PETROLEUM MULCH AND ITS EFFECT ON CERTAIN SELECTED ASPECTS OF SWEET CORN PRODUCTION IN THE BEQA'A PLAIN

by

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ABSTRACT

During the 1962-1963 period, comparisons were made of three dates of planting, of two varieties of sweet corn and of mulch bands of different widths in a dryland experiment.

Ear yields of sweet corn decreased as the date of planting was delayed from April to May. The yields were 116, 94 and 22 kilograms per dunum for April 4, April 27 and May 17 plantings, respectively.

The shorter-growing-period variety (Spancross) outyielded the longer-growing-period variety (Ioana). Yields were 112 and 41 kilograms per dunum, respectively. A trend in yield and several agronomic characteristics favouring the widest mulch band (twelve inches wide) was observed. The best yielding combination was the earliest planting date, the short-growing-period variety and the widest mulch band.

Mulched-weeded, weeded-only and non-weeded plots of sweet corn planted to the Spancross variety under both dryland and irrigated conditions were compared during the 1963-1964 period to observe their effects on the growing crop. Irrigated plots (twice during the growing period) outyielded the non-irrigated plots with a difference of 256 kilograms of husked ears per dunum. Bigger and better quality ears were also obtained. Mulched-weeded plots (twelve inches wide mulch band) had one week earlier emergence, faster rate of growth and better quality ears than weeded-only and non-weeded plots. Weeds competed severely for moisture and nutrients and had a depressing effect on yield, rate of growth and maturity.

Irrigated x mulched-weeded treatment gave the best response under the Beqa'a conditions with a maximum ear yield of 607 kilograms per dunum. It

had the tallest and most vigorous plants, longest and heaviest ears, fastest rate of growth and earlier maturing crop than the rest of the treatments.

A warming effect equivalent to one month elapse in springtime was induced by a petroleum mulch band twelve inches wide. A maximum increase in soil temperature at six centimeters depth under petroleum mulch was $11^{\circ}F$.

The pot experiments indicated that a continuous film of petroleum mulch conserved soil moisture and kept the top soil moist for longer periods than did a non-mulched surface.

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INTRODUCTION

It is generally accepted that soil environmental factors such as temperature, moisture content, nutrient content, bacterial activity and organic matter influence plant growth.

Various mulching materials ranging from plant debris to synthetic films have been used for many years in agriculture to manipulate temperature, moisture and physical structure of the soil. Application procedures, costs and availability of mulching materials are critical considerations to the grower.

A liquid spray-on mulch, a specially formulated water emulsion of petroleum resins, has been developed by the Esso Research and Engineering Company.* This mulch, called Encap, requires relatively simple handling, application and disposal procedures. It is a dark colored liquid applied by spraying the soil surface in bands over the seed row immediately after planting the seeds. As it sets up it forms a thin, black, continuous film becoming an integral part of the soil surface. It appears to offer little hindrance to the emerging seedlings.

Due to its dark color and semi-permeable character, it is believed to affect both soil temperature and moisture and as a consequence would affect many other soil characteristics and modify cultural practices.

Since water is a limiting factor in the Beqa'a plain, a semi-arid area, practices that would induce more efficient utilization of the available precipitation should result in increased crop yields.

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* Esso Research and Engineering Company. Linden, New Jersey, USA.

Modifying the soil temperature to promote germination and earlier seedling establishment, would enable earlier planting, and consequently an earlier harvest. The water available early in the season would therefore be utilized more efficiently.

Various soil mulching materials have been tested throughout the world and many of their benefits to agriculture have been proven by research workers. Farmers in many areas have adopted the practice of soil mulching and have realized some advantages from the practice. Little work, if any, has been conducted in the countries of the Middle East. Experiments were conducted at the Agricultural Research and Education Center of the American University of Beirut to introduce the concept of soil mulching into the area and to investigate the claimed effects of petroleum mulch which were tested elsewhere such as promoting vigorous seedling growth for earlier and better yields, maximizing utilization of sparse rainfall and/or irrigation supplies and whether or not the use of petroleum mulch could be justified under the Beqa'a climatic and soil conditions.

During the two-year period from April 1963 to July 1964, experiments to study the effects of this petroleum mulch on growing crops were conducted at the Agricultural Research and Education Center. In the first experiment (April to August 1963) the effects of mulch bands of different widths on certain selected aspects of two sweet corn varieties planted at three different dates and grown under dry conditions were studied. In the second experiment (March to July 1964) the effect of a band of mulch twelve inches wide applied directly over the row with varying conditions of cultivation and moisture supply on sweet corn was studied.

Data to compare the effects of the different treatments on emergence rate, plant growth, plant height, yield of husked ears, soil temperature, soil moisture and several other agronomic characteristics were collected and analyzed.

REVIEW OF LITERATURE

Written and verbal reports of farmers, gardeners, research workers and others, support the many claims put forward of substantial increases in crop yields following the use of mulches. The benefits were variously attributed to the conservation of moisture, suppression of weed growth, protection from erosion, increased infiltration of water, increase or decrease of temperature fluctuations, enhanced mineral nutrient availability, enhanced nitrification, and other effects (4, 19, 27, 42).

So many soil and plant characteristics are believed to be modified by mulching that it was not usually possible to attribute the benefits derived from a mulch to improvement in any one factor.

The literature on the different mulching practices and their effects is reviewed with emphasis on their effect on soil temperature, soil moisture, and plant growth.

Mulches and Soil Temperature

Mederski and Jones (27) from their studies revealed that plants such as corn which are native to warm climates were favoured by relatively high soil temperatures at the early growth stages. Although low root zone temperature had long been known to depress both the growth and the nutrient uptake of corn, it was evident that the growth of corn was directly influenced by root zone temperature conditions.

Germination and early development of corn were shown by Willis *et al.* (53) and Burrows and Larson (5) to be closely related to early season soil temperatures. Miller and Bunger (28) reported on the work by

Richard and Hagan and by McCallan who found the minimum soil temperature range for germination and emergence to be from 52° to 64°F, with optimum soil temperature from 77° to 86°F. These results were also confirmed by Willis et al. (53) who concluded that the optimum temperature for young corn seedlings was in the range of 75° to 85°F.

The usual effect of a mulch whether of soil, plant residues or inert material like paper and petroleum has always been to raise soil temperature during cold weather. It has generally been found, however, (5) that under organic mulches such as straw and saw dust, soil temperatures are lower during the day and slightly higher at night than those of bare soil and that the daily ranges of temperature were very much lower as a result of insulation.

In the spring the soil temperature maxima reaches favourable corn germination levels in bare soil about two weeks earlier than it does in wheat-straw mulched soil (21). Moody et al. (30) on the other hand found that corn mulched with three tons of wheat straw per acre was sixty centimeters taller at tasseling and produced forty two bushels per acre more grain than did non-mulched corn.

The use of plastic films as a means of modifying the soil climate has been investigated by many research workers. Army and Hudspeth (2) demonstrated that the microclimate of the seed zone could be modified by covering the soil with plastic film. Soil temperature and moisture content were higher under plastic cover than under bare soil, and spring germination of grasses and sorghum was accelerated by the treatments. With grain sorghum, Adams (1) found early season soil temperature at the three-inch depth to be 10°F higher under complete cover with clear plastic than under bare soil. Plant development was accelerated, maturity was hastened and grain yields were increased by the cover. Hanks et al. (15) carried out experiments in Kansas to determine the influence of mulches of various materials on net radiation, soil temperature and evaporation. They concluded that soil temperature was highest under the clear plastic treatment followed by the check, black painted gravel, aluminum painted and straw covered treatments, respectively. More detailed studies by Clarckson (7) in North Carolina revealed that average soil temperature at one-, three-, and six-inch depths under a black polyethelene mulch was usually 1-5°F higher than at comparative depths under non-mulched conditions. Night temperatures under the plastic were higher than those of non-mulched areas. Takatori et al. found soil temperature under petroleum mulch to be higher than under either clear or black plastic films (49).

In Arizona, an increase in temperature of 18.3°F over bare soil at two-inch depths was obtained under petroleum mulch due to absorptivity. Maximum temperature increases at two-inch depths of 8.8°F, 15.2°F and 20.6°F. were obtained with three-, six-, and ten-inches wide, petroleum mulch strips, respectively (23).

Germination and Growth

Emergence of sorghum was significantly more rapid when temperature increased from 50° to 70°F (47, 53). Burrows and Larson (5) found that lower soil temperature under straw mulch reduced early growth of corn. Van Wijik et al. (51) supported the theory that early season corn growth was decreased by lowered temperatures caused by a mulch of crop residues. They also cited the findings of Lehenbauer who found that for a range of temperature from 50° to 86°F there was an increase in the rate of seedling growth with increasing temperatures, while from 86° to 90°F there was little influence, and at temperatures of 90° to 111°F there was a decrease. Louis et al. (23) found that by using petroleum mulch on sweet corn in New Jersey, the emergence date was advanced by approximately three days.

Nutrients

Uptake of nitrogen, phosphorus, potassium, calcium, and magnesium by crops was significantly increased with increasing temperatures up to at least 67°F (27, 32). As found by Mack and Barber (24) moisture level did not affect yield and phosphorus uptake at a soil temperature of 16°C but did have an effect on both at soil temperatures of 21° to 33°C. Under green house conditions, Nielsen et al. (32) showed an interacting effect of soil temperature and fertility level on growth and ion absorption by corn. They also observed that dry weight of the plants at thirty days increased with increasing temperature in the range of 40° to 80°F. In the temperature range of 16° to 20°C, a 2°C differential in soil temperature had a measurable effect on the rate of conversion of NH_4-N to NO_3-N (33).

Moisture Uptake and Transpiration

Tew et al. (50) reported on the work by Kramer who observed that water absorption was less with lower soil temperatures. This correlation was more evident in crops that normally grow in warm soils than among those that normally grow in cool soils. They also cited the results of Korvin and Novitskaya who found that the transpiration rates during early stages of growth were lower in plants grown in soil at 6° to 8°C than in comparable plants grown in soil at 15° to 20°C. By increasing the soil temperature from 10° to 40°C, Tew et al. (50) found transpiration rates to double under all temperature conditions. While Hanks (14) showed that if all other conditions, such as moisture content or thickness of mulch were equal, evaporation was directly proportional to the temperature of the soil.

Uptake of water by corn roots was found by Peters (35) to be a function of the specific moisture content as well as the moisture tension. He found that uptake of water and elongation of corn roots were decreased as the moisture tension increased and explained it as due either to reduced enzymatic action or translocation of solutes as the tissues became dehydrated.

Crop Maturity and Yield

Miller and Bunger (28) found sweet corn plants growing through clear perforated plastic strips were ready to harvest one week earlier than those on bare soil. Experiments carried out by Esso Research and Engineering Company and affiliates in Sweden, Germany and the United States proved that petroleum mulch promoted faster germination, better growth and earlier maturity of the sweet corn crop. An average increase of sweet corn yield by 10% was attributed to the use of petroleum mulch in more than twenty experiments conducted throughout the United States (10).

Results obtained by Stacy et al. (43) in Georgia indicated that high temperatures towards the end of the season were beneficial if rainfall was adequate. Nielsen et al. (32) found that yield of corn tops increased almost consistently with increasing soil temperatures from 41° to $80^{\circ}F$. Root yields also increased with temperature increase from 67° to $80^{\circ}F$. In Spink County, Moldenhauer and Westin (29) proved that the effect of June and July average maximum temperatures on wheat and corn yields over-shaded the effect of rainfall for these two months.

Mulches and Soil Moisture Studies

As pointed out by Baver (3) the mechanism of the evaporation of water from soils had been the subject of much controversy for a long time. This was especially true from the point of view of the practical significance of water losses by evaporation and methods for controlling or minimizing such losses.

By comparing water usage from plastic covered and uncovered soil plots growing corn, Shaw (42) and Peters and Russell (36) found that evaporation from the soil surface accounted for 40 percent to 70 percent of the total water loss. In lysimeter studies at Coshocton, Ohio, Harrold et al. (16) showed that corn growth could be sustained with soil moisture alone when evaporation was eliminated and they estimated evapo-transpiration to be composed of 56 percent evaporation and 44 percent transpiration. Both clear and black plastic films have been reported by Takatori et al. (49) to retain soil moisture better than petroleum mulch or unmulched soils. Their results, however, indicated that some retention of moisture was obtained with petroleum mulch. At Fort Collins, Colorado, Bement et al. (4) found that soil moisture at the one-inch depth was maintained for a longer period under a petroleum mulch than in the check. Approximately three-fourths inches of the top soil was maintained above wilt point for a time period sufficient for germination (six - seven days) with mulch strips four to six inches wide while with mulch strips ten to sixty-four inches wide up to eight inches of water over a complete growing season could be conserved (23). In lysimeter experiments, a blanket petroleum mulch treatment greatly reduced evaporation losses with the rate of as low as 3 percent of that from bare soil with a wet surface. Cracks in the film caused an increased rate of moisture loss, and overall conservation of moisture by strips was found to be limited to the first week of drying (10).

On deep, permeable, well drained soil Holt and Van Doren (17) reported that corn was able to use water to a depth of five feet or more. They also found the period of highest water requirement was from tasseling to kernel formation. Similar work by Gard et al. at Illinois (11) indicated that the use of two, two-inch irrigations ten to fourteen days apart during the tasseling and shooting stages of growth resulted in economically desirable corn yield increases. Several other workers reported that corn yield and growth were adversely affected by increased soil moisture stress especially at certain stages of growth (12, 20). Drouth occuring during the tasseling period was found by Howe and Rhoades (18) to have a much greater effect on yield than a similar drouth period occuring during the early stages of growth. However, Parks and Knetsch (34) did not find any significant effect of drouth occuring during the period extending from tasseling to maturity on yield of corn. Previous work by Robins and Domingo (38) revealed that soil moisture depletion to the wilting percentage by corn at certain physiologic growth stages markedly depressed grain yield. The major zone of soil moisture depletion of plastic covered plots was found by Russell and Danielson (40) at Urbana, Illinois to move down through the soil as the growing season progressed. At the end of the growing season they found that the corn plant obtained practically all of its moisture from below the four-feet depth, and observed that a constant relation existed between total water disappearance and corn yield.

Effect of Weeds

It was found by many research workers (26, 37, 45) that weeds compete with crops for water, light and mineral nutrients. Results of experiments conducted by Burrows and Olson (6) on the reaction of small grains to various densities of wild mustard revealed that growth, tillering and yield of wheat were adversely affected by the presence of wild mustard. Even a very light weed infestation was found by Godel (13) to lower the yield of grain crops.

Corn has been shown by several research workers (39, 48, 52) to be a poor weed competitor. When infested with foxtail throughout the season yield reductions in corn ranged from 8.2 to 23.5 bushels per acre. Vengris (52) reported that when corn was infested with weeds, it had reduced nitrogen, phosphorus and potassium uptake and had lower calcium and magnesium content.

Studying varying conditions of cultivation, weed control and moisture supply on corn, Swanson and Jacobson (48) found that weed-free irrigated corn plots produced the best yield (116 bushels per acre); while non-cultivated, non-irrigated plots produced the lowest yields (76 bushels per acre). Their results also revealed that under irrigated conditions it may not be necessary to clean cultivate. One cultivation or use of herbicide may be adequate. In fifteen experiments conducted by Staniforth and Weber (46) yield reductions of soybeans in weed-infested plantings averaged approximately 3.7 bushels per acre or 10 percent of weed-free beans when weeds were left for the entire season.

Results of an experiment carried out at the American University Farm in 1961 by Saghir (41), have demonstrated that yields at harvest of post emergence applications of DNOC or DNBP on annual weeds in onion proved to give approximately 8 percent and 40 percent higher net income than hand weeded and unweeded plots, respectively.

Weeds in plots with petroleum mulch cover had accelerated growth and a denser population. Since cultivation of the petroleum mulched plots with convential farm machinery equipment would not be possible, studies were carried out by Esso Research and Engineering Company of the United States and Esso Research Limited of England to investigate the possibility of incorporating a pre-emergence herbicide with the petroleum emulsion. Many herbicides were evaluated at various concentrations on a number of crops. A number of mulch-herbicide formulations showed synergistic activity as evidenced by better weed control and/or less crop injury. Generally petroleum mulch applied in combination with recommended herbicides resulted in very satisfactory weed control and crop tolerance. Weed control by pre-emergence herbicides in conjunction with petroleum mulch was at least equivalent to normal control, and in some cases, the mulch enhanced the characteristics of the herbicides. These improvements were persumably associated with the control that the petroleum mulch effects on the leaching of the chemicals in the soil (23).

Of the herbicides tested on maize, atrazine incorporated with the mulch at the rate of one pound per acre gave the best weed control and its effectiveness was unaltered by the petroleum mulch (10).

