EFFECT OF IRRIGATION INTERVAL ON SEASONAL STOMATAL BEHAVIOR AND YIELD OF POTATOES AND CORN

by

Mohammed Byberdi

A Thesis Submitted to the Faculty

of Agricultural Sciences in Partial Fulfillment of

The Requirements for the Degree of

MASTER OF SCIENCE IN AGRICULTURE

Major: Soils

Minor: Irrigation

Approved:

H. D. Fuehring
In Charge of Major Work

[signature]

[signature]

Marcel Awad

[signature]
Chairman, Graduate Committee

American University of Beirut

1964

IRRIGATION INTERVAL

BYBORDI

ACKNOWLEDGEMENT

The author wishes to acknowledge with sincere gratitude and deep respect the constant guidance and supervision and constructive suggestions of Dr. Howard Dale Fuehring during the course of this experiment and his excellent remarks during the preparation of the manuscript.

Grateful acknowledgement is also expressed to Miss Armineh Bezdikian for typing this manuscript.

Mohammed Bybordi

ABSTRACT

The effects of irrigation interval on stomatal behavior and yield of the corn and potatoes were studied. The oil drop penetration method, as an indicator of the degree of stomatal opening, was related to the degree of soil moisture stress. Increasing the irrigation interval beyond one week reduced the corn and potato yields significantly. Return above labor cost was found to be highest from weekly irrigation interval for both crops. The stomatal opening technique worked well as an indicator of soil moisture status. The stomata closed gradually with depletion of soil moisture and the three-week irrigation interval had little effect on the subsequent behavior of stomata. The method must be calibrated with each species of the plant because of differences in the stomatal size. As a tentative recommendation, corn and potatoes should be irrigated when the leaves of the plants no longer absorb grades 10 and 7, respectively.

TABLE OF CONTENTS

LIST OF TABLES

Table		Page

LIST OF FIGURES

INTRODUCTION

Corn and potatoes are two of the major feed and food crops of the world. Potato (Solanum tuberosum L.) usually produces more food per unit area than is obtained from the cereal crops. Some 25 million hectares of potatoes are planted throughout the world, with an annual production of 280 million metric tons (6) and average yield per hectare of 11 tons. In Lebanon, the area is about 6,000 hectares, producing about 50,000 metric tons of potatoes annually (6) at a value of about L.L. 4,400,000 (1) with an average production of 8 tons per hectare.

Corn (Zea mays L.) is one of the most efficient sources of grain and roughage for livestock production because of the high yields obtainable on irrigated lands with adapted hybrids. At the same time there is a need for growing efficient feed crops in Middle East countries to boost the production of animal food products which are needed if the present protein deficient diet is to be alleviated. World production of corn is about 214 million metric tons produced from 103 million hectares, with an average yield of 2.1 tons per hectare (6). In Lebanon, about 6,000 hectares produce 12,000 metric tons of corn annually, with an average yield of 2 tons per hectare. The local production does not suffice the needs of the farmers and hence some is imported (about 9,000 tons in 1960) (32).

Corn and potatoes cannot be grown profitably without irrigation in the arid and semi-arid areas of the Middle East. Local laws concerning water rights are one of the conditioning factors in crop production of Middle East countries and much of the time irrigation water is delivered to the farmers at certain intervals not modifiable by farmers.

The determination of the optimum irrigation interval along with an easy technique whereby the soil moisture tension can be determined directly in the field is of vital importance to the farmers of this part of the world because water shortage is an ever-challenging problem.

The degree of stomatal opening has proved to be a good indicator of soil moisture status through use of the oil-drop technique but needs to be correlated for each crop species and climatic environment. The experiment reported here was conducted mainly at the Agricultural Research and Education Center, Beka'a plain, Lebanon, during 1963 to study the effect of irrigation interval on:

1. Stomatal behavior of corn and potato plants.
2. Yield of corn and potatoes.
3. Use of the oil-drop technique as a method for direct field determination of soil moisture depletion and irrigation timing for corn and potatoes.

REVIEW OF LITERATURE

The effect of soil moisture variations on crop growth has been the subject of much research particularly in irrigated agriculture. Most of the work reported has been limited to studies of plant response to different soil moisture levels and the results have indicated that both potato and corn have their peak water use and response to irrigation at certain stages of their growth period.

