treatment F also had a significantly large head size than treatment A at 5% level. The head sizes obtained for treatments B and C were also significantly larger than the head size for treatment D at the 5%.

1st rains 1980

The effect of weeding frequency on head size was more pronounced and highly significant. Treatment C had the largest head size which was significantly larger than the head sizes for treatments A, F, and D at the 1% level of significance. Treatment E also had a significantly larger head size than treatments A and F at the 1% level and significantly larger than treatment D head diameter at 5%. The effect of treatment B on head size was significantly higher than the effect of A at 1% and higher than the effect of treatment F at 5%. Treatment D effect on head size was also significantly higher than the effect of treatment A at the 5% level. Weeding frequency A had the smallest heads.

The results again show that treatment weeded i.e. E and C and the weeding all season control B had a definite advantage over treatments weeded after anthesis D and F and the no weeding control A. The reason for the better performance by treatments weeded before anthesis has been given in the previous sections, i.e. treatments weeded before anthesis had weeds removed at a time when weed competition is most deleterious in the life of a crop. This has been shown by various workers to occur in the early stages of a crop's life (Gurnah, 1976; Kasasian and Seeyave, 1960; Nieto et. al., 1968). Again the results obtained for sunflower suggest that weeding early is important and that the critical weed competition period for this crop most probably lies between the first two weeks after planting and anthesis. There were no significant differences between head sizes obtained for treatment C and E, thus suggesting that one weeding of sunflower at two weeks after emergence is adequate. The results also indicate that it is

TABLE 20: Effect of plant density on head-diameter in cms.

Plant density	2nd rains 1979	1st rains 1980
P_1	13.96	13.92
P_2	14.50	15.60
P_3	15.47	17.29
S.E.	0.32	0.21
L.S.D. - 5%	0.92	0.61
L.S.D. - 1%	1.22	0.81
C.O.V.(%)	10.83	6.81

not necessary to weed the sunflower crop throughout the season.

Effect of plant density on head diameter.

2nd rains 1979

Table 20 shows that head diameter increased as plant-density decreased, so that population 3, the lowest density used, had the largest size of heads. Heads from population 3 were significantly larger than those from population 1 at the 1% level and also significantly larger than those from P_2 at the 5% level of significance. There was no significant difference between the head sizes obtained from populations 1 and 2.

1st rains 1980

Again head size increased with decreasing plant density and P_3 had the largest head size. The differences in head size obtained from populations P_2 and P_3 and that obtained from population P_1 were significant at the 1% level. Plants from P_3 also had a significantly larger head size than those from P_2 at the 1% level.

The results from both seasons clearly show that head size increases with decreasing plant-density, probably because of decreased inter-plant competition as plant density decreases. Clements et al., (1929) found that lowering the seeding rate of Marquis spring wheat to half of the normal resulted in larger heads but it reduced yield and kernel weight. Wilson and Swanson (1962) also reported increased head size as the number of wheat plants per square foot decreased. Klimov (1968), Galgoczi (1967), and Turchi (1974) all working on sunflower reported increased head size with decreasing plant density.

Singh *et. al* (1977) in their studies of variability and correlations in sunflower (*Helianthus annuus* L.) observed high variability for seed yield, 1,000 seed weight, plant height and seed filling. They reported that during selection for increased yield more emphasis should be given on seed weight and head diameter.

Effect of weeding frequency on 1,000 seed weight.

2nd rains 1979

No significant difference between the various weeding frequency treatment effects on seed size was observed. Treatment B (weeding all season) had the highest seed weight, followed by treatments C and E, i.e. treatments weeded before anthesis. Treatment A (no weeding all season) had the lowest seed weight.

1st rains 1980.

A highly significant weeding frequency effect on

TABLE 21: Effect of weeding frequency on the 1,000 seed weight in gms.