MATERIALS AND METHODS

The experiments were carried out during the period of April 1963 to July 1964 on fertile productive clayey Beqa'a soil of the Agricultural Research and Education Center of the American University of Beirut. The soil is low in organic matter, nitrogen and phosphorus and medium to high in potassium. It is calcareous with a pH of around 8.0. In the 1963 experiment, nitrogen in the form of ammonium nitrate and phosphorus in the form of simple superphosphate were each applied at the rate of four kilograms per dunum. In the 1964 experiment, nitrogen was applied at the rate of twelve kilograms of N per dunum, and phosphorus at the rate of twenty kilograms of P_2O_5 per dunum. The fertilizer was broadcast uniformly and disced down.

The site of the experiment is typical of semi-arid regions with inadequate rainfall. On the whole, the climate is dry and hot in summer and cold in winter with frost hazards until April. Amount and distribution of rainfall and mean monthly temperatures as obtained from official meteorological data of the Agricultural Research and Education Center are shown in table 1.

The amount of rainfall recorded for the period of September 1962 till August 1963 was relatively high (524.25 mm.) when compared with that recorded for similar periods in previous years.

1962-1963 Mulch Experiment

An exploratory experiment was conducted during the season of 1962-1963 to investigate the possibilities of producing a crop of sweet

Table 1.- Amount and distribution of rainfall and mean monthly maximum and minimum temperatures at the A.R.E.C. for the years 1963 and 1964.

Month	Rainfall (mm)		Mean Temperature °C			
	1962-63	1963-64	1962-63		1963-64	
			max.	min.	max.	min.
September	0.00	0.00	31.40	11.78	29.68	12.45
October	19.30	49.60	24.48	9.71	23.62	9.30
November	0.00	16.40	22.32	5.89	18.00	4.36
December	164.10	70.60	11.95	3.54	11.12	-0.40
January	124.10	60.60	11.90	2.30	5.93	-4.12
February	70.00	183.80	12.24	2.60	7.70	-0.40
March	82.35	52.80	12.97	0.95	14.43	3.67
April	53.30	13.90	18.71	5.24	16.03	3.24
May	11.70	23.70	21.00	7.00	20.90	4.63
June	0.00	0.00	28.76	12.34	28.50	12.40
July	0.00	0.00	30.45	13.61	31.80	14.40
August	0.00	0.00	32.74	14.37	31.90	14.40
Total	524.85	471.40				

corn on natural precipitation with the help of petroleum mulch sprayed in bands of different widths over the seed row. Two sweet corn varieties were tested; namely, Spancross which has a relatively short growing period and is some what winter hardy and Ioana which has a longer growing period than Spancross and is less winter hardy.

Design of the Experiment

The design of the experiment was a split-split plot design in which three dates of planting; April 4, April 27 and May 17, 1963 made up the main plots and two sweet corn varieties, Spancross and Ioana, made up the sub-plots. Five treatments; four-, eight- and twelve-inch mulch bands with a check and a 100 percent mulch cover were used in the sub-sub plots. All treatments were replicated four times. Since it was not applied in some of the replications of the different planting dates due to adverse weather conditions, the 100 percent cover treatment was eliminated from the analysis of the data.

Equipment Used

Bouyoucos gypsum moisture blocks were installed directly under the seed row at ten-, twenty five- and forty-centimeter depths in the last two planting dates only in two of the replicates. Moisture readings were recorded weekly.

Cultural Practices

The experimental site was disc plowed, harrowed and some of the stones were removed to provide a more uniform soil surface for better mulch film qualities.

Each plot consisted of four rows five meters long. The rows were spaced one meter apart. Spancross and Ioana variety sweet corn seeds were planted five centimeters deep by a hand planter and spaced thirty centimeters apart in the row. One seed was planted per hill. After planting, a small stone hand roller was passed four times over the seed row to smooth and compact the soil surface.

After planting the seeds and compacting the soil surface, the liquid mulch was sprayed on at an approximate rate of 0.4 liters per square meter by a modified pneumatic knap-sack sprayer. Two adjustable wooden boards were used to limit the mulch bands to desired widths. All these operations were completed within a period of three days for each planting date. All the plots were kept weed free by hand cultivation whenever required. Extra care was practiced in pulling the weeds from the mulch film.

Harvesting was done by hand when the ears were at a desirable stage for table serving. Only four meters in each of the middle two rows were harvested for ear and forage yields. Plant height at harvest was obtained by averaging the height of two plants in the middle two rows. Ears of each plot were sacked seperately, then were husked, described and weighed. One representative ear was chosen for length and width measurements. Three pounds of forage were taken for the moisture sample.

No supplemental water was added throughout the experiment.

<u>1963-1964 Mulch Experiment</u>

Based upon the data and knowledge gained in the previous year, a more detailed experiment was carried out.

The soil was fall plowed, then 12 kilograms of nitrogen as ammonium nitrate and 20 kilograms of P_2O_5 as simple super-phosphate per dunum were spread uniformly and disced down. A rotary tiller was used to break the soil clods and to smooth the soil surface.

<u>Design and Treatments</u>

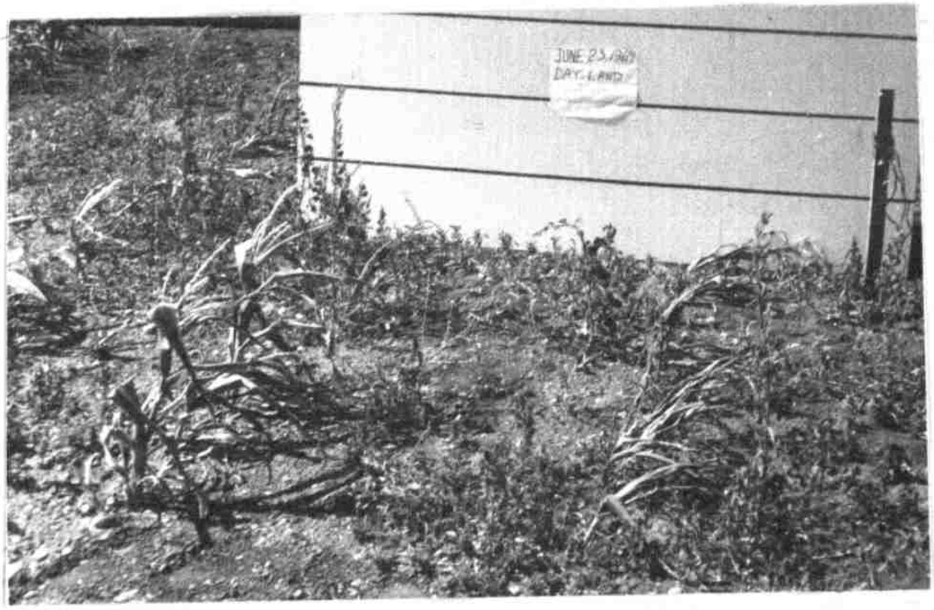
The experimental area was laid out in a split plot design in which the main plots were: Two irrigations each of 10 centimeters of water, and no irrigation. The sub-plots were the following three treatments: No cultivation, cultivation and a mulch band of twelve inches and hand cultivation only (table 2 and photographs on pages 18-20). All the treatments were replicated four times. Moreover, one observation plot of 100 percent mulch cover was included in each of the main plots.

Table 2. A coded table of the different treatments studied in the 1963-1964 experiment.

Code	Treatment
A	Non-irrigated x non-weeded
B	Non-irrigated x mulched-weeded
C	Non-irrigated x weeded-only
D	Irrigated x non-weeded
E	Irrigated x mulched-weeded
F	Irrigated x weeded-only

Each plot consisted of four rows five meters long. The rows were spaced one meter apart. Plots were laid two meters apart. Sweet corn seeds of the Spancross variety secured from the Burpee Seed Company and testing 90 percent germination were planted by a hand planter five centimeters deep and spaced thirty centimeters apart in the row. One seed was planted per hill. The soil over the seed row was packed by a small stone roller passed over it four times. The mulch was sprayed on certain plots in twelve-inch bands over the seed row.

All plots were planted, packed and sprayed on March 31, 1964.



Treatment A = Non-irrigated x non-weeded

Treatment D = Irrigated x non-weeded

Treatment B = Non-irrigated x mulched-weeded

Treatment E = Irrigated x mulched-weeded

Treatment C = Non-irrigated x weeded-only

Treatment F = Irrigated x weeded-only

EQUIPMENT USED

Water Studies

1. Moisture Blocks:

For percent available soil water determinations Bouyoucos gypsum moisture blocks were installed at ten-, twenty five- and forty-centimeter depths under one seed row of each of the treatments in the middle two replicates before the corn seeds were planted. Weekly readings using a Bouyoucos moisture meter were recorded.

2. Irrigation:

Certain plots were flood irrigated using gated pipes. Ridges 15 centimeters high were made by hand around each of the plots.

The first irrigation was applied on May 29, 1964 and the second on June 19, 1964.

Temperature Studies

Maximum - Minimum Palmer thermometers model 35 B were installed in the third replicate under all treatments, and under one of the 100 percent mulch cover observation plots. The sensitive tip was placed horizontally at a depth of six centimeters under the seed row, and was connected by a sealed casing running under the soil surface to the indicating dial which was put in a wooden box outside the plot.

Temperature readings starting April 1, 1964 were recorded four times daily; at 8, 12, 18 and 22 hours until the harvest time (July 2, 1964).

Spraying Equipment

The liquid mulch was applied at the rate of 0.6 - 0.7 liters per square meter (Appendix A) by modified four oaks pneumatic knap sack sprayer with a capacity of 4.2 gallons (10).

Before filling the sprayer, the mulch was passed through a twenty mesh filter. After the sprayer was partially filled with twelve liters of mulch, it was pressurized by an external source of compressed air to a pressure of about 3.5 kilograms per square centimeter.

Data Recorded

Emergence date and rate were observed and recorded by counting the emerging plants daily.

Plant height was measured weekly by averaging the height of five plants taken at random from the middle two rows of each of the twenty four plots with the tips of the leaves extended until tasseling, after which the tassel was considered as the tip of the plant.

Dates of tasseling and silking were also recorded.

Moisture and temperature data were recorded.

All the plots were hand picked on July 2, 1964. Only thirteen plants in the middle of each of the two rows were harvested.

Data on plant height at harvest, state of maturity, average number of tillers per plant, number of ears per plant, yield of husked ears, length of the husked ear, and stover yield were observed and recorded.

Weed Population

The species of weeds in the uncultivated plots were the same in all of the four replicates. The density of the weeds in the irrigated plots, however, was greater (35 plants per square meter) than that in the unirrigated ones (15 plants per square meter).

The scientific and common names of the weeds found in the plots are listed in table 3 according to the intensity of infestation.

Table 3. Scientific and common names of the weeds present in non-weeded plots listed in decreasing intensity of infestation.

Scientific name	Common name
Amaranthus retroflexus	Pigweed
Brassica kaber	Wild mustard
Amaranthus blitoides	Prostate pigweed
Chenopodium opulifolium	Goose foot
Carthamus flavescens	Golden safflower
Heliotropium bovi	Heliotrope
Solanum alatum	Winged nightshade
Tribulus terrestris	Caltrops
Xanthium brassilum	Sheepbur
Anchusa azurea	Bugloss
Sonchus olercus	Sow thistle

The cultivation of treatments B, C, E and F was done by hand. Weeds were removed five to seven days after their emergence. Special care was taken while pulling the weeds from the mulch film so as not to destroy the mulch film.

Statistical Analysis

Statistical methods appropriate to the split plot and split-split plot designs were used to analyze the data (8). Analysis of variance and the L.S.D. test were used to analyze the difference between the treatment combinations of the 1962-63 data, while on the 1963-64 data instead of the L.S.D. test the single degree of freedom and Duncan's Multiple Range test were used (8).

RESULTS AND DISCUSSION

1963 Experiment

Ear Yield

Weight differences of husked corn ears were found to be statistically significant in both date of planting and variety trials as shown in tables 4, 5 and 6.

The mean weights of husked corn ears from April 4 and April 27 plantings (116 and 94 kilograms per dunum, respectively) were significantly higher than that of May 17 planting (22 kilograms per dunum). This was partly due to the great loss of soil moisture by evaporation before the seeds were planted on May 17. The plants of the earlier plantings thus, were able to utilize the available soil moisture before that date and were able to yield more. These results are in agreement with those of Mufti (31) who found that grain yields in maize decreased as the date of planting was delayed from March to June.

The yield of Spancross variety (112 kilograms per dunum) was significantly higher than that of Ioana variety (41 kilograms per dunum) ($P = 0.01$). This was due to the depletion of available soil moisture by evapo-transpiration before Ioana variety, which has a longer growing period than spancross, was able to bear ears and complete its life cycle later in the season (table 5).

There were no statistically significant differences ($P = 0.05$) among the plots having different widths of mulch bands and the check. There existed however, a trend in favour of the twelve-inch mulch band

Table 4. Comparison of characteristics* of sweet corn planted at three different dates and grown under dryland conditions.

Character analyzed	Dates of planting in 1963		
	April 4	April 27	May 17
Ear yield (kgs/dunum)	116	94	22
Plant height at harvest (cms)	72	75	66
Ear length (cms)	11.0	11.5	12.0
Ear width (cms)	3.59	3.35	3.14
Number of barren stalks in 50 plants	22	25	36
Stover yield (kgs/dunum)	117	85	-

* Means joined by the same sub-line do not differ significantly at $P = 0.01$.

\- No data obtained.

treatment which gave the highest yields (table 6).

The mulch supply for the 1963 experiment had separated during its shipment due to freezing. To homogenize it, steam was passed through the mulch. Forty eight hours after applying the mulch to the soil surface the resultant film cracked into small flakes characteristic to cracking upon drying of a clayey surface. The inability of the mulch film to maintain its semi-permeable character may account for the lack of significance between check and mulched treatments.

It is evident from these results that an earlier date of planting, short-growing period variety and wider mulch bands have favorable effects

Table 5. Comparison of the effect of two sweet corn varieties, Spancross and Ioana, on the following characteristics* of sweet corn produced under dryland conditions.

Character analyzed	Variety	
	Spancross	Ioana
Ear yield (kgs/dunum)	112	41
Plant height at harvest (cms)	58.4	81.7
Ear length (cms)	11.3	11.7
Ear width (cms)	3.5	3.2
Number of barren stalks in 50 plants	17	37
Stover yield (kgs/dunum)	74	123

Table 6. Comparison of the effect of different mulch-band width on the following characteristics* of sweet corn produced under dryland conditions.

Character analyzed	Bare soil	Mulch-band width (inches)		
		4	8	12
Ear yield (kgs/dunum)	72	71	74	91
Plant height at harvest (cms)	66.8	67.9	71.5	74.0
Ear length (cms)	11.7	11.1	11.7	11.5
Ear width (cms)	3.3	3.3	3.4	3.5
Number of barren stalks in 50 plants	28	27	28	26
Stover yield (kgs/dunum)	85	102	102	108

* Means joined by the same sub-line do not differ significantly at P = 0.01.

on the ear yield of sweet corn. So, for dry-land conditions an early date of planting and early maturing varieties will give the best yields. These results are in accordance with the findings of Worzella et al. (54) who found that Senator Capelli, a late maturing durum wheat, produced the least amount of grain (94.2 kg per dunum) while Florence Aurore, an early maturing variety, gave the maximum grain yield (142.2 kg. per dunum).

Plant Height at Harvest

Date of planting had no significant effect ($P = 0.05$) on final plant height (table 4). Significant varietal differences ($P = 0.01$), however, were obtained (table 5). Plants of Spancross variety were significantly shorter (58 centimeters) than those of Ioana variety (82 centimeters). These results were in accordance with the characteristics of the two varieties. There were no statistically significant differences ($P = 0.05$) among the plants of the plots with different widths of mulch bands and the check (table 6). There existed, however, a trend in favor of the twelve-inch-wide-mulch-band treatment which gave the tallest plants (74 centimeters) compared to those of the check (66.3 centimeters).

Average Ear Length and Width

Date of planting had a significant effect on ear width ($P = 0.01$). Ears from the two earlier plantings were significantly thicker than ears from the later plantings. Neither the variety nor the mulch treatment had any significant effects on ear width (tables 4, 5 and 6).

As shown in tables 4, 5 and 6 differences in ear length were not significant ($P = 0.05$) under all the studied variables.

Barren Stalks

Neither dates of planting nor mulch treatments had any significant effect ($P = 0.05$) on the number of barren stalks (tables 4, 5 and 6). Significant differences ($P = 0.01$) in the number of barren stalks, however, were found between the two varieties (table 5). Ioana variety had thirty seven barren stalks out of fifty, while Spancross had only seventeen. This was partly due to the inability of the late maturing variety, Ioana, to set ears without adequate soil moisture later in the season.

Stover Yield

None of the variables studied had a significant effect on stover yield (tables 4, 5 and 6) for vegetative growth was limited by moisture depletion.

1964 Experiment

Plant Emergence, Height and Rate of Growth

Plant Emergence

As shown in table 7 plant of mulched plots emerged one week earlier than in the bare soil.