Effect of Irrigation on Corn

Robins and Domingo (28) showed that moisture depletion to the wilting point at the time of tasselling or pollination decreased maize yields by 22 and 50 per cent when the moisture deficit lasted for one to two and six to eight days respectively. They also concluded that the depletion of available soil moisture after maturity did not affect the yields and moisture content of the plants.

Somerhalder (35) found that once the needs of the corn plant are satisfied, added water is used less efficiently by producing little or no increase in yield. When there was no irrigation after planting, the yield was 111 bushels per acre, while a 3-inch pretassel irrigation produced 130 bushels per acre, and the last treatment produced 138 bushels with 8 inches of irrigation. The first three inches produced an increase of 19 bushels compared to an increase of 8 bushels for the additional five inches. Three irrigations centered on the pollination stage produced yields comparable to that where soil moisture tension was low up to time of maturity. Three irrigations applied on a 14-day rotation water delivery schedule produced similar yields.

Gard, et al. (8) used three levels of water supply 1. natural rainfall 2. rainfall with two 2-inch water applications and 3. rainfall with irrigation at the rate of 2-inches each week from the 7th to 12th week. The three year average corn yields for the respective three moisture levels with plow-down fertilizer applied were 90, 117, and 122 bushels per acre. The high moisture level plots received a 3-year average of 6.53 inches of irrigation and yielded 32 bushels per acre more corn than the nonirrigated. The medium moisture level plots received 4-inches of irrigation water and yielded 27 bushels per acre more corn than nonirrigated corn.

With respect to soil moisture, Kiesselbach (21) reported that severe early drouth resulted in stunted size and delayed silking with many partially or completely barren plants. Drouth following fertilization was observed to shorten the ears by drying back from the tip and to reduce the kernel size due to destruction of productive tissue. In a year of severe drouth, two supplemental irrigations of 3 inches each were reported to have increased fodder yields from 2.11 to 5.72 tons per acre and grain yields from none to 72.4 bushels per acre. The author suggested that two additional, well distributed, 3-inch irrigations would have raised the yield to about 115 bushels per acre on the experimental fertile soil.

From an eight year experiment Gertel et al. (9) concluded that the dryland yield of corn was 26.8 bushels per acre, while that of irrigated corn was 48 bushels per acre. Annual variations ranged from 2 per cent to 29 per cent of the mean for irrigated and 12 to 47 per cent for dryland.

Howe and Rhoades (15) found that the yield of grain ranged from 69 bushels per acre without irrigation during the growing season to 153 bushels per acre where a low soil moisture tension was maintained throughout the season by adding 14.2 inches of water to the soil in six irrigations. In general, an increase in the number of irrigations accompanied by a greater net input as irrigation water resulted in increased yields.

Singleton (33) used dry and wet treatment on corn. In the dry treatment the plots were not irrigated until the tension reached 4.1 atmospheres at nine-inch depth in the row. These plots received three irrigation and a total net application of 12 inches of water. In the wet treatment, the plots were irrigated when the tension reached 0.8 atmospheres in the row. These plots received eight irrigation totalling 24 inches. Four inches of rain fell in the period from July 1 to September 15, making the seasonal water application 16 and 28 inches, respectively. The average yield on the drier plots was 85 percent of that on the wet plots. However, 240 pounds of nitrogen produced 79 extra bushels of corn on the wet plots and only 35 extra on the dry plots.

Turmov (39) studied the effect of irrigation at soil moisture levels of 70% and 80% of the field capacity, and reported that the grain yield was improved by irrigation in both wet and dry years. At 80% soil moisture level the yield of grain was 600 kg. per hectare higher than at the 70% level, and the additional yield represented 19.2% of the yield obtained without irrigation.

Kellerman (19) from eight years of studies on April and July harvested maize, in which the treatments included fortnightly, ten-day, and weekly intervals, concluded that for April corn, the first irrigation should be given after the third leaf appears; irrigation should be bimonthly at 40 millimeters and should cease from the beginning of ripenning. Irrigation for July maize should be confined to the period between the third-leaf stage and ripenning with 40 millimeters at weekly intervals.