Weeding Frequency	2nd rains 1979	1st rains 1980
A	61.15	58.29
B	71.19	64.30
C	70.34	68.19
D	62.38	61.95
E	64.99	64.32
F	63.33	59.45
S.E.	3.36	0.65
L.S.D. - 5%	9.49	1.85
L.S.D. - 1%	-	2.46
C.O.V.(%)	17.74	3.61

seed size was observed. Table 21 shows that treatment C had the largest seed size while treatment A no weeding all season) had the smallest seed size. The seed size obtained from treatment C was significantly larger than the seed sizes obtained from all the remaining treatments at the 1% level of significance. Treatment E had a larger seed size than treatment A and F the difference being significant at 1%, and also a larger seed size than D significant at 5%. The difference in the seed size obtained from B and the seed sizes from treatments A and F was significant at 1%. The seed weight from treatment B was also significantly higher that the seed weight from treatment D at 5%. Treatment D also had a significantly larger seed size than treatments A and F, at 1% level.

The results indicate that treatments weeded before anthesis C and E and the weeding all season treatment B had the highest weights, and in both seasons the no weed control (A) had the lowest weight. Although the results were highly significant in the second crop, there were no significant differences among treatments in the first crop (1979). The results also show that seed weights from the 1979 crop were higher than those from the 1980 crop.

2nd rains 1979 was a relatively dry season compared to the 1st rains 1980. In a dry season the amount of moisture available may have been limiting, resulting in relatively less weed growth and thus reduced competition. This would reduce the effect of the various weeding treatments on seed weight. In 1980 because there was more moisture available and therefore more weed growth and weed competition, the effects of the weeding treatments could be expressed on a larger scale than in the previous season, hence the difference in the seed weights from the two crops.

The results from the 1980 crop show that the treatment weeded up to anthesis C obtained a significantly greater seed weight than treatment E (one weeding before anthesis) and treatment B (control). The results seem to suggest that in a wet season it is necessary to weed up to anthesis in order to obtain the maximum seed weight, while in drier conditions one weeding before anthesis is adequate. It has already been suggested that this could be an indication that the critical weed competition period lies between two weeks after emergence and anthesis. The 1,000 seed weight results also show that it is not necessary to weed the sunflower crop all through the season, because beyond the critical period the crop can effectively suppress further weed growth. The results also show that in the treatments weeded after anthesis, seed weight decreased as the weeding frequency decreased.

Effect of plant density on 1,000 seed weight.

2nd rains 1979

Plant-density effect on 1,000 seed weight was found to be significant with population 3 having a significantly higher seed weight than population 1 at the 1% level. Population 1 had the lowest seed weight. (Table 22).

1st rains 1980

Plant density had a highly significant effect on seed size, all treatment comparisons being significant at the 1% level of significance.

The results show that as plants per unit area decreased the 1,000 seed weight increased. Willey and Holliday (1971) reported a decrease in 1,000 grain weight for wheat and barley as the plant-population increased. Kirby (1967, 1969) had obtained similar results. However Wilson and Swanson (1962) reported a decreased seed weight as plant-number per square foot decreased, the reduction being apparantly due largely to delayed maturity.

Klimov (1968). Turchi (1974) and Galgoczi (1967)

TABLE 22: Effect of plant-density on 1,000 seed weight in gms.

Plant-density	2nd rains 1979	1st rains 1980
P_1	59.34	57.75
P_2	67.45	62.95
P_3	69.89	67.55
S.E.	2.37	0.46
L.S.D. - 5%	6.71	1.31
L.S.D. - 1%		1.74
C.O.V.(%)	17.74	3.61

observed that seed weight decreased with increasing plant density in sunflower trials. According to Galgoczi (1967) the reduction in seed weight at high plant densities is partly due to a high incidence of empty kernels.

Effect of weeding frequency on yield.