Table 7. Comparisons of the emergence of sweet corn planted on March 31, 1964 under twelve-inches-wide-mulch band and under bare soil.

Date	Average emerging out of 19 seeds	
	Mulch	Bare
April 7	6	0
April 9	14	3
April 16	17	16

At the end of one week six plants from the mulched treatment had emerged. Two days later fourteen plants in the mulch treatment had emerged while only three plants were showing in the bare soil treatment.

Plant Height

Pronounced differences in plant size and appearance between mulched treatments (B and E) and other treatments (A, C, D and F) were apparent and statistically significant (P = 0.01) sixteen days after planting (table 9).

Until the forty seventh day (May 17) after planting the plants of mulched treatments (B and E) were taller than those of other treatments

Table 8. Comparison of average plant heights and height differences* of weeded-only, non-weeded and mulched-weeded treatments under dryland and irrigated conditions for the period of April 16 - June 17, 1964**

Treatments and differences among treatments***	Date of recording							
	April 16	April 23	April 30	May 7	May 17	May 27	June 5	June 17
	Days after planting							
	16	23	30	37	47	57	66	78
	Plant height in centimeters							
A	4.75	8.65	13.75	17.10	24.80	44.8	42.65	44.60
B	8.38	13.50	18.57	27.10	38.30	55.85	72.80	77.50
C	4.50	8.55	13.13	18.13	25.20	52.50	67.35	71.05
D	5.00	8.28	13.53	19.60	25.40	46.65	60.25	61.75
E	8.50	13.40	18.73	26.25	39.35	58.15	98.30	101.05
F	4.88	9.08	13.63	15.68	23.90	51.75	81.40	89.20
	Height difference							
E-A	3.75	4.75	4.98	9.15	14.55	13.35	55.65	56.45
E-D	3.50	5.12	5.04	6.65	13.95	11.50	38.05	39.30
E-C	4.00	4.85	5.60	8.12	14.15	5.65	30.95	30.00
E-B	0.12	-0.10	0.16	-0.85	1.05	2.30	20.80	23.55
E-F	3.62	4.32	5.10	10.75	15.55	6.40	16.90	11.85

*Height difference was calculated with respect to plant height of treatment E.

**After June 17th there was no increase in height.

***Treatment code in table 2 on page 17.

(A, C, D and F) and statistically significant (P = 0.01). There were, however, no statistical differences noted among the rest of the treatments (tables 8 and 9 and figure 1).

On May 27, fifty seven days after planting, there were no statistically significant differences among all the treatments (P = 0.01). This shows a change in the trend toward taller plants under the mulch treatment. This change in trend could probably be attributed to a faster and more intensive depletion of the available soil moisture by the larger, more vigorous plants of treatments B and E. It could then be expected that these plants would have a slowed down rate of growth during that period, hence plants of other treatments (A, C, D and F) with more available soil moisture would continue their growth and attain comparable heights. Soil moisture data for that date confirm this (tables 16, 17 and 18). During the week of May 17 to 27, the available soil moisture for all treatments at a depth of ten centimeters was zero. At a depth of twenty-five centimeters, however, it was 38 and 80 percent, and at forty centimeters 85 and 95 percent for mulched-weeded (treatments B and E) and weeded-only plots (treatments C and F), respectively. The available soil moisture of non-weeded plots (treatments A and D) was comparable to those of weeded-mulched plots (treatments B and E) at corresponding depths (tables 16, 17 and 18).

On June 5th, seven days after the first irrigation of treatments D, E and F, the plant height of all treatments was as follows: Plants of treatment E (irrigated x mulched-weeded) had the maximum plant height which was significantly higher than the rest of the treatments (P = 0.01), followed by those of treatment F (irrigated x weeded-only). However, there were no statistically significant differences among treatments B, C and D.

Plants of treatment A were significantly shorter than the rest. It could be concluded from this, that presence of weeds had the same retarding effect on plant height as lack of moisture. These results are in agreement with the findings of Marani and Fuchs (25) who found that unirrigated cotton had no appreciable growth while the irrigated cotton resumed vegetative growth.

Plant height of treatment E being significantly taller than those of treatment F seven days after irrigation, when they were not so ten days before, indicates that plants of treatment E had more physiological potentialities for growth than those of treatment F under the same moisture level. Therefore, a mulch band twelve inches wide had a favourable effect on plant height and this was true only under irrigated conditions.

The non-significant height differences among plants of treatments B, C and D emphasize that height of plants in non-irrigated x weeded-only plots were comparable to those irrigated x non-weeded ones.

From June 17th until harvest time, July 2nd, all treatments had different heights and all their differences were statistically significant at the one percent level with those of treatment E (irrigated x mulched-weeded) being the tallest (101.05 centimeters), and those of treatment A (non-irrigated x non-weeded) being the shortest (44.60 centimeters).

Table 9 further reveals that a mulch band twelve inches wide with no irrigation did not compensate for lack of moisture and that two irrigations during the critical period of plant growth (tasseling to kernel formation gave significantly taller plants. However, the non-irrigated mulched plots had significantly taller plants than irrigated non-weeded plots which indicates that even with applying water, weeds were able to smother the plants and that mulching and weeding would give taller plants than weeding only, and both had taller plants than those of non-irrigated non-weeded ones. This fact stresses the necessity of weeding the plots for eliminating

Table 9. Comparison of sweet corn plant heights* of non-weeded, mulched-weeded and weeded-only treatments under dryland and irrigated conditions during the period April 16 to June 17, 1964**.

Date	Treatment and plant height (Before irrigation)					
	Non-irrigated x non-weeded	Irrigated x non-weeded	Non-irrigated x weeded-only	Irrigated x weeded-only	Non-irrigated x mulched-weeded	Irrigated x mulched - weeded
April 16	4.75	5.00	4.50	4.88	8.38	8.50
April 23	8.65	8.28	8.55	9.08	13.50	13.40
April 30	13.75	13.53	13.13	13.63	18.57	18.73
May 7	17.10	19.60	18.13	15.68	27.10	26.25
May 17	24.80	25.40	25.20	23.90	38.30	39.35
May 27	44.80	46.65	52.50	51.75	55.85	58.15
	(After irrigation)					
	Non-irrigated x non-weeded	Irrigated x non-weeded	Non-irrigated x weeded-only	Non-irrigated x mulched-weeded	Irrigated x weeded-only	Irrigated x mulched-weeded
June 5	42.65	60.25	67.35	72.80	81.40	98.30
June 17	44.60	61.75	71.05	77.50	89.20	101.05

* Means joined by the same sub-line do not differ significantly at P = 0.01.

** Maximum plant height was attained by June 17.

competition between the crop and the weeds.

Also studying plant height differences between those of treatment E taken as a reference and the rest of the treatments in table 8 shows that those differences were increasing until May 17th, after which they became smaller till the first irrigation. Only seven days following the first irrigation, the plant height differences were tripled. This confirms the assumption that available soil moisture became limiting after May 17th and that mulch effect was noticeable until then, and that the acquired potentialities of treatment E plants earlier in the season were unable to function in the absence of adequate moisture. However, they resumed their function at a greater pace directly after supplying the plots with water. Thus beneficial effects attained by the plants from the use of petroleum mulch such as increased ion absorption due to higher root temperatures, as well as increased diffusion rates, reaction velocities, solubility, synthesis and translocation could only be better utilized with the presence of sufficient moisture. Weeds had noticeable effect on plant growth and vigour throughout the growing season under both irrigated and dryland conditions.

Rate of Growth

Rate of plant growth (centimeters per week) followed the same trend as that of plant height (table 10). Plants of mulched plots (treatment B and E) had the highest rate of growth and this rate increased as the season advanced, except during the week of May 18-27 when treatments A, C, D and F had a greater rate of plant growth than those of treatments B and E. This could be attributed to a more intensive and rapid soil moisture depletion by the more vigorous plants of treatments B and E and to the fact that plants of treatments A, C, D and F were in earlier stages of growth than those of B and E and hence their growth was not complete, especially when we had no rain during that week. After irrigating treatments D, E and F, the rate of plant growth of treatment E was the greatest and this offers a further proof that those particular plants were more advanced physiologically and were able to utilize more efficiently the available soil moisture.

Plants of mulched plots were physiologically more developed. This could be attributed to a more vigorous and intensive root system, larger leaf area and better assimilation which were the direct result of more favourable soil temperature brought about by the presence of a petroleum mulch film.

The rate of stem elongation of the plants under dryland conditions declined as the wilting point was approached (May 28 to June 5). The net result was that plants subjected to stress in the vegetative stage were shorter than those that received water before the wilting point was reached. Non-weeded plants had the smallest rate of stem elongation after May 28. This was due to the shading effect and competition offered by the weed population. These results are in accordance with the findings of Denmead and Shaw (9) who reported on the reduction of stem elongation by moisture stress in the vegetative stage of growth.

Growth Curves

Growth curves (figure 1) show that increasing soil temperature to the optimum range correlates with increased corn height in the interval from sixteen to forty-two days after planting (April 16 - May 12). In the interval from sixteen to forty-two days after planting, the height of the non-mulched corn lagged about eight days behind the mulched corn.

Table 10. Comparison of plant growth rates (centimeters per week) among weeded-only, non-weeded and mulched-weeded treatments under dryland and irrigated conditions for the period April 16 - June 17, 1964*.

Treatment	Rate of plant growth (centimeters per week) during:						
	April 16-23	April 24-30	May 1-7	May 8-17	May 18-27	May 28 - June 5	June 6-17
A	3.9	5.1	3.4	5.4	14.0	0	0
B	5.1	5.1	8.5	7.8	12.3	13.2	2.7
C	4.1	4.6	5.0	5.0	19.1	11.6	2.2
D	3.3	5.3	6.1	4.1	19.9	10.6	0.9
E	4.9	5.3	7.5	9.2	13.2	31.2	1.6
F	4.2	4.6	2.1	5.8	19.5	23.1	4.6

*After June 17 there was no plant growth.

This lag which decreased to about five days at forty-two days after planting corresponded to an observed five-day difference between tasseling dates in favour of the mulched plots. Of particular interest is the slope of the growth curves during the early and later stages of development. During the interval between sixteen and forty-two days after planting (April 16 - May 12), the rate of height increase when the soil was mulched at planting was approximately 1.8 times that of the corn in non-mulched soil. During and before this period, non-mulched soil temperatures were suboptimum while mulched soil temperatures were in the optimum range or over 75°F (figure 5). In the interval from forty-five to seventy-eight days after planting, maximum non-mulched soil temperatures had increased to within optimum range, and the slopes for mulched and non-mulched soil became parallel.

Water had a marked effect on growth rate and accentuated it in favour of the mulch. After the first irrigation (May 29) plants of mulched plots had the greatest growth rate increase.

Growth curves as shown in figure 1 indicate that the initial gain in plant height with soil mulching would be sustained even though the mulch film became ineffective fifty days after planting. Actually, the mulch film started to crack and disintegrate thirty days after planting. It maintained, however, a semi-continuous cover till the 60th day after planting. Moreover, on the irrigated plots the film was washed completely away after the first irrigation which was fifty days after planting. Assuming that plant height in the early stage of plant development is a good indication of over all plant development, the data suggest that the benefit from soil mulching was a consequence of soil warming prior to May 12th rather than after this time. Tassels appeared at 66 $\pm$ 5 days after planting and at this time the growth curves became parallel.

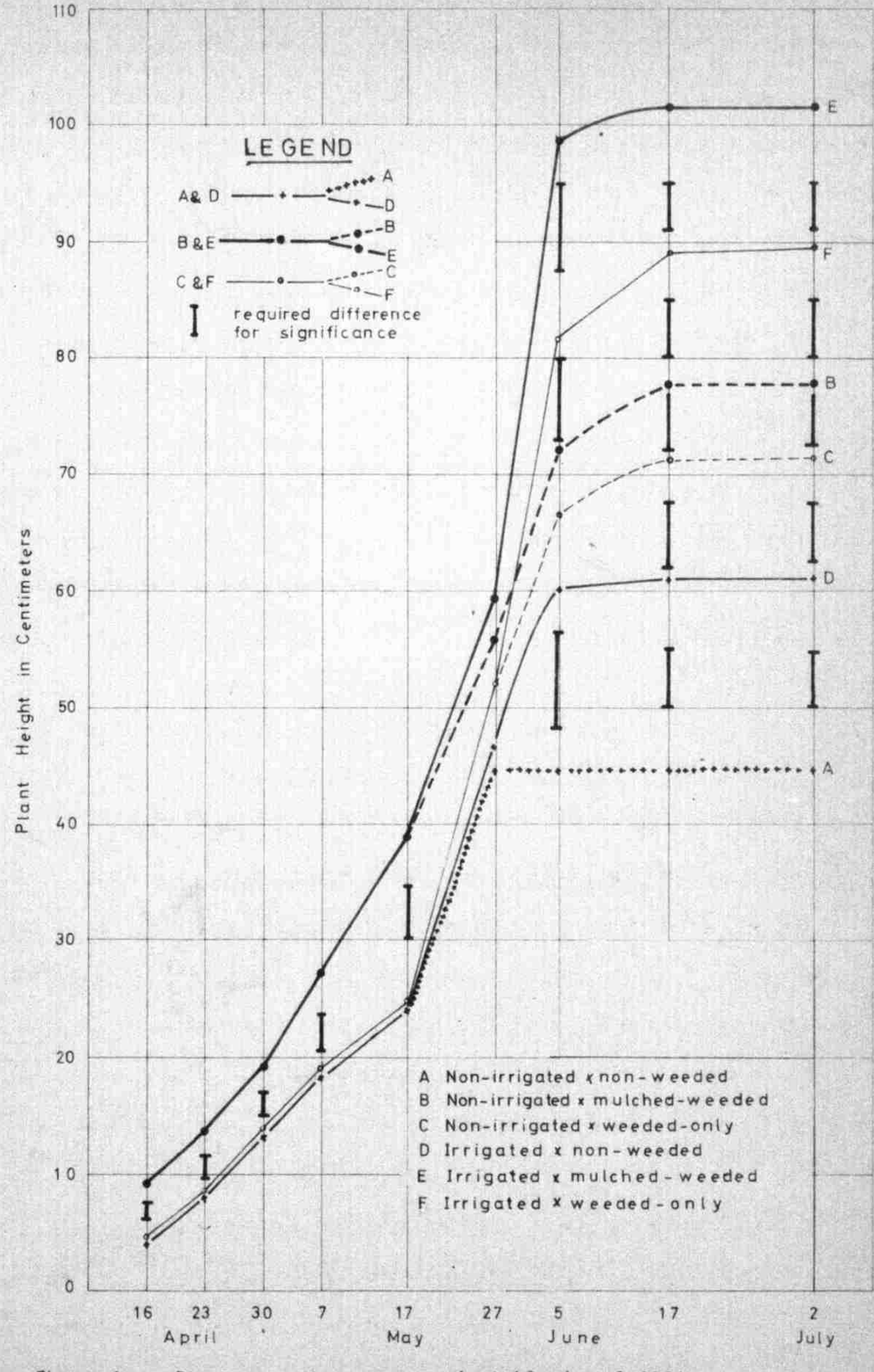


Figure 1 - Plant growth curves April 16 - July 2, 1964

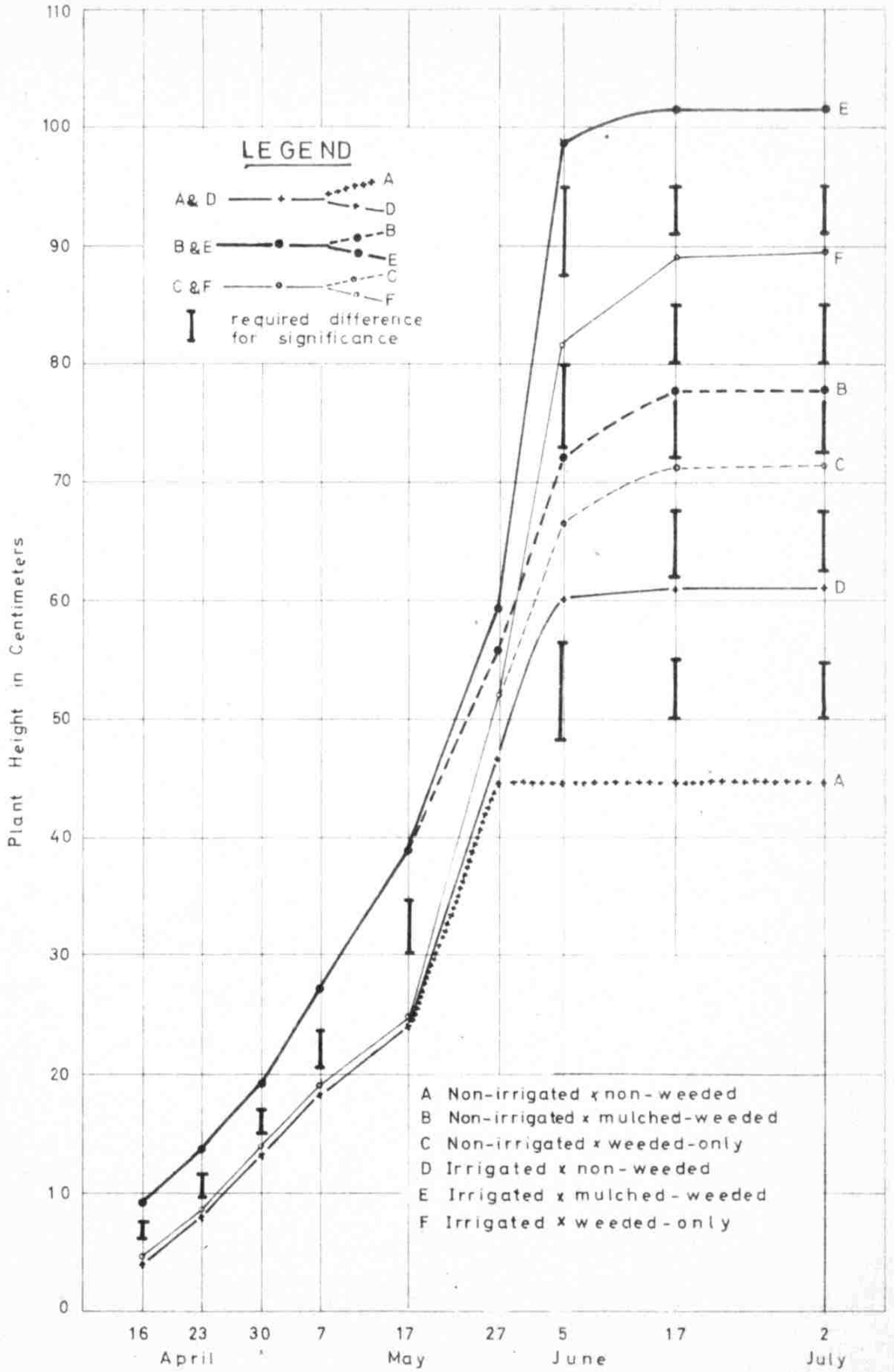


Figure 1 - Plant growth curves April 16 - July 2, 1964

Ear Yield

An examination of the data in table 11 shows that the weight of husked ears was influenced by the moisture level, the cultural practice used and the interaction of these two.