Pittman and Stewart (26) reported best yields of corn at about twenty inches of water yearly, the yield tending to decrease above 30 inches. Israelson (16) is sponsor for the claim that, with plenty of water on fertile soils, 60 to 80 bushels of corn or 17 to 20 tons of corn silage per acre are possible. However, greater yields than this are commonly produced under irrigation.

Vazquez (40) reported that there was no significant difference in production between frequent irrigation (when 20% of the available moisture had been depleted from the root zone) and intermediate irrigation (when 60% of moisture had been depleted). When irrigation was conducted throughout the growth season or until the hard dough stage, plots outyielded those which received irrigation to the tasselling or silking stage only, when yield reductions of 12.9 and 9.3 cwt per acre occurred.

Rosic (31) conducted an experiment on brown forest soils under average annual rainfall of 250 millimeters and three water application levels of 1000, 2000, and 4000 cubic meters per hectare. He found an increase of yield amounting to 87.1 per cent from the application of 1000 cubic meter of water per hectare. He suggested that 400 cubic meter should be applied at time of tasselling, 300 at earring and 300 at the time of pollen shedding..

Robins and Rhoades (30) concluded that the rates of water use seldom exceed 0.1 inch per day until corn is 8 to 12 inches high. The rate then gradually increases to 0.25 to 0.30 inch per day during the period of growth from silking to the soft dough stage. The rate declines gradually as the weather becomes cooler and the plants mature. A deficiency of moisture during tasselling and silking sharply lowers the yield.

Effect of Irrigation on Potatoes

Hampton *et al.* (13) showed an average increase in yields of irrigated potatoes of 71 bushels per acre. In this experiment with 18.9 and 23.7 inches of water use, yield increases of 109 and 52 bushels per acre were reported over non-irrigated plots which only received 12.1 and 15 inches of rainfall during the growing season. Under irrigation, the 75 per cent yield increase was almost entirely an increase of No. 1 potatoes.

Fulton (7) found that one inch of water every 7 days on light soils and 1.5 inches every 10 days on heavier soils was an effective plan, but additional irrigation was necessary if the available moisture at a depth of 6-inch fell to 50 per cent.

Jones and Johnson (18) irrigated potatoes when soil moisture tension rose to 0.3, 0.6, 1.2, 2.4, and 4.8 atmosphere in the first foot of soil. Irrigation at 0.3 atmosphere tension gave a higher yield, both total and of number 1 potatoes, than irrigating at higher tensions. Irrigation at 0.3 produced 217.8 bushels per acre of number 1 potatoes and 32.2 bushels per acre when irrigated at 4.8 atmospheres.

Corey and Meyers (4) used short, medium and long frequencies corresponding to 1/3 and 2/3 depletion of available soil water within the top two feet of soil and long frequencies in which plots were irrigated when there was a marked visible drouth stress. The yield of U.S. No. 1's was significantly reduced from 195.2 cwt. per acre to 106 cwt. per acre in the long frequency irrigation treatment, although the total yield for all treatments was about the same.

Robins and Domingo (29) showed that total yields were affected considerably less than yield or percent of U.S. No. 1 grade by the moisture stresses imposed. With 4 to 7 days of irrigation interval the total yield was 18.8 tons per acre and U.S. No. 1, 12.7 tons per acre. The least yield was produced with frequencies of 16 to 22 days and was 14.1 tons per acre, with 5.4 tons per acre of grade U.S. No. 1.

Jacob et al. (17) in their experiment with Katahdin potatoes indicated that the exact optimum level of minimum soil moisture may vary from year to year but it seems to be in the neighborhood of 20 to 40 inches of mercury tension, which corresponds to 50% to 60% of field capacity. Irrigation when maximum tension was 40 inches of mercury at 12 inches produced 574 bushels per acre of U.S. No. 1 and when at 2.5 inches of mercury the yield was 528 bushels per acre.

Singleton (33) concluded that maintaining a high moisture level (tension less than 0.8 atmospheres at the 9-inch depth in the row) has produced greater yields than lower moisture levels (tension less than 4 atmospheres at the 9-inch depth in the row). Potatoes are also affected by periods of high tension during the time the tubers are forming and growing. High tension during this period caused a greater percentage of malformed tubers, which reduced the market grade of potato even more than it reduced the yield.