2nd rains 1979

Table 23 shows that treatment B (weeding all season) had the highest yield while treatment A (no weeding all season) had the lowest yield and the difference between the two yields was significant at the 1% level. Treatment E (one weeding before anthesis) had the second highest yield, followed by treatment C (weeding up to anthesis). The yield obtained from treatment E was significantly higher than the yield from treatment A at the 1% level. The yield obtained from treatment C was also significantly higher than that obtained from A at the 5% level. The yield difference between treatment F and treatment A was also significant at 5%.

1st rains 1980

A highly significant effect of weeding frequency on yield was observed. Again the weeding all season treatment (B) had the highest yield, which was significantly higher than the yield obtained for treatments A, F and D at the 1% level of significance. The yields obtained from treatments C and E were also

TABLE 23: Effect of weeding frequency on yield in Kgs/ha.

Weeding Frequency	2nd rains 1979	1st rains 1980
A	814.49	1105.47
B	1274.91	1903.79
C	1124.47	1846.56
D	980.80	1417.54
E	1222.65	1784.78
F	1158.77	1379.83
S.E.	108.02	81.84
L.S.D. - 5%	306.85	232.48
L.S.D. - 1%	408.94	309.82
C.O.V.(%)	34.10	18.00

significantly higher than the yields obtained from treatments A, D and F at the 1% level. The yield difference between treatments D and A was significant at 1% while that between F and A was significant at 5%.

The results show that while there were no significant yield differences between the treatments B, C and E, the yield decreased as the number of weedings decreased. The same pattern is observed for treatments A, F and D in that as the frequency of weeding increased the yield also increased.

The yield results conform to the pattern observed for the other factors already considered in the previous sections. The treatments weeded before anthesis significantly outyielded the treatments weeded after anthesis. The weeding all season treatment B had the highest yield in both crops, while the no weed control A, had the lowest yield, as would have been expected, since treatment B suffered no weed competition all season while treatment A had weed competition all through.

The better performance of the treatments weeded before anthesis (E and C) over treatments weeded after anthesis (D and F) suggests that early weeding of sunflower is necessary in order to obtain high yields. It was also shown in both crops that treatments B, C and E did not differ significantly in their yields. This again suggests that while weeding all season will give the highest yields, one weeding before anthesis or weeding up to anthesis is sufficient to give yields that are comparable to those that would be obtained by weeding all season.

According to available literature not only does weed competition reduce yields, but there are critical weed competition periods during which weeds are most deleterious to crops (Nieto et al., 1968; Gurnah, 1976; Allan, 1974). The results obtained here have shown that the least weeded plots had the least yields and that yields increased as weeding frequency increased, thus supporting the view that weed competition reduces yields.

It has also been indicated that this critical period occurs during the early part of the crops life and according to Kasasian and Seeyave (1969), the critical weed competition period covers the first 25-33% of the life of many crops. In treatments C and E weeding operations were carried out in the early periods of the crop growth. Treatment E was weeded only once before anthesis (2 weeks after emergence) while treatment C was kept weed-free up to anthesis (from 2nd week up to the 7th week in 1979 and 2nd week up the 9th week in 1980.) Since these treatments were weeded early and obtained significantly better yields than treatments in which weeding was delayed, it must be assumed that their better performance is due to the fact that these treatments were free of weed competition during the period in which weed competition is critical. This therefore suggests that the critical weed competition period in sunflower lies between the first two weeks after emergence and anthesis.

The results have also shown that weeding all season is not necessary, since the control B did not obtain significantly better yields than treatments C and E. After the crop has formed a sufficient canopy to cover the ground it suppresses further weed growth and further weedings are not necessary. Beyond the critical period, most crops have been reported to compete more favourably so that weeds occurring after the critical period do not have a depressing effect on the performance of the crop (Nieto et al., 1968). The results have also shown that there were no significant differences between yields obtained from treatments C and E in both seasons and in 1979, treatment E obtained a higher yield than treatment C. This seems to suggest that only one weeding of sunflower at two weeks after emergence is necessary to give good yields. Van Eijnatten (1972) concluded from his timing of weeding in sunflower trials that weeding once at 4 weeks after emergence of the sunflower was adequate, while Johnson (1972) reported that sunflowers required to be cultivated at 2 and 4 weeks after sowing. Johnson (1972) also reported that yields were significantly reduced by weeds not removed until 6 weeks after sowing. The results obtained and reported in this work are in agreement with available literature.