There was a highly significant difference between the mean weight of the corn harvested from irrigated and that harvested from the non-irrigated plots (irrigated on May 29 and June 19). The yield of husked ears from the irrigated plots (mean of D, E and F treatments) was 387.2 kilograms per dunum, while that from the non-irrigated plots (mean of treatments A, B and C) was about one third as much (131.2 kilograms per dunum).

Ear yields varied greatly with the different cultural practices. Mulched-weeded plots (mean of B and E treatments) produced the heaviest yield (412.66 kilograms per dunum), while the non-weeded plots (mean of A and D treatments) produced the lowest yield (53.67 kilograms per dunum). Weeded-only plots (mean of C and F treatments) had an intermediate yield of 311.34 kilograms per dunum. All the yield differences were highly significant (P = 0.01).

The interaction moisture level x cultural practice had a highly significant effect on the yield of sweet corn (table 11). Irrigated x mulched-weeded plots (treatment E) had the greatest yield (607.26 kilograms per dunum), while irrigated x weeded-only plots (treatment F) had a lower yield (447.20 kilograms per dunum) and the difference was highly significant (R = 0.01). Non-irrigated x mulched-weeded plots (treatment B) and non-irrigated x weeded-only (treatment C) had 218.03 and 176.00 kilograms per dunum, respectively. The difference in yield was not significant (P = 0.01). However, they both had a significantly lower yield than irrigated x weeded-only plots. Irrigated x non-weeded plots (treatment D) had a significantly

Table 11. Comparison of sweet corn ear yield* (kilograms per dunum) produced under various moisture treatments and cultural practices.

Treatment	Non-weeded	Mulched-weeded	Weeded-only	Mean of moisture treatments (kgs/du.)
Irrigated	107.1	607.3	447.2	387.2
Non-irrigated	-	218.0	176.0	131.3
Mean of cultural practice	53.5	412.6	311.6	

Main plot: Moisture treatment

Treatment	Irrigated	Non-irrigated
Mean	387.2	131.2

Sub plot: Cultural practice

Treatment	Non-weeded	Mulched-weeded	Weeded-only
Mean	53.5	412.6	311.6

Interaction: Moisture treatment x cultural practice

Treatment	Non-irrigated x non-weeded (A)	Irrigated x non-weeded (D)	Non-irrigated x weeded-only (C)	Non-irrigated x mulched-weeded (B)	Irrigated x weeded-only (F)	Irrigated x mulched-weeded (E)
Mean	-	107.1	176.0	218.0	447.2	607.3

* Means joined by the same sub-line do not differ significantly at P = 0.01

\- No ears were harvested ( ) Treatment code lower yield than non-irrigated x mulched-weeded and non-irrigated x weeded-only plots (P = 0.01). Non-irrigated x non-weeded plots (treatment A) had no ears. These results are in agreement with the findings of Swanson and Jacobson (48).

Ear yield data is of great economical importance regarding the use of petroleum mulch. It is to be emphasized that under the climatic and soil conditions of this experiment significant differences in yield between mulched-weeded and non-mulched-weeded were obtained only when water was applied. Weeds had a severe depressing effect on yield equivalent to that of complete moisture depletion.

These results are in agreement with the results of Letey and Peters (22) who found that corn yields were closely related to the soil moisture stress to which the plant is subjected during the growing season.

Number of Ears Per Plant and Weight Per Ear

Moisture level and cultural practice had highly significant effects on both the number of ears per plant (table 12) and the weight per ear (table 13). Irrigated plots had an average of 0.94 ears per plant and 111.0 grams per ear, while the non-irrigated plots had an average of 0.57 ears per plant and 47.0 grams per ear. The differences were highly significant (P = 0.01). This followed the same trend as for ear yields. Mulched-weeded plots had the highest number of ears per plant (1.11 ears per plant) and the heaviest ears (108 grams per ear), while non-weeded plots had the lowest number of ears per plant (0.24 ears per plant) and the smallest ears (35 grams per ear) with those of weeded-only plots having an intermediate number of 0.9 ears per plant and medium size ears (94 grams per ear). All differences were highly significant (P = 0.01).

The interaction irrigation x cultural practice had no significant effect on the number of ears per plant but they had a highly significant effect on the weight per ear. Irrigated x mulched-weeded plots had the heaviest ears (143 grams per ear) followed closely by those of irrigated x weeded-only plots with an average weight of 120 grams per ear. The difference was highly significant. Both had significantly heavier ears (P = 0.01) than the rest of the treatments for which no statistical differences were found.

The great differences in the number of ears per plant and the weight per ear between irrigated and non-irrigated plots are of extreme value in studying the different growth stages of sweet corn. The first irrigation was applied on May 29, seven days before tasseling and twelve days before silking, therefore, water was not limiting during the pollination period on the irrigated plots while it was on the non-irrigated plots. The second irrigation was applied on the same plots on June 19 during the filling stage of the sweet corn kernels. Thus, the water stress was partly removed during the critical stages of plant development and hence the greater yields. These results are in accordance with the findings at Arizona by Stanberry et al. (44) who found that attention to the irrigation schedule was important only during the pollination period of sweet corn.

Average Ear Length

Irrigation, cultural practice and interaction of cultural practice x irrigation had a highly significant effect on ear length of sweet corn (table 14). Irrigated plots had an average ear length of 14.71 centimeters while ears of non-irrigated ones were half that size (7.53 centimeters). The difference in ear length was highly significant (P = 0.01). There was no statistically significant difference between the ear lengths of mulched-weeded and weeded-only plots (14.3 and 13.3 centimeter respectively). Both had

Table 12. Comparison of average number of ears per sweet corn plant* produced under various moisture treatments and cultural practices.

Treatment	Non-weeded	Mulched-weeded	Weeded-only	Mean of moisture treatment (ears/plant)
Irrigated	0.49	1.31	1.03	0.94
Non-irrigated	-	0.92	0.78	0.57
Mean of cultural practice	0.24	1.11	0.90	

Main plot: Moisture treatment

Treatment	Irrigated	Non-irrigated
Mean	0.49	0.57

Sub-plot: Cultural practice

Treatment	Non-weeded	Mulched-weeded	Weeded-only
Mean	0.24	1.11	0.90

* Means joined by the same sub-line do not differ significantly at P = 0.01.

- No ears were harvested.

Table 13. Comparison of weight per ear* (grams per ear) of sweet corn produced under various moisture treatments and cultural practices.

Treatment	Non-weeded	Mulched-weeded	Weeded-only	Mean of moisture treatment (gms/ear)
Irrigated	70.0	143.0	120.0	111.0
Non-irrigated	-	73.0	68.0	47.0
Mean of cultural practice	35.0	108.0	94.0	

Main plot: Moisture treatment

Treatment	Irrigated	Non-irrigated
Mean	111.0	47.0

Sub-plot: Cultural practice

Treatment	Non-weeded	Mulched-weeded	Weeded-only
Mean	35.0	94.0	108.0

Interaction: Moisture treatment x cultural practice

Treatment	Non-irrigated x non-weeded (A)	Non-irrigated x weeded-only (C)	Irrigated x non-weeded (D)	Non-irrigated x mulched-weeded (B)	Irrigated x weeded-only (F)	Irrigated x mulched-weeded (E)
Mean	-	68.0	70.0	73.0	120.0	143.0

* Means joined by the same sub-line do not differ significantly at P = 0.01.

\- No ears were harvested. ( ) Treatment code.

Table 14. Comparison of sweet corn ear length in centimeters* produced under various moisture treatments and cultural practices.

Treatment	Non-weeded	Mulched-weeded	Weeded-only	Mean of moisture treatment (cms)
Irrigated	11.75	16.63	15.75	14.71
Non-irrigated	-	11.63	10.94	7.53
Mean of cultural practice	5.88	14.13	13.34	

Main plot: Moisture treatment

Treatment	Irrigated	Non-irrigated
Mean	14.71	7.53

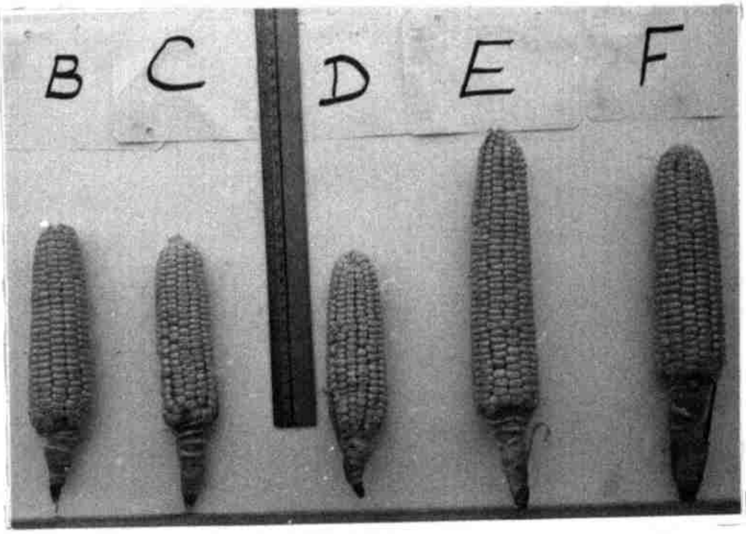
Sub plot: Cultural practice

Treatment	Non-weeded	Mulched-weeded	Weeded-only
Mean	5.88	14.13	13.34

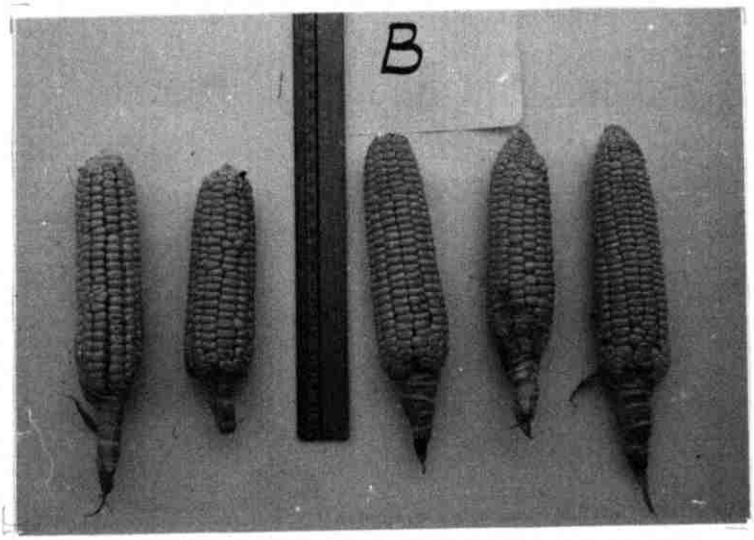
Interaction: Moisture treatment x cultural practice

Treatment	Non-irrigated x non-weeded (A)	Non-irrigated x weeded-only (C)	Non-irrigated x mulched-weeded (B)	Irrigated x non-weeded (D)	Irrigated x weeded-only (E)	Irrigated x mulched-weeded (F)
Mean	-	10.94	11.63	11.75	15.75	16.63

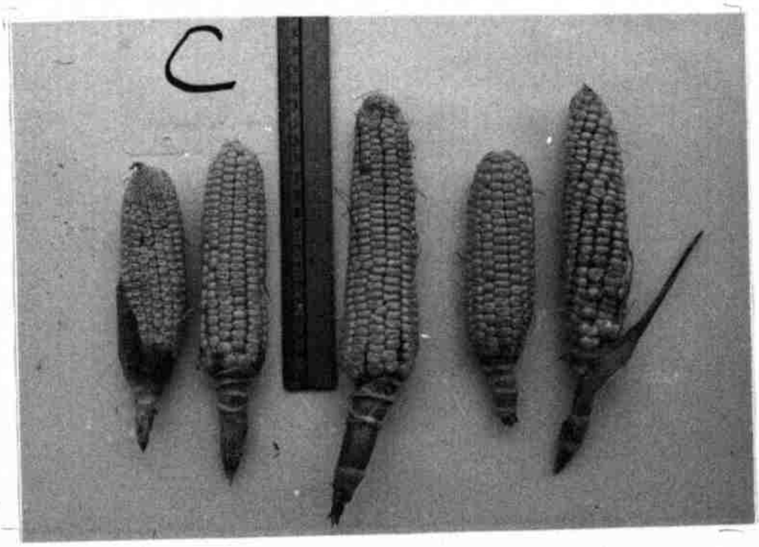
* Means joined by the same sub-line do not differ significantly at P = 0.01
- No ears were harvested ( ) Treatment code



All treatments
Sample ear
comparison



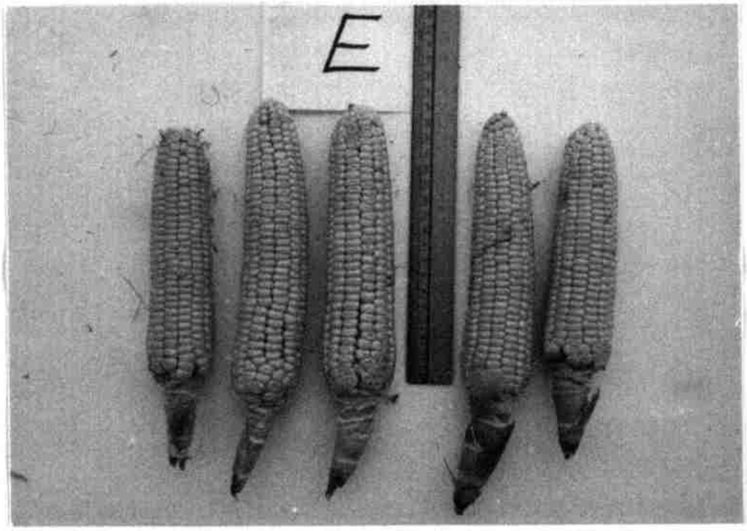
Treatment B*
Non-irrigated x
mulched-weeded



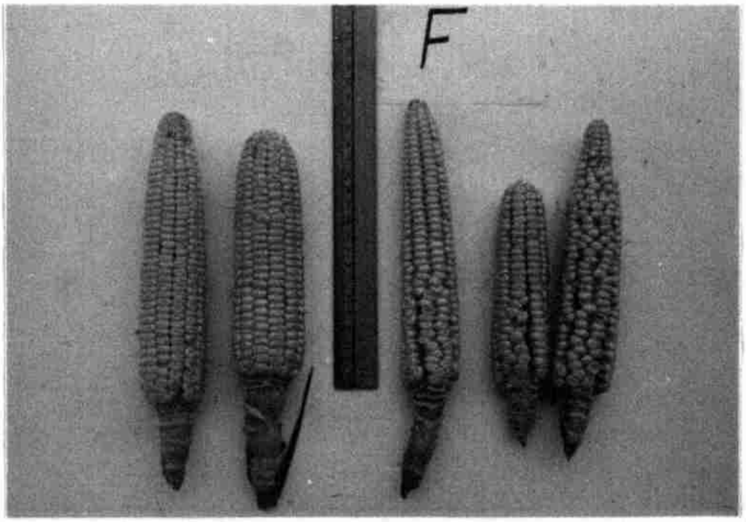
Treatment C
Non-irrigated x
weeded-only

* Treatment A had no ears

Treatment D
Irrigated x
non-weeded



Treatment E
Irrigated x
mulched-weeded



Treatment F
Irrigated x
weeded-only

ears longer than those of non-weeded plots and the difference was highly significant (P = 0.01).