Over the years several investigators have been able to determine the actual yield reductions that are due to weed competition in various crops. In 1964 Denham reported yield reductions in maize plots due to weeds to range from 41 - 86%. In a series of trials carried out at Kitale (Allan, 1967, 1970), unweeded plots of maize gave 33% and 31% less yield respectively than clean weeded ones. Mani et al., (1968) reported yield reductions of more than 50% in rice, maize, onion and cotton, due to weed competition. According to the results obtained here (Table 24) unweeded plots suffered yield reductions of 36% in 1979 and almost 42% in 1980. The difference in yield reduction in the two seasons must be due to the weather conditions. The first rains are normally heavier than the short or 2nd rains and the greater availability of moisture may have resulted in more weed growth and competition in the 1980 crop than the 1979 crop, hence the greater yield reduction during the ~~former~~ latter season..

TABLE 24: Percent yield reduction below weed-free control.

Treatment	1979	1980
A(no weeding all season)	36.09	41.94
C(weeding up to anthesis)	11.81	3.01
D(weed-free after anthesis)	23.07	25.54
E(one weeding before anthesis)	4.10	6.25
F(one weeding after anthesis)	9.11	27.52

The table shows that in 1979 the yield reduction for treatment C was 11.81% while that for treatment E was only 4.10% below the weed-free control. In 1980 the yield reduction for treatment C was 3.01% and the yield reduction for treatment E was 6.25%. This probably means that while the yield differences between the two treatments were not significant over the two years, in a wet season it is necessary to weed the sunflower crop up to anthesis for better yields.

Effect of plant density on yield.

2nd Rains 1979.

Although yield increased up to population 2 then decreased when the plant density was reduced beyond 55,000 plants per hectare, there were no significant differences between the yields obtained from the plant densities tested. Population 2 had the highest yield while population 3 had the lowest (Table 25).

TABLE 25: Effect of plant-density on yield in Kgs/ha.

Plant density	2nd rains 1979	1st rains 1980
P_1	1084.59	1927.93
P_2	1124.49	1547.72
P_3	1078.97	1243.33
S.E.	76.43	57.79
L.S.D - 5%	215.79	164.39
L.S.D. - 1%	287.00	219.08
C.O.V.(%)	34.10	18.00

1st rains 1980

Table 25 shows that population 1 had the highest yield and also shows that yield decreased with decreasing plant density. Differences in yield between the various plant densities were significant at the 1% level of significance.

The results from the two crops suggest that the final yield is favoured by high plant densities. The plant density which gave highest yield for the short rains was 55,000 plants per hectare (P_2) and that for the long rains was 74,000 plants per hectare (P_1). Decreasing the plant density below 55,000 plants/ha in 1979 and below 74,000 plants/ha in 1980 resulted in a reduction of yields. Higher populations than 55,000 plants/ha during the short rains will result in severe competition for the limited moisture, hence the lower yields; but the long rains will favour higher plant populations. At the lower density (44,000 plants/ha) the space left for weed growth and competition also increases, and the increased competition from the increased growth of weeds could be a contributing factor to the reduction in yield per unit area. Higher densities allow for less weed growth and competition.

Several workers have shown that yields increase with increasing plant populations (Genter and Camper, 1973; Clement et al., 1929; Percival, 1921; Goldsworthy, 1970; Johnson and Harris 1967). Stickler and Laude (1960) observed that weed control in sorghum was more effective at the lower densities, and Brown and Shradder (1959) reported that low populations are desirable in drought years because plant size is less in wide than in narrow rows and less vegetative development would generally mean more moisture available during grain development. Giesbrecht (1969) reported a substantial increase in corn grain yield with increasing population in years when moisture was adequate. In years when moisture was inadequate peak prouduction occurred at a much lower density. The results obtained here have shown this to be the case for the sunflower crop. Alessi and Power (1975) reported that higher populations fixed the greatest percentage of solar energy which was indicated by higher dry matter production. Plant populations with the highest dry matter production also had the highest yields. Van Eijnatten (1973), Turchi (1974) and Zubriski and Zimmerman (1974) all working on sunflower reported that yields increased with increasing plant density.

WEEDS

Effect of weeding frequency on weeds.

Number of weedings per season

Treatments	1979	1980
A	Nil	Nil
B	5	7
C	3	4
D	2	3
E	1	1
F	1	1

Due to the nature of the weeding scheme it was not possible to subject the weed dry matter data to statistical analysis, as at various time during sampling some treatments would not have any weeds collected. However, the analysis of the effect of weeding frequency on the agronomic characteristics of sunflower considered in this text indicates that weed dry matter had a negative influence on the characters as the dry weights, head diameter yield etc., improved with increasing weeding frequency.

Effect of Plant density on weed dry matter.

Table 26 shows the effect of plant density on weed dry matter. Although the data not analysed statistically (for the reason given above) it indicates that weed dry matter in both seasons increased with decreasing plant density so that the lowest density had the highest weed dry matter.

TABLE 26: Effect of Plant-Density on weed-dry matter (kg/ha).

Year 1979	Plant Density	Sampling time in weeks after planting.						
		4	6	8	10	12	14	16
	P_1	3055.8	5978.7	4629.8	5021.6	6948.3	-	-
	P_2	3624.3	8388.9	7751.5	8750.3	9042.1	-	-
	P_3	4786.1	12102.2	10916.5	12870.7	12446.8	-	-
Year 1980	P_1	468.4	2976.6	3567.3	5824.0	7105.2	13001.7	13846.1
	P_2	489.0	5115.1	4036.2	8671.2	11131.3	21536.6	22141.6
	P_3	1146.0	13052.9	7266.8	18771.1	19535.1	36740.3	31062.3

Types of Weeds growing in Sunflower:

The most common weeds in the two seasons are listed below:-

	Botanical name	Common name
1.	*Galisonga parviflora*	Gallant soldier
2.	*Bidens pilosa*	Black jack
3.	*Oxalis* spp.	Oxalis
4.	*Amaranthus* spp.	Pig weed
5.	*Polygonum convolvulus*	Black bind weed
6.	*Tagetes marigold*	Mexican marigold
7.	*Erucastrum arabicum*	
8.	*Cyperus rotundus*	Nut grass
9.	*Portulaca oleracea*	Purslane
10.	*Commelina* spp.	Wandering Jew
11.	*Datura stramonium*	Thorn apple
12.	*Setaria* spp.	Love grass

CONCLUSION

Weeding treatments:

From the results presented I would conclude that:

(1) early weeding of the sunflower crop is necessary to obtain high dry matter and for high yields;

(2) The crop should be weeded before anthesis. It has been established that the critical weed competition period lies between the first two weeks after emergence and anthesis. The results also show that one weeding at two weeks after emergence is sufficient to give satisfactory yields, more so during the dry seasons. Any more weedings beyond anthesis in the sunflower is not necessary as the crop is then able to suppress weed growth and competition. The results are in agreement with those reported by Kovacik (1966); Johnson (1971) and Ven Eijnatten and Wamburi (1973).

Plant density treatments:

(1) When the results are considered from the single plant-point of view, dry matter yields of the individual plant organs, the total dry matter and the yield of the single plant increased with decreasing plant density.

(2) The results have also shown that the total dry matter and final yield per unit area of land increased with increasing plant density and decreased with decreasing plant density. The high numbers of plants at the high densities compensated for the greater size of plant at the

lower densities.