Irrigated x mulched-weeded plots (treatment E) had the longest ears (16.63 centimeters) followed by those of irrigated x weeded-only plots (15.75 centimeters). Both had significantly longer ears than those of irrigated x non-weeded (11.75 centimeters) non-irrigated x mulched-weeded treatment (10.94 centimeters). Non-irrigated x non-weeded plots produced no ears (Photographs, pages 46 and 47) of corn.

Stover Yield

Moisture level, cultural practice and interaction moisture level x cultural practice had highly significant effects on stover yield of sweet corn plants (table 15).

Irrigated plots had significantly higher stover yield (220 kilograms per dunum) than those that received no supplementary water (55 kilograms per dunum). There was no statistical difference in the stover yield between mulched-weeded (treatment B and E) and weeded-only plots (treatments C and F), but plots that were mulched-weeded and weeded-only had a significantly (P = 0.01) higher stover yield than the non-weeded plots (treatments A and D). Irrigated x mulched-weeded plots (treatment E) gave the highest stover yield (288 kilograms per dunum) followed by irrigated x weeded-only plots (treatment F) with 285 kilograms per dunum. The difference was not statistically significant. Non-irrigated x non-weeded plots (treatment A) had the lowest stover yield (0.1 kilograms per dunum). Non-irrigated x weeded-only, irrigated x non-weeded and non-irrigated x mulched-weeded plots (treatments B, C and D) had intermediate stover yields of 76, 84 and 91 kilograms per dunum respectively, with no statistically significant differences found among them. They had, however, significantly lower yields

Table 15. Comparison of sweet corn stover yield* (kilograms per dunum) produced under various moisture treatments and cultural practices.

Treatment	Non-weeded	Mulched-weeded	Weeded-only	Mean of moisture level (kgs/dunum)
Irrigated	88.90	287.75	285.00	220.55
Non-irrigated	0.10	90.90	75.50	55.50
Mean of cultural practice	44.50	189.31	180.25	

Main plot: Moisture treatment

Treatment	Irrigated	Non-irrigated
Mean	220.55	55.5

Sub-plot: Cultural practice

Treatment	Non-weeded	Mulched-weeded	Weeded-only
Mean	44.50	189.31	180.25

Interaction: Moisture treatment x cultural practice

Treatment	Non-irrigated x non-weeded (A)	Non-irrigated x weeded-only (C)	Irrigated x non-weeded (D)	Non-irrigated x mulched-weeded (B)	Irrigated x weeded-only (F)	Irrigated x mulched-weeded (E)
Mean	0.10	75.50	88.90	90.90	285.00	287.75

* Means joined by the same sub line do not differ significantly at P = 0.01

( ) Treatment code

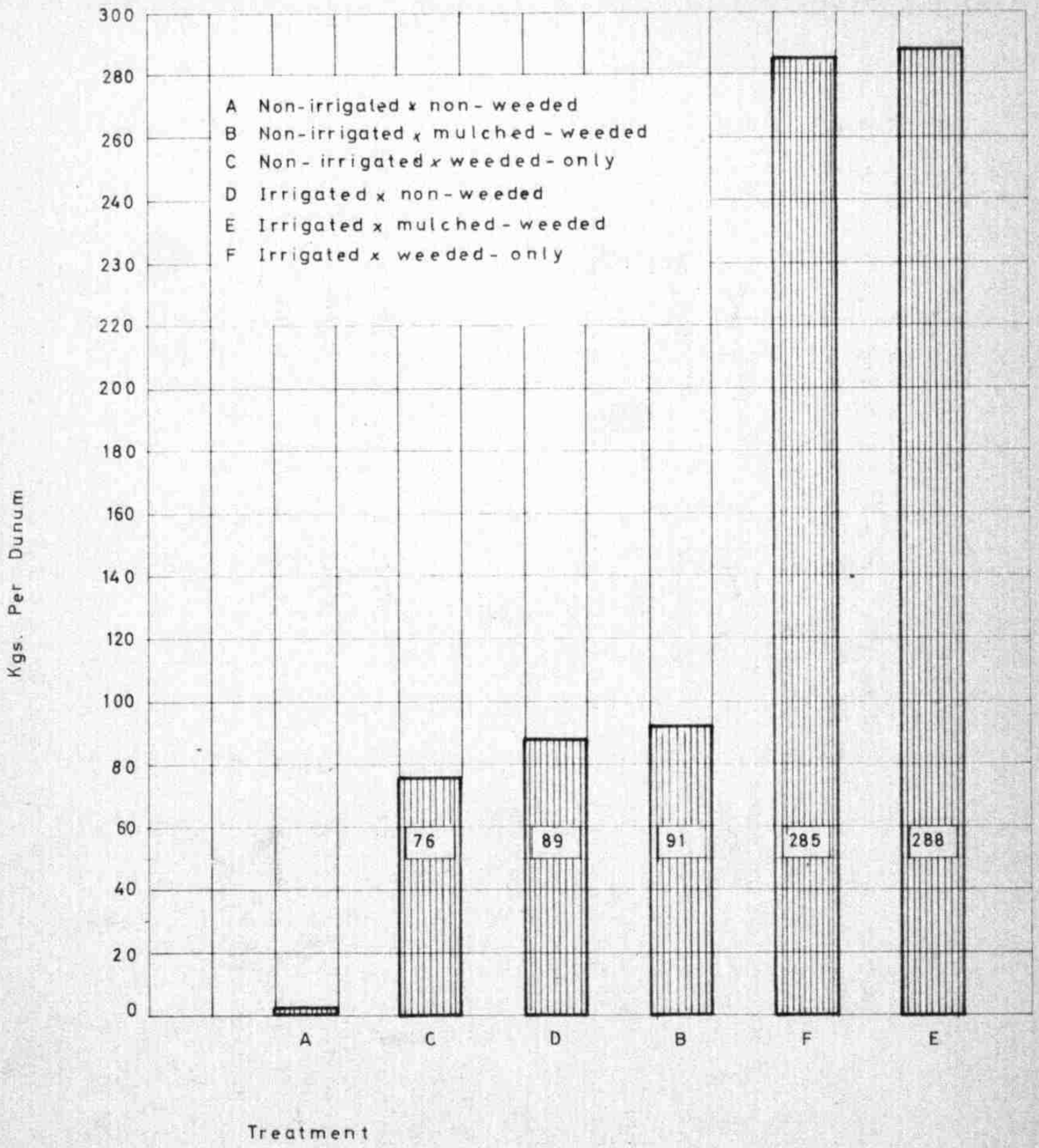


Figure 2 - Comparison of stover yield according to treatment A, B, C, D, E & F.

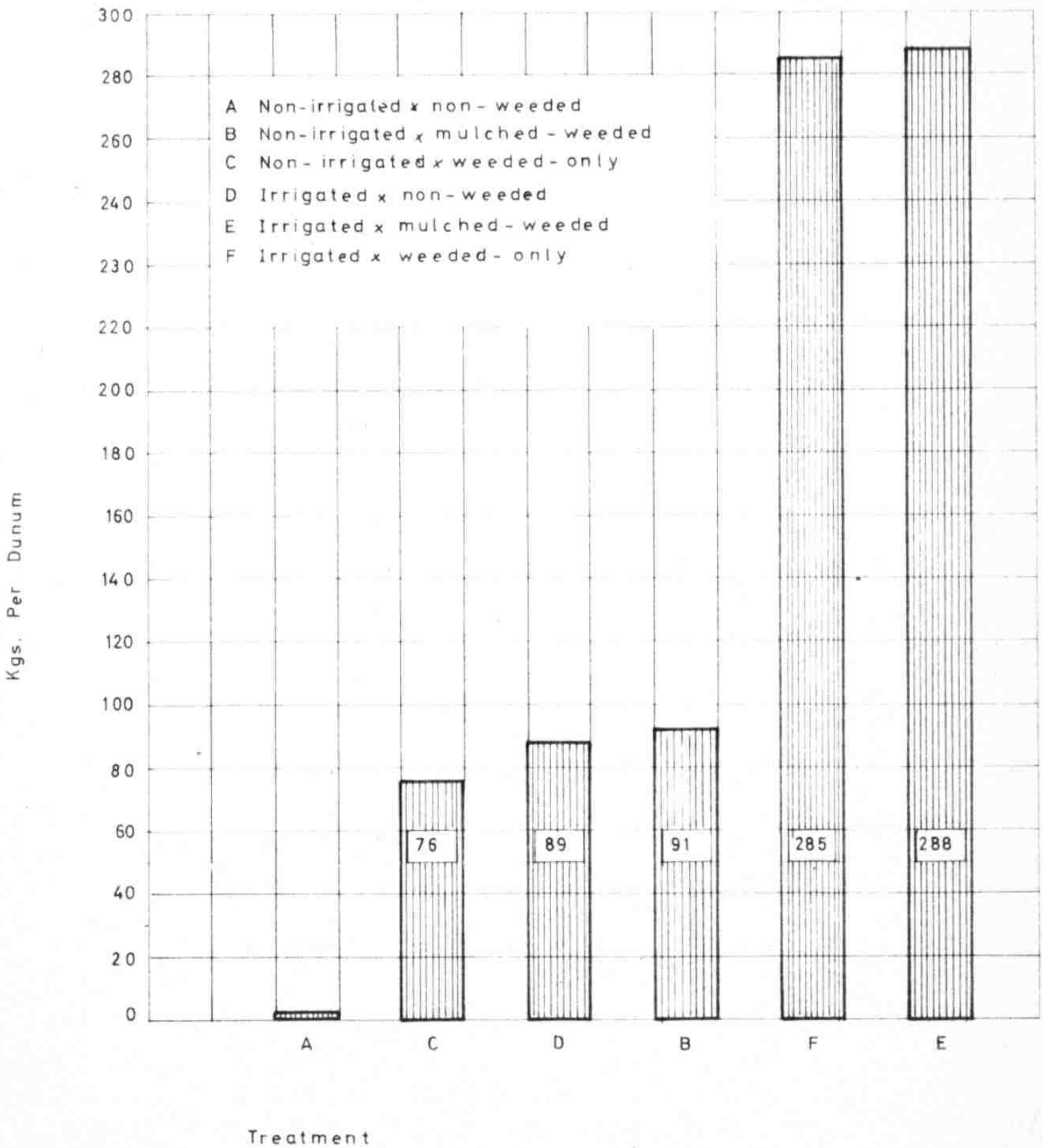


Figure 2 - Comparison of stover yield according to treatment A,B,C,D,E & F.

than treatments F and E, and significantly higher yields than treatment A (figure 2).

Stover yields were affected mainly by moisture supply and weed competition and these factors had a greater effect than petroleum mulch. It is evident that the initial gain in plant size due to petroleum mulch at the early stages of development was levelled off at later stages of growth by the limited moisture supply.

Soil Moisture Studies

Percent available soil moisture fluctuations at ten (table 16), twenty-five (table 17 and figure 3) and forty centimeter depths (table 18 and figure 4) under the different treatments were recorded throughout the growing season (April 1 to July 2, 1964).

Available Soil Moisture at Ten Centimeter Depths

Until April 23, percent available soil moisture at ten centimeter depths was maintained at one hundred percent availability. Total rainfall before April 1 was 433.3 millimeters (table 1). A total of 13.9 millimeters of rainfall was recorded between 10 and 17 for that month. After April 17 a depletion of available soil moisture was noticed. The last rains for this year came during the month of May (23.7 millimeters of rainfall were recorded for the period May 5 to May 9) which restored part of the depleted soil moisture. On May 27 the percent available soil moisture was zero (table 16). It was observed that soil moisture at this depth was mainly influenced by environmental conditions. It was found from this data that the different treatments had no observable influences on soil moisture at ten centimeter depths and no pattern could be established for the depletion process. Any deductions drawn from the obtained data of the moisture blocks

Table 16. Percent available soil moisture at ten centimeters depth under irrigated and dryland plots of non-weeded, mulched-weeded and weeded-only treatments during the period April 1 to July 2, 1964.

Date	Irrigated			Dryland		
	Non-weeded	Mulched-weeded	Weeded-only	Non-weeded	Mulched-weeded	Weeded-only
April 1-23	100	100	100	100	100	100
April 30	85	90	80	85	90	80
May 7	70	50	55	70	50	55
May 17	95	75	100	95	75	100
May 27	0	0	0	0	0	0
May 29	100	100	100	0	0	0
June 5	10	0	30	0	0	0
June 17	0	0	0	0	0	0
June 19	100	100	100	0	0	0
June 23	85	60	95	0	0	0
July 2	0	0	0	0	0	0

Table 17. Percent available soil moisture at twenty-five centimeters depth under irrigated and dryland plots of non-weeded, mulched-weeded and weeded-only treatments during the period April 1 to July 2, 1964.

Date	Irrigated			Dryland		
	Non-weeded	Mulched-weeded	Weeded-only	Non-weeded	Mulched-weeded	Weeded-only
April 1-30	100	100	100	100	100	100
May 17	100	100	100	100	100	100
May 27	0	38	80	0	38	80
May 29	100	100	100	0	25	52
June 3	75	62	70	0	0	0
June 5	38	12	25	0	0	0
June 17	0	0	0	0	0	0
June 19	100	100	100	0	0	0
June 23	92	60	80	0	0	0
July 2	0	0	0	0	0	0

Table 18. Percent available soil moisture at forty centimeters depth under irrigated and dryland plots of non-weeded, mulched-weeded and weeded-only treatments during the period April 1 to July 2, 1964.

Date	Irrigated			Dryland		
	Non-weeded	Mulched-weeded	Weeded-only	Non-weeded	Mulched-weeded	Weeded-only
April 1-30	100	100	100	100	100	100
May 17	100	100	100	100	100	100
May 27	75	85	95	75	85	95
May 29	100	100	100	55	60	70
June 3	75	45	55	0	0	0
June 5	60	15	40	0	0	0
June 17	0	0	0	0	0	0
June 19	100	100	100	0	0	0
June 23	95	62	85	0	0	0
July 2	0	0	0	0	0	0

readings would be speculative. However, by sampling mulched and non-mulched plots on April 9 it was found that mulched rows had three percent more moisture under the mulch band than under the non-mulched rows (20.49 percent versus 23.37 percent moisture). Further soil sampling on April 29 and May 17 revealed that moisture percentages were almost identical under mulched and non-mulched rows (table 19). After May 9, plots of treatments A, B and C did not receive water either as rain or as supplemental irrigation. Plots of treatments D, E and F, however, received two irrigations on May 29 and June 19. After each irrigation, soil moisture depletion was maximum under the mulched plots (treatment E) and least under weeded-only plots (treatment F), while non-weeded plots (treatment D) had intermediate values.