(3) It has also been indicated that during the short rains a lower density than would be used in the long rains is to be favoured. Van Eignatten (1973), Turchi (1974) and Zubriski and Zimmerman (1974) reported similar results. Therefore it is to be concluded that for high yields, high densities should be used, and these should be varied during the short or long rains, using higher densities during the long rains than during the short rains as very high densities during the short rains would lead to severe competition resulting in reduced yields.

Suggestions for Future Work.

(1) Studies could be carried out to study the effect of weeding frequency on the yield of Sunflower at different levels of soil fertility, with the aim to find out if the critical weed competition period is influenced by soil fertility, and if it is, to find out the required number of weedings at the optimal level of fertilizer application.

(2) A greater range of herbicides should be tested to establish suitable herbicides for Sunflower under Kenyan conditions, then go on to test the suitable rates of application of the herbicides that would have been selected through these trials.

Since it has been established that weeding is necessary only within a limited period of the crop's growth cycle, trials should be carried out to compare the cost of conventional methods of weed removal versus the cost of use of herbicide.

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APPENDICES

Appendix Table 1. Summary of Analysis of Variance showing the effects of different treatments on head diameter of the sunflower crop (1979).

ANOVA TABLE

Source	df	SS	MSS	F	
TOTAL	72	15,787.06			
LEVEL	1	15,443.45			
TOTAL/LEVEL	71	343.62			
REPS.	3	115.83	38.61	51.27	**
TREATS.	17	98.86	5.82	2.30	*
W/F	5	45.10	9.02	3.57	**
P'S.	2	28.10	14.05	5.55	**
W/FXP'S	10	25.66	2.57	1.01	N/S
ERROR	51				

Appendix Table 2. A Summary of Analysis of Variance showing the effects of different treatments on head diameter of the sunflower crop (1980).

ANOVA TABLE

Source	df	SS	MSS	F	
TOTAL	72	17,850.75			
LEVEL	1	17,535.96			
TOTAL/LEVEL	71	314.79			
REPS.	3	3.90	1.30	1.14	N.S.
TREATS.	17	253.11	14.89	13.14	**
W/F	5	98.11	19.65	17.34	**
P'S	2	136.99	68.50	60.46	**
W/FXP'S	10	17.89	1.79	1.57	N.S.
ERROR	51	57.78	1.13		

Appendix Table 3. A Summary of Analysis of Variance showing the effects of different treatments on the yield of sunflower crop (1979).