Available Soil Moisture in the Zone Between Twenty-Five and Forty Centimeters Depths

At twenty-five and forty centimeters depths, available soil moisture was maintained at one hundred percent availability until May 17 after which a steady decrease in availability was noted. This was probably due to a deeper penetration in that zone by the growing roots and to depletion of soil moisture in the top twenty centimeters of the soil by evapo-transpiration and consequent upward movement of water. Thus at twenty-five and forty centimeter depths, water availability was maintained at one hundred percent level twenty four days longer than at ten centimeter depths. From this we can deduce that sweet corn roots were extracting the needed water until May 27 mainly from the top twenty-five centimeters of the soil. After that date, the roots were drawing up moisture from the zone between twenty-five and forty centimeter depths. Percent soil mois-

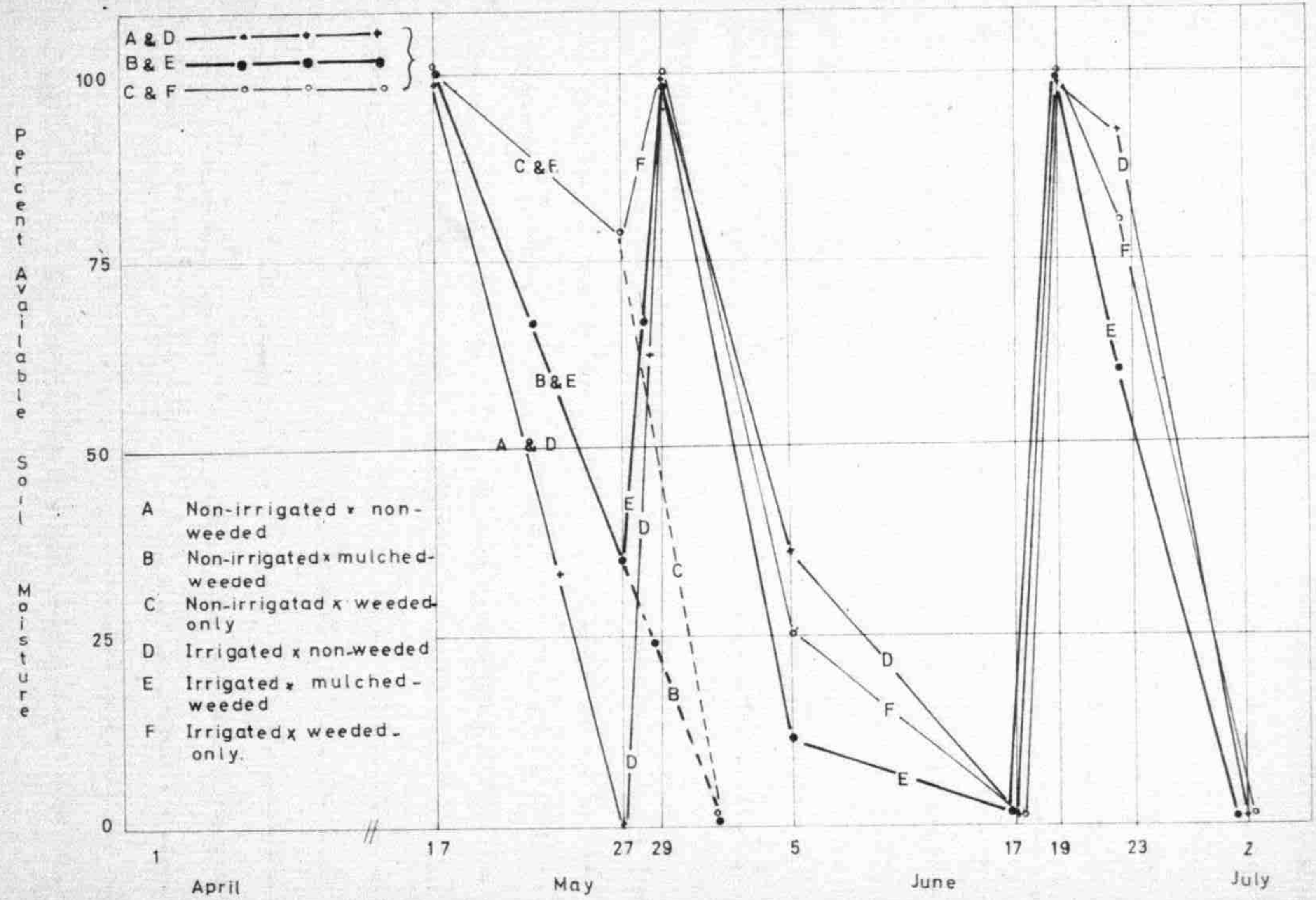


Figure 3 - Percent available soil moisture at twenty five centimeters deep under treatments A, B, C, D, E & F during the period April 1 to July 2, 1964

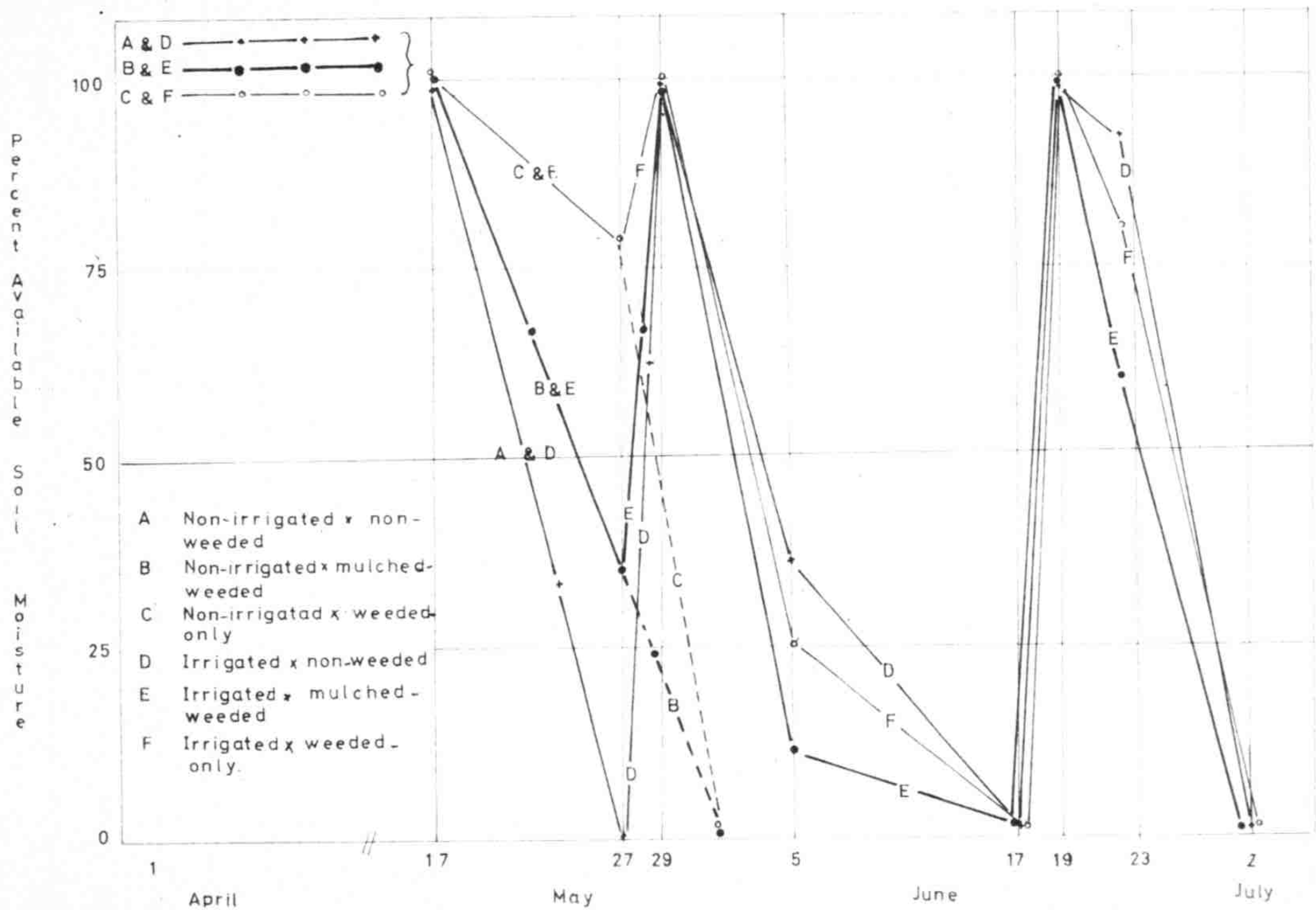


Figure 3 - Percent available soil moisture at twenty five centimeters deep under treatments A, B, C, D, E & F during the period April 1 to July 2, 1964

Table 19. Comparison of percent soil moisture at ten, twenty-five and forty centimeters depths under twelve inches wide mulch band and bare surface.

Depth centi-meters	Treatment	Percent soil moisture on: April 9	April 23	May 19
10	Mulched surface	23.37	21.89	20.16
	Bare surface	20.49	21.73	20.51
25	Mulched surface	21.86	20.96	20.26
	Bare surface	21.31	20.89	20.29
40	Mulched surface	21.26	19.93	19.36
	Bare surface	21.40	18.13	19.47

ture determinations by sampling the soil at twenty-five and forty centimeter depths on April 9, April 23 and May 19 revealed no differences in moisture between mulched and non-mulched plots (table 19).

Maximum depletion of available soil moisture at both depths was under non-weeded plots (treatments A and D) and the least depletion was under weeded-only plots (treatments C and F), while mulched-weeded plots (treatments B and E) had intermediate values. The rate of moisture depletion was faster at twenty-five than at forty centimeter depths (figure 3 and 4). Zero percent availability at twenty-five centimeter depths (table 17) was recorded at about one week earlier (May 27) in the non-irrigated x non-weeded plots than in other plots (about June 3). Depletion pattern is in accordance with the findings of Russell and Danielson (40).

At forty centimeter depths, all the non-irrigated plots reached zero percent availability about June 3. This was due to the fact that at twenty-five centimeter depths roots of weeds in addition to the corn roots were also extracting moisture, while at forty centimeter depths only the corn roots were extracting the available soil moisture since the shallow root system of the weeds did not reach to this depth.

Following each of the two irrigations, maximum depletion of available soil water at both depths was under mulched-weeded plots (treatment E), while non-weeded plots (treatment D) had the least depletion, with weeded-only (treatment F) having intermediate values (figures 3 and 4). This depletion was more intensive at twenty-five than at forty centimeter depths.

These findings could be explained on the basis that non-weeded plots had mainly shallow rooted plants, the weeds, which formed a cover inducing cooler soil temperatures, with few corn plants which were small and

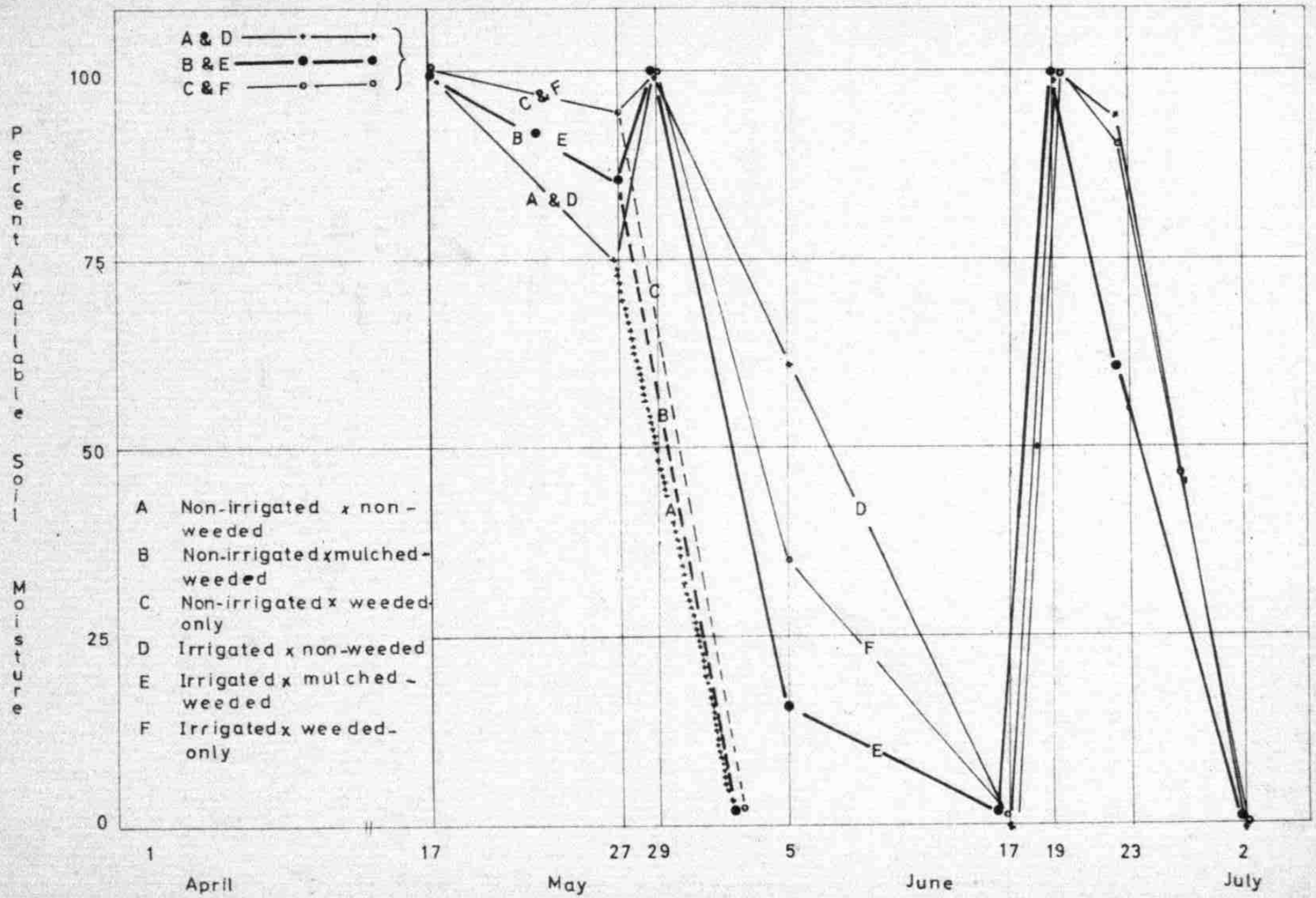


Figure 4 - Percent available soil moisture at forty centimeters deep under treatments A, B, C, D, E & F during the period April 1 to July 2, 1964.

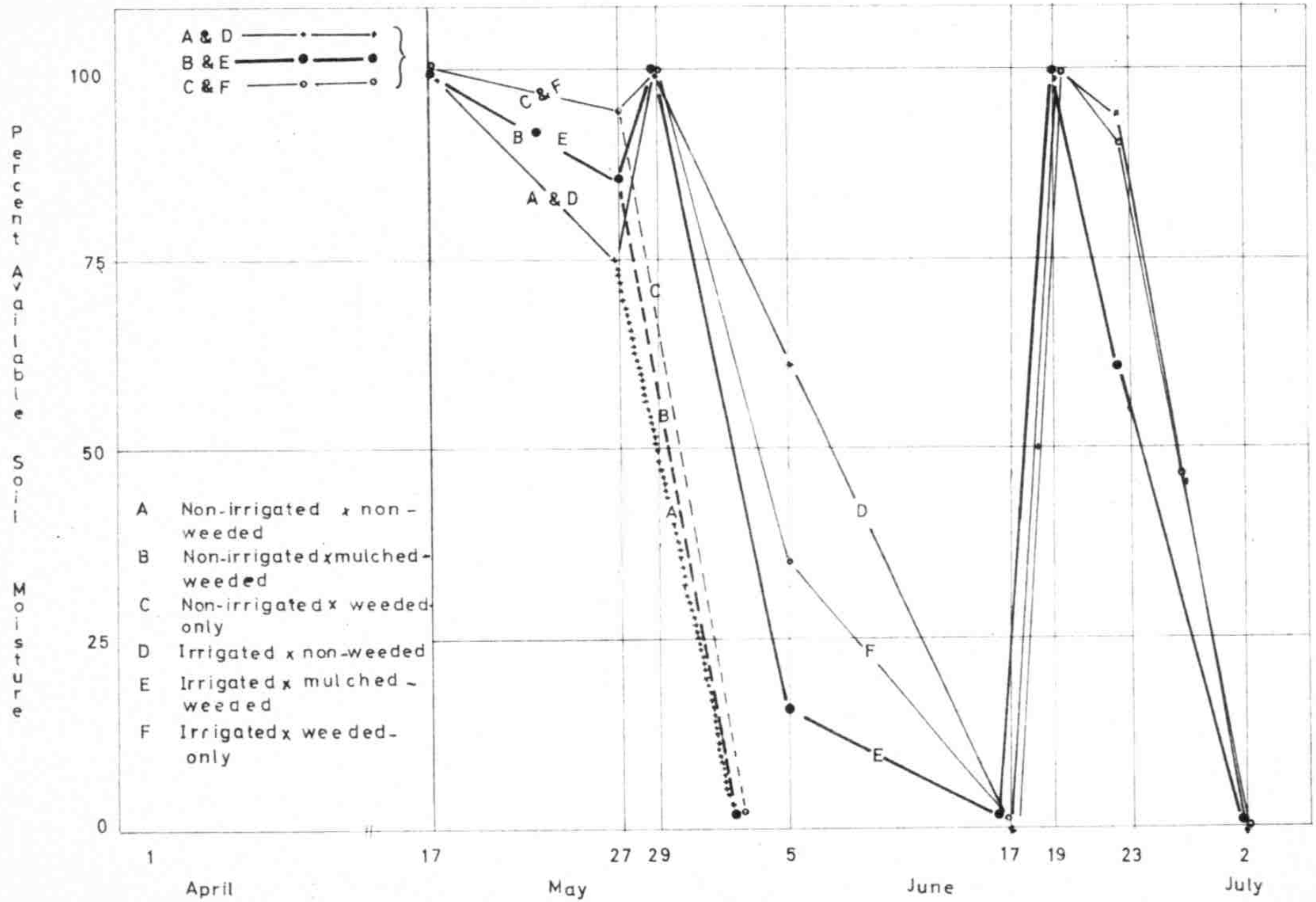


Figure 4 - Percent available soil moisture at forty centimeters deep under treatments A, B, C, D, E & F during the period April 1 to July 2, 1964.

weak. Thus moisture depletion was less intensive than that of other plots which had a greater number of vigorous deep-rooted corn plants. These moisture data further proves that plants of mulched-weeded plots were able to draw more moisture at comparable depths than those of weeded-only plots only because they were more vigorous and had larger and more extensive root systems. Those results are in agreement with those of Robinson (39) who found that a weed cover between the drill rows of flax resulted in a cooler soil and more soil moisture than when the flax fields were weed free.