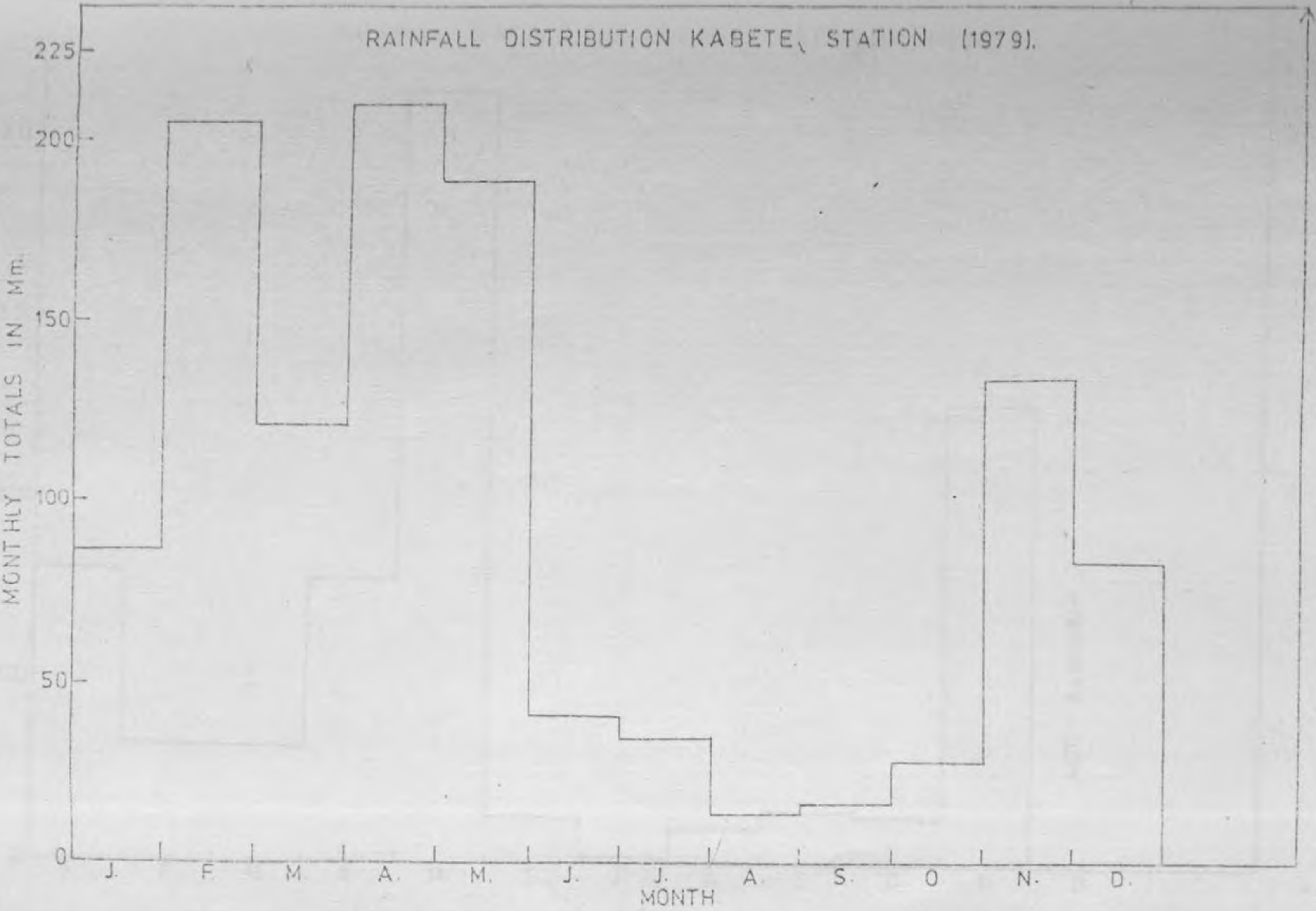
ANOVA TABLE

Source	df	SS	MSS	F
TOTAL	72	118,297,373.6		
LEVEL	1	86,490,182.42		
TOTAL/LEV.	71	31,807,191.18		
REPS	3	21,868,777.28		
TREATS.	17	2,813,790.83	161,517.11	1.18 N.S
W/F	5	1,743,817.25	342,763.45	2.49 N.S
P'S.	2	29,565.62	14,782.81	0.11 N.S.
W/FXP'	10	1,040,407.96	104,040.80	0.74 N.S.
ERROR	51	7,124,623.07	139,698.49	

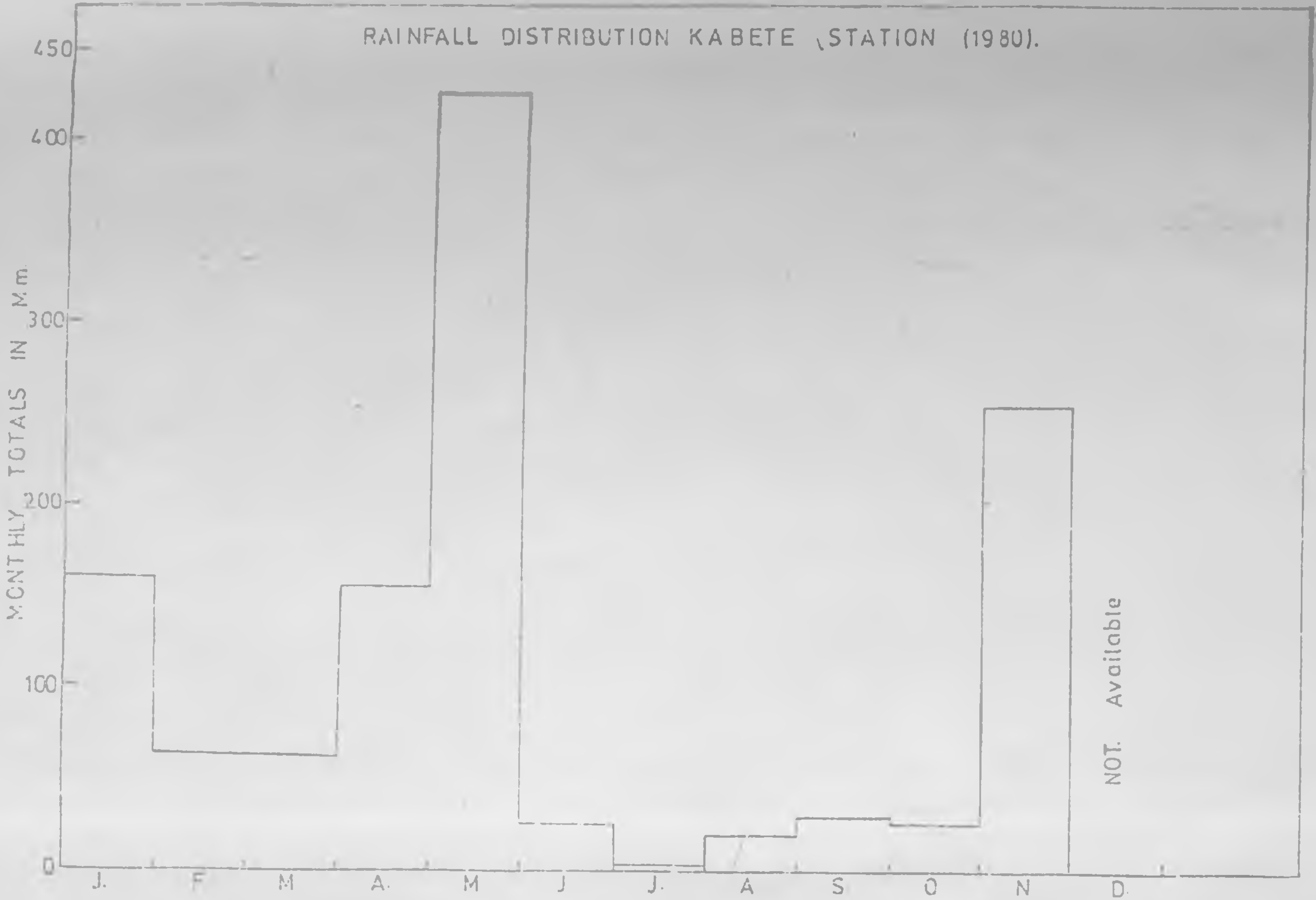
Appendix Table 4. A Summary of Analysis of Variance showing the effects of different treatments on the yield of the sunflower crop (1980).

ANOVA TABLE

Source	df	SS	MSS	F	
TOTAL	72	195,109,253.20			
LEVEL	1	178,150,586.90			
TOTAL/LEV.	71	16,958,666.30			
REPS.	3	358,419.20			
TREATS.	17	12,510,651.00	735,920.65	9.18	**
W/F	5	6,110,102.00	1,222,020.4	15.24	**
P'S.	2	5,647,141.40	2,823,570.7	35.21	**
W/FXP'S	10	753,408.40	75,340.84	0.94	
ERROR	51	4,089,596.00	80,188.16		



Appendix Fig. 1. Rainfall Distribution, Kabete Station in 1979.



Appendix Fig. 2. Rainfall Distribution, Kabete Station in 1980.