Thus, it could be concluded that available soil moisture was depleted to the forty centimeter depths by June 3, weeds had an unnoticeable effect on soil moisture fluctuations before May 17, after which they competed drastically with the corn for the soil moisture. Evidence of possible water conservation by petroleum mulch film twelve inches wide was lacking. However, more vigorous plants with deeper root system were produced that required more soil moisture than plants of non-mulched plots. To further investigate the possibilities of water conservation by petroleum mulch film a pot experiment was conducted (appendix B).

Soil Temperature Fluctuations

As shown by figure 5 and the data in table 20, soil temperatures at a depth of six centimeters were higher under a twelve-inch-wide-petroleum-mulch band than under other treatments. This confirms that application of petroleum mulch results in an increase of the soil temperature of the seed microclimate to an optimum range. This further proves the work of Takatori et al. at California (49) who obtained an increase of 15°F at a depth of four centimeters under a mulch band twelve inches wide.

Until May 26, there was no difference in soil temperature among treatments A, C, D and F which had lower temperatures than those of treatments B and E at all times. A maximum difference of 11°F in soil temperature occured between 12:00 noon and 6:00 p.m., and a minimum difference of 2°F during the night between treatments B and E and treatments A, C, D and F.

Figure 5 indicates that soil temperature under all treatments had the same trend throughout the growing season. A thorough observation of the graph reveals that soil temperature of treatments B and E during the period of April 8 to May 5 at any time of the day was comparable to those of treatments A, C, D and F for the period May 6 to May 26. Thus the twelve-inch-wide-mulch band had a warming effect on soil microclimate equivalent to an elapse in time of approximately one month under normal planting conditions. The same graph points out that soil temperature under the mulch band warmed up faster in the morning and attained higher temperatures during the day time. Of particular interest is that, during the period from 6:00 p.m. to 10:00 p.m., when normally the air and soil temperatures drop, the mulched soils did not dissipate the warmth gained as quickly as the rest of the treatments and retained it for longer periods during the night.

As the season advanced, differences in soil temperature among the various treatments became smaller and almost negligible. This could be attributed to the deterioration of the mulch film and to the high air temperatures towards the end of May. It should be emphasized that since the mulch is not expected to maintain its film properties for more than six weeks after its application, it had served its full purpose of plant growth.

Soil moisture had a bearing on soil temperature. Treatments which did not have additional water in May and June had higher temperatures treatments B and E at all times. A maximum difference of 11°F in soil temperature occured between 12:00 noon and 6:00 p.m., and a minimum difference of 2°F during the night between treatments B and E and treatments A, C, D and F.

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Table 20. Comparison of weekly average of daily soil temperature fluctuations (^{o}F) at six centimeter depths under non-weeded, mulched-weeded and weeded-only treatments before irrigation, with weekly maximum and minimum air temperatures.

Week	Time	Non-weeded	Mulched-weeded	Weeded-only	Air temperature Max.	Min.
April 1-7	22 - 8	51	52	50		41
	8	52	54	51		
	12	68	80	67		
	12 - 18	73	84	73	69	
	18	65	71	65		
	22	55	59	56		
April 8-14	22 - 8	46	47	46		36
	8	51	52	50		
	12	58	65	56		
	12 - 18	62	73	62	54	
	18	55	59	55		
	22	52	57	52		
April 15-21	22 - 8	47	49	47		36
	8	52	56	52		
	12	68	77	66		
	12 - 18	69	79	69	57	
	18	60	67	60		
	22	57	64	58		

Table 20 (Continued).

Week	Time	Non-weeded	Mulched-weeded	Weeded-only	Air Temperature Max.	Min.
April 22-28	22 - 8	50	51	49		38
	8	56	61	55		
	12	72	79	71		
	12 - 18	76	84	74	66	
	18	68	72	68		
	22	59	70	60		
April 29-May 5	22 - 8	51	52	50		35
	8	56	60	55		
	12	70	75	69		
	12 - 18	72	77	71	62	
	18	65	68	63		
	22	60	65	61		
May 6-12	22 - 8	48	50	48		37
	8	57	60	56		
	12	69	74	68		
	12 - 18	70	76	72	62	
	18	63	68	64		
	22	60	67	61		

Table 20 (Continued)

Week	Time	Non-weeded	Mulched-weeded	Weeded-only	Air temperature Max.	Min.
May 13-19	22 - 8	53	55	53		39
	8	60	65	60		
	12	72	79	78		
	12 - 18	75	83	79	67	
	18	66	74	70		
	22	60	70	66		
May 20-26	22 - 8	59	60	56		45
	8	72	75	71		
	12	78	84	81		
	12 - 18	79	85	83	76	
	18	72	78	75		
	22	70	73	70		

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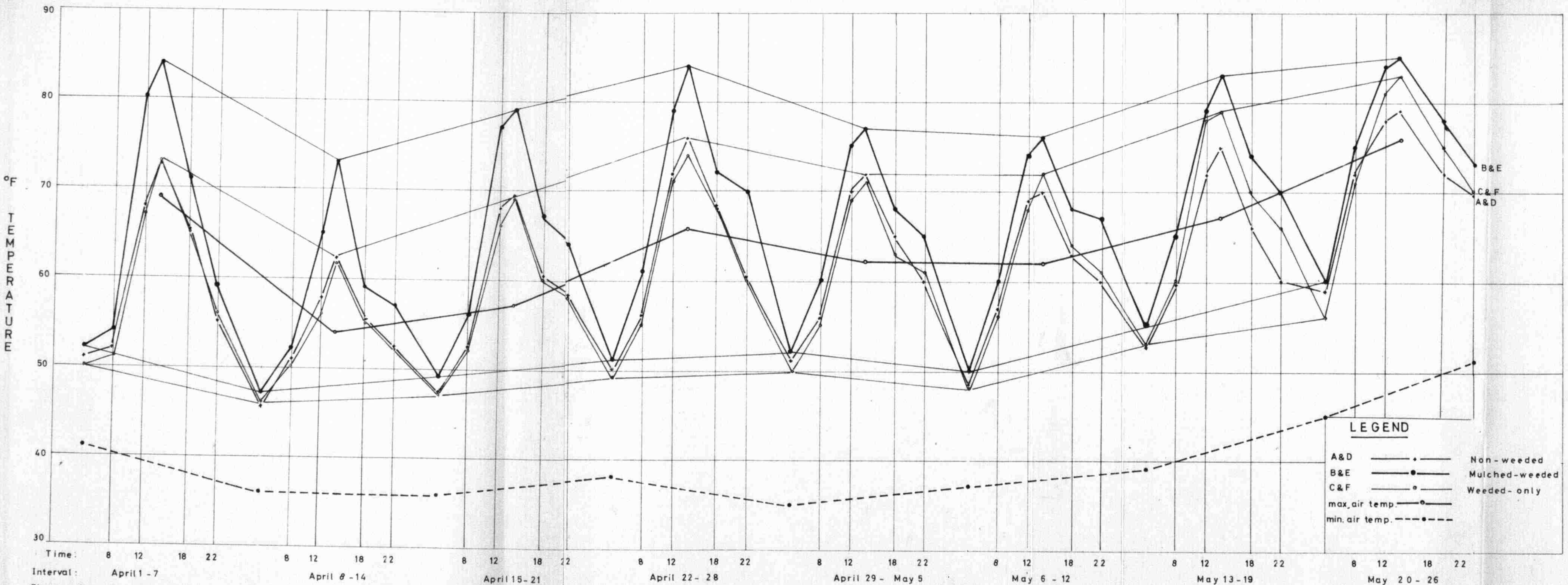
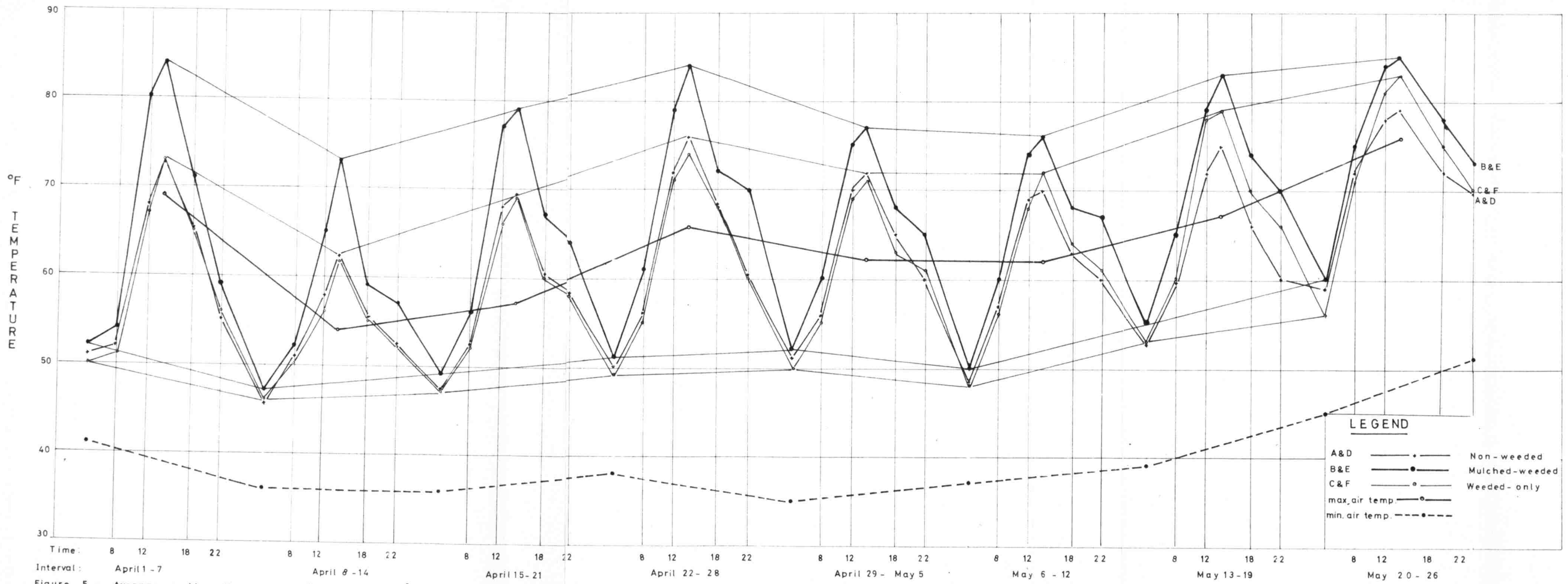


Figure 5 - Average weekly soil temperature* fluctuations (°F) six centimeters deep under treatments A&D, C&F, B&E are plotted against maximum and minimum air temperatures.

*Each point on the graph is the average of seven readings taken at the specified time during each week.



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*Each point on the graph is the average of seven readings taken at the specified time during each week.

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than those that did (figure 6 and table 21). No temperature differences between treatments A and B were apparent, but there was an 8°F maximum difference between treatment E and treatments D and F. This difference was not expected since the mulch film was washed out during the first irrigation on May 29, and if any differences were to be found it would have been among treatment B and treatments A and C, for traces of the mulch film were still present. An explanation to this could be that either the soil over the sensitive tip of the thermometer was cracked or that its soil cover was washed away thus exposing it to the sun rays. During the period of May 13 to June 10, soil temperature was lower under treatments A and D than under the rest of the treatments, because during that period the weed population of those treatments had attained their maximum growth, forming a continuous cover which had a shading effect thus inducing a lower soil temperature. Following that period, the weeds on the non-irrigated plots (treatment A) died and the shading effect was eliminated. On the irrigated plots (treatment D) the weeds continued growing, but there was no temperature difference between treatment D and treatment F because the irrigation water eliminated this difference as the cooling effect was greater than the shading effect of the weed population.

Due to the dark color, the high solar absorptivity and the mulch-to-soil contact function of petroleum mulch, soil temperatures under treatments B and E were higher than those of other treatments. Better conduction of heat by petroleum mulch is due to the formation of a film that becomes an integral part of the soil surface.

Soil temperature response due to a petroleum mulch film was largest during day light hours. The loss of heat by free radiation was rapid during the evening but slower than from a mulch-free surface with

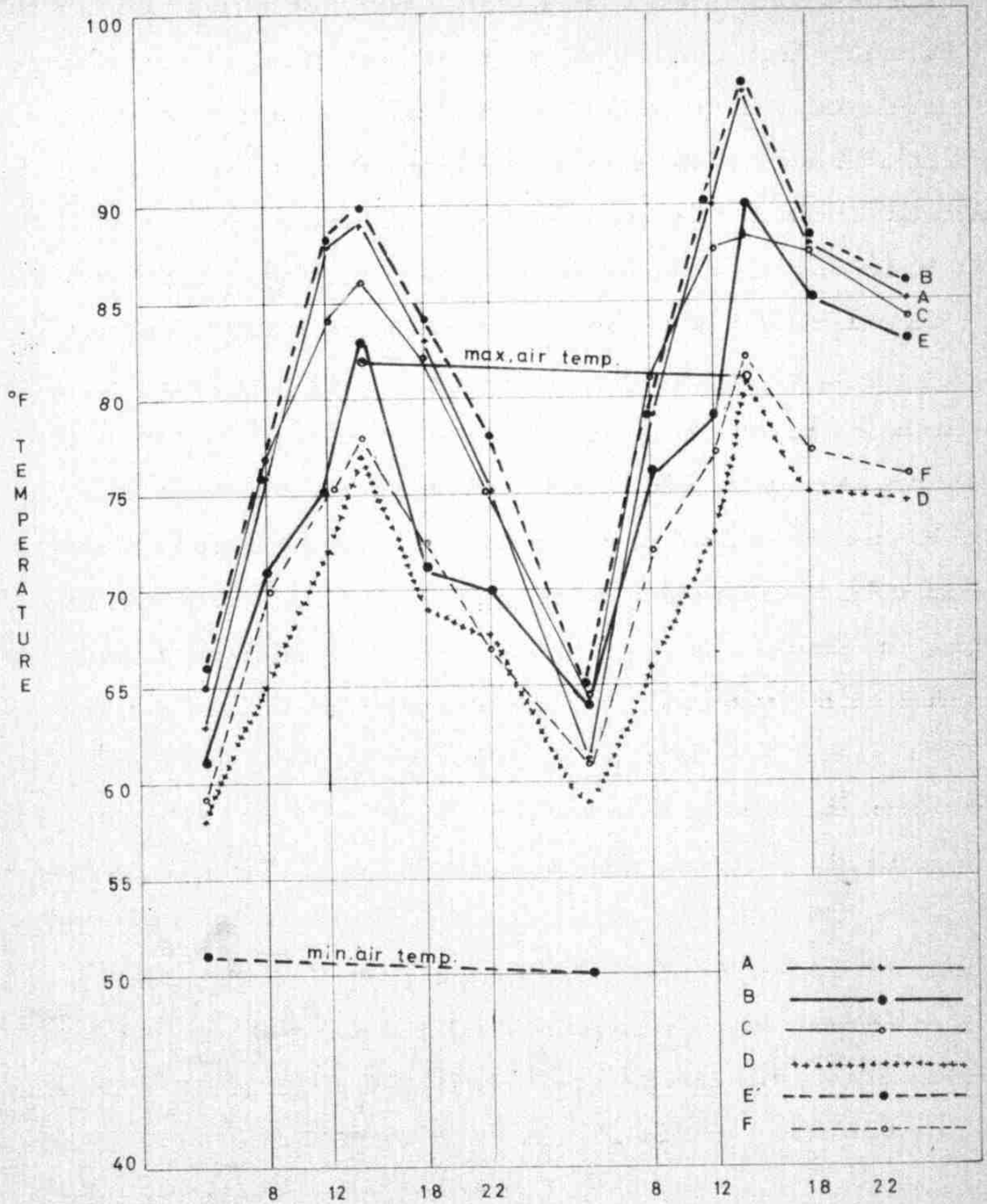

Figure 6 - Average weekly soil temperature fluctuations* (°F) six centimeters deep under irrigated (treatments D, E & F) and non-irrigated (treatments A, B & C) plots are plotted against maximum and minimum air temperatures.

*Read in figure 5.

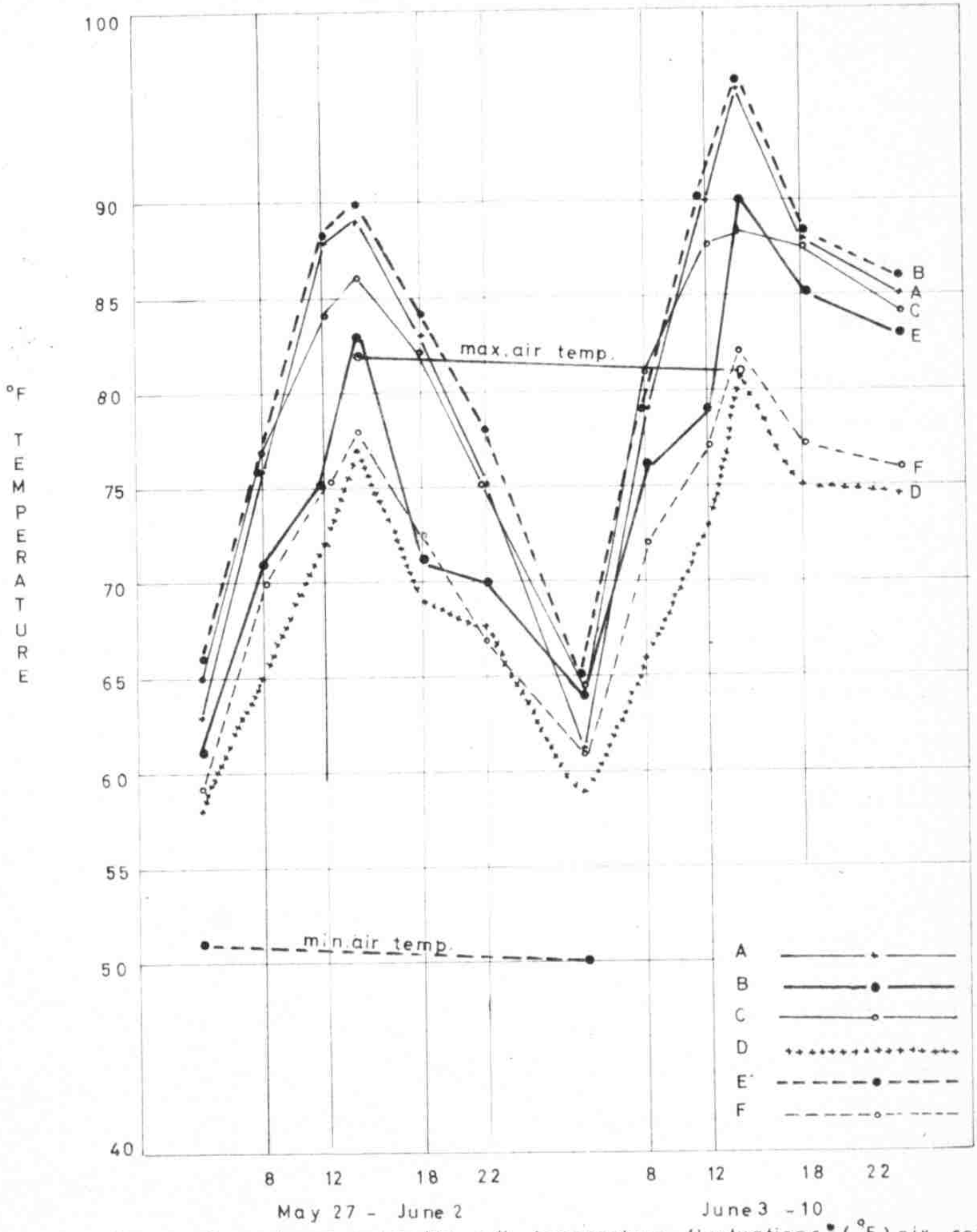

Figure 6 - Average weekly soil temperature fluctuations* (°F) six centimeters deep under irrigated (treatments D, E & F) and non-irrigated (treatments A, B & C) plots are plotted against maximum and minimum air temperatures.

*Read in figure 5.

Table 21. Comparison of weekly average of daily soil temperature fluctuations (^{o}F) at six centimeter depths under non-weeded, mulched-weeded and weeded-only of dryland and irrigated treatments with weekly maximum and minimum air temperatures during the period of May 27 to June 10, 1964,

		Non-weeded		Mulched-weeded		Weeded-only		Air temp.	
Week	Time	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Irrigated	Non-irrigated	Max.	Min.
May 27-June 2	22 - 8	59	65	61	66	58	63		51
	8	70	77	71	76	65	76		
	12	75	84	75	88	72	88		
	12 - 18	78	86	83	90	77	89	82	
	18	72	82	71	84	69	83		
	22	67	75	70	78	68	75		
June 3-10	22 - 8	61	65	64	65	59	61		50
	8	72	81	76	79	66	79		
	12	77	86	79	80	73	90		
	12 - 18	82	89	90	96	81	96	81	
	18	77	86	85	88	75	88		
	22	76	84	83	86	75	85		

little retention of heat during the hours of darkness.

Takatori et al. (49) found as petroleum mulch band width increased, soil temperature increased markedly up to the six-inch width, and that differences in soil temperature between the six-, twelve- and twenty four-inch bands were small and for most practical purposes insignificant.

Under the climatic and soil conditions of the Beqa'a, a mulch band twelve inches wide would warm up the soil earlier in the morning, induce higher day-time temperatures and retain the heat for longer periods into the night. It would also supply a warming effect comparable to an elapse of one month in the spring. As a result of warming up the soil, an earlier planting of one month and a consequent earlier harvest were possible.

SUMMARY AND CONCLUSIONS

Three dates of planting (April 4, April 27 and May 17), two sweet corn varieties (Spancross and Ioana) and mulch bands of variable widths (four-, eight- and twelve-inch wide) were studied in a dryland petroleum mulch experiment, conducted at the Agricultural Research and Education Center during the 1962-1963 season.

Data obtained on ear yield, plant height at harvest, ear length and width, number of barren stalks and stover yield indicate that the heaviest ear yield (116 kilograms per dunum) was obtained with the earliest planting date (April 4, 1963) and the lowest yield was obtained with latest date (May 17, 1964). The data further proves that under dryland conditions the short-growing season variety (Spancross) outyielded the long-growing period variety (Ioana) by 71 kilograms of husked ears per dunum (112 versus 41 kilograms per dunum for Spancross and Ioana varieties, respectively). Spancross variety had significantly ($P = 0.01$) shorter plants and less barren stalks than Ioana. This indicates that the limited available water and nutrients were channelled to bearing ears in the Spancross variety rather than producing excessive vegetative plant growth as in the Ioana variety. The widths of the petroleum mulch bands (four-, eight- and twelve-inch wide) had no significant effects on any of the observed characteristics. There did exist, however, a trend in favor of the twelve inches wide petroleum mulch band. The lack of differences among the mulched and non-mulched plots could be attributed to limiting available soil moisture which was not sufficient to maintain the vigorous plant growth of the mulched plots obtained in the early season.

It could then be concluded from this experiment, that under the climatic conditions prevailing at the Agricultural Research and Education Center, water is the limiting factor in crop production and any cultural practice enabling better utilization of the available soil moisture would result in substantially increased yield returns. Early planting dates and short growing period varieties are strongly recommended for dryland agriculture such as that in the Beqa'a Plain.

During the 1963-1964 growing season, a petroleum mulch experiment was conducted under both dryland and irrigated conditions (limited amount of irrigation water) with varying hand-weeding practices.

A petroleum mulch band, twelve inches wide was found to advance the emergence of sweet corn seedlings in the spring by one week. Rate of plant growth in centimeters per week was, until the 47th day after planting, greater under the mulch treatment (average 6.6 centimeters per week) than under bare soil (4.5 centimeters per week). There was no difference between weeded and non-weeded plots. As soil moisture became limited between May 18 and 27, the rate of plant growth under bare soil was greater than of that under the mulch treatment.

After the first irrigation, however, plants of the mulched treatment had maximum rate of plant growth (31.2 centimeters per week), while plants of non-weeded plots had the least rate of growth (10.6 centimeters per week), with those of weeded-only having an intermediate value (23.1 centimeters per week). Hence petroleum mulch band twelve inches wide stimulated a faster rate of plant growth than a bare surface. Weeds had a negligible effect on the rate of plant growth until the fifty seventh day following planting, after which they severely retarded plant growth. Ear yields varied greatly with the different treatments.

A significant yield difference between mulched and non-mulched treatments was found only in the irrigated plots while no such difference was found under dryland conditions and this further confirms the results of the 1963 experiment. The highest yield was obtained from the irrigated x mulched-weeded plots (607.3 kilograms per dunum) while irrigated x weeded-only plots produced a lower yield (447.2 kilograms per dunum) and the difference was highly significant. Non-weeded plots produced the lowest yield under irrigated conditions, (107.1 kilograms per dunum) while under dryland conditions no ears were produced. This is due to severe competition between the corn plant and weeds for moisture and nutrients. Irrigated x mulched-weeded plots produced the heaviest ears (143.0 grams per ear) while irrigated x weeded-only plots produced lighter ears (120 grams per ear) and the difference was highly significant. However, no significant differences were found among the ears of non-irrigated x weeded-only, irrigated x non-weeded and non-irrigated x mulched-weeded treatments. Mulched-weeded plots had more ears per plant (1.11 ears per plant) than the other treatments (0.90 and 0.24 ears per plant for weeded-only and non-weeded treatments, respectively). Only one significant difference in stover yield was found between irrigated and non-irrigated treatments. Thus, a mulch band twelve inches wide supported more vigorous plants which produced more and heavier ears and consequently a greater yield than a bare surface and this was true only under irrigated conditions. Weeds under both irrigated and dryland conditions depressed the yield and the effect was more severe under dryland conditions.

Moisture depletion was maximum under the mulched-weeded plots and least under the non-weeded plots with those of weeded-only having an intermediate value. Hence, in the field experiment, no indication of moisture conservation by the mulch band was detected, however, it is evident that the more vigorous plants of mulched plots with their extensive root system were able to pump the available soil moisture faster than those plants receiving other treatments. The pot test indicated that a petroleum mulch film does conserve more moisture than a bare surface, therefore, any possible moisture conservation under the mulch band in the field was utilized by the growing corn plants. Early in the season, the annual weeds depleted the soil moisture but later on they acted as barrier which reduced evaporation.

Soil temperature six centimeters under the mulch band was higher than under a bare surface by a maximum of 11°F during the month of April which is the critical period in the early stages of plant growth. Under the climatic conditions of the Beqa'a, therefore, a mulch band twelve inches wide warmed up the soil earlier in the morning, induced higher day-time temperatures and retained the heat for longer periods into the night. It also supplied a warming effect comparable to an elapse of one month in the spring. As a result of warming up the soil, an earlier planting of one month and a consequent earlier harvest were possible. As the season advanced, differences in soil temperature among the various treatments became smaller and almost negligible due to the deterioration of the mulch film. Irrigation water and weed cover induced lower soil temperatures due to their cooling effects which subdued the mulch effect. Temperature differences were due to the higher absorptivity of the dark colored mulch film and its intimate contact with the soil surface.

Thus, the data obtained indicate that a petroleum mulch band twelve inches wide had favorable effects on plant emergence, rate of growth, ear yield and soil temperature. Yield increase over non-mulched plots was obtained only when the soil moisture stress was removed during the critical period in the stages of plant development (tasseling to kernel formation). Petroleum mulch induced one week earlier plant emergence and supported more vigorous and bigger plants than a non-mulched surface. It raised the soil temperature at six centimeter depths by a maximum of 11°F during the month of April. Soil moisture stress, if continued throughout the growing season, was found to depress plant growth and to reduce yields tremendously. Limited amounts of irrigation water, however, that removed the soil moisture tension at certain stages during the plant growth, tripled the yield of ears and stover and accelerated the rate of plant growth. Weeds competed severely with the crop for moisture and their effect was more pronounced under dryland conditions where they smothered the sweet corn and resulted in its consequent death. Pot test data indicate that petroleum mulch did conserve moisture during a minimum period of one week which is the most critical period in plant establishment. The field experiment results support this but rather indirectly.

Economic analysis of the yield data indicate that under irrigated conditions, a petroleum mulch band twelve inches wide resulted in an increase of 160 kilograms per dunum in ear yield over a non-mulched surface which is equivalent to 95 dozens of ears (average ear weight = 140 grams) selling for about 95 Lebanese pounds. The total expenses of using petroleum mulch are estimated at 15 to 25 Lebanese pounds per dunum. Thus a net income of 70 to 80 Lebanese pounds per dunum which is profitable enough to recommend the practice of petroleum mulching provided more research verified these findings.

It is hoped that these experiments would seed the concept of soil mulching and incite further work on this subject to test various mulching materials with variable amounts of supplementary water.

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APPENDIX

A. Application Rate of Petroleum Mulch

At the Agricultural Research and Education Center, applying petroleum mulch at the recommended rate of 0.4 liter per square meter of 55 percent water emulsion was not sufficient to maintain a continuous film for longer than twenty-four hours after its application. The mulch film would crack in thin small flakes resembling cracking of a clayey surface following drying. The soil at the Center is of the clayey type predominent in 2:1 clays (Montmorillonite and illite) which expand upon wetting and shrink upon drying thus inducing cracks in the soil surface. The relatively thin film of petroleum mulch apparently had a lower expanding capacity than the soil and a weak structure unable to maintain its continuity under the forces exerted on it by the soil surface.

To determine a spraying rate that would maintain a continuous film on the soil of the Agricultural Research and Education Center a series of laboratory experiments were conducted in Abingdon, England at the Laboratories of Esso Research Limited during September 1963. Two soil types, one sampled from the experimental plots of the Agricultural Research and Education Center and the other sampled from the experimental plots of the Esso Research Limited were distributed to twenty four aluminium pans (sise 30 x 20 x 6 centimeters) then watered and packed uniformly. Application rates of 0.4, 0.8 and 1.2 liters of 55 percent water emulsion petroleum mulch per square meter replicated four times were applied on the two soils. The pans with the different rates were distributed at random in a glass chamber in which the air temperature was maintained at 28°C by means of flood lights.

Twenty four hours after it was applied, cracks in the mulch film were noticed in the pans containing the AREC soil with the application of 0.4 liter of mulch per square meter, no cracks were visible in the film on the Abingdon soil sprayed with an equivalent rate. The film with the 0.4 liters-per-square-meter spraying rate on the AREC soil was destroyed by a slight shower of water. None of the other films had any cracks during the duration of the experiment (one month) nor were they destroyed by slight showers of water.

From this experiment it was found that an application rate of 0.4 liters per square meter was not enough to maintain a petroleum mulch film on the AREC soil which might explain the failures encountered in obtaining a continuous film during the 1963 experiment. A heavier rate of application (0.8 - 1.2 liters per square meter) would maintain a continuous mulch film on the AREC soil.

In the 1964 experiment a spraying rate of 0.6-0.8 liters per square meter was applied on all the plots. The mulch film remained intact and maintained its structure and pliability for a minimum period of six weeks after spraying.

B. Moisture Studies in a Pot Test

July 9 - July 12, 1964

Six pairs of clay pots (diameter 15 centimeters, depth 14 centimeters) were each filled in the evening of July 9 with 2500 grams of air-dry top soil sampled from the experimental plots of the Agricultural Research and Education Center. To bring the soil to field capacity, nine hundred milliliters of water were added to each pot and left overnight for them to reach equilibrium. In the morning of July 10, petroleum mulch was sprayed on six pots at the rate of 0.8 liters of 55 percent emulsion petroleum mulch per square meter to fully cover the soil surface. The pots were set in pairs in open air on the roof of one of the AREC buildings. All pots were weighed regularly.

Average cumulative water loss per pot from 7:00 a.m. July 10 to 1:00 p.m. July 12 was 180.5 and 516 milliliters of water for mulched and non-mulched pots, respectively. The mulched pots lost significantly (P = 0.01) less water than the non-mulched pots (table 22).

The average rate of water loss during 52 hours (table 22) from the mulched pots was 3.5 milliliters per hour while that of the non-mulched pots was 9.9 milliliters per hour, and the difference was highly significant (P = 0.01).

Table 22. Comparison of cumulative water loss and rate of water loss* between mulched and non-mulched pots during the period 7:00 a.m. July 10 to 1:00 p.m. July 12, 1964.

Treatment	Total water loss (milliliters) until:						
	July 10 9:00	11:00	13:00	18:00	July 12 9:00	11:00	13:00
Blanket mulch cover	12.2	23.3	44.7	67.7	161.0	168.3	180.5
Bare surface	61.7	138.5	217.7	316.7	497.3	505.8	516.0
	Rate of water loss (milliliters per hour) until:						
	July 10 9:00	11:00	13:00	18:00	July 12 9:00	11:00	13:00
Blanket mulch cover	5.7	11.7	11.2	7.5	3.4	3.4	3.5
Bare surface	34.6	69.3	54.4	35.2	10.4	10.1	9.9

* All differences between mulched and non-mulched pots were significant at all periods (P = 0.01).