Haddock (11) in his experiment with Russet Burbank potatoes on a loamy soil concluded that irrespective of the method of irrigation used, yields were increased significantly between irrigation treatments W_1 (available soil moisture in root zone is 20%), W_2 (40%), W_3 (70%), and W_4 (90%). No interaction between soil moisture condition and method of irrigation was indicated. In furrow irrigation when depth of water used increased from 10 inches to 39 inches the yield increased from 234 cwt. per acre to 374 cwt. per acre.

Blake et al. (3) irrigated potatoes when the soil moisture tension reached values of 0.8, 1.2 and 2.5 atmospheres at the 9-inch depth. The yields were greatly decreased by 41.3% and 70.5% in two consecutive years. The data indicated that potato yields were equally good when soil moisture tension was between 0.8 and 1.2 atmosphere before irrigation.

Struchtemeyer et al. (38) reported that with Katahdin potatoes and irrigation when available soil moisture fell to 50 per cent as measured with gypsum blocks a significant increase in yield resulted from irrigation in three years out of four. The average yield for four years was 472 bushels per acre as compared to 365 bushels per acre on nonirrigated plots. Struchtemeyer (37) also found that as the per cent available soil moisture left in the soil decreased from 70 to 15 the yield of tubers in grams per crock fell from 224 to 77. It was concluded that a shortage of soil moisture either early or late in the growth cycle of potato reduced the yield. Shortage of soil moisture in the last half of the growing season tended to reduce yield more than a shortage during the first half of the growing season.

Stockton (36) has summarized potato irrigation studies and suggested that irrigation should be done when the tension is in the range of 40 to 60 centibars. Irrigating at tensions above or below this range can be harmful to yield and quality. Irrigating when the soil moisture tension is below 40 centibars, probably because of poor aeration, can result in reduced yields. When the soil moisture tension reached 70, wilting was apparent and the plants were being stressed because of a soil moisture deficit.

It may be concluded that for maximum yields irrigation should be continued to as close to harvest as possible and as water use follows tuber developmentwith its maximum value just after the vine growth is mature. Therefore, adequate irrigation during flowering or tuber formation is necessary if a good yield is to be obtained.

Stomatal Opening and Irrigation Time

Halevy (12) reviewed the literature on stomatal behavior as affected by moisture stress and reported that the use of changes in stomatal opening as an indicator for begining of moisture stress was first suggested by Loftfield in 1921. In 1941, Oppenheimer and Elge developed a practical technique whereby they used an infiltration method for determining the stomatal aperture as an indicator for irrigation of orange trees. They used only pure kerosene and determined the degree of opening by the time elapsed from the time of application to the starting of absorption and also by measuring the shape and number of spots.

In 1936, Maximov and Zernova (23) studied the stomatal movement of irrigated wheat plants in order to relate certain characteristic changes in stomatal movement to the time of irrigation need. Their results showed that stomata of non-irrigated plants opened very little and only early in the morning, whereas stomata of irrigated plants remained wide open throughout the day. Dry weights and yield of grain of the plants at harvest showed that this difference in stomatal behavior between the non-irrigated and irrigated plants seemed to have affected their assimilation. Finally, they concluded that the degree of stomatal opening during the day may indicate how much water is available to the plants and data from this might help in working out a definite schedule for irrigation of wheat.

Glover (10) reported that maize stomata were markedly affected by severe drouth lasting about a week or more in that they do not recover their apparent pattern of normal behavior after the water supply to the plant is restored although the leaves regain their turgidity and seem normal. On the other hand, sorghum stomata recovered well from severe drouth lasting fourteen days and their recovery followed fairly closely behind the restoration of turgidity to the leaves.

Darrow and Dewey (5) conducted an experiment with strawberry varieties and found that under drouth condition stomata of Marshall plants opened very slightly for a short time in the early morning while in contrast on irrigated plants about 80 per cent had opened by 9:00 A.M.; 25 per cent remained open at 1:00 P.M.; 50% were open at 3:00 P.M.; and nearly all were closed at 5:00 P.M. Under drouth conditions the stomata of topped plants opened more and stayed open much longer than those of untopped plants.

Magness and Furr (22) studied stomatal activity in leaves of apple trees and reported that when the soil moisture of dry plots was reduced almost to the wilting point in the surface 2 feet, less than 60% of the stomata opened on trees in these dry plots and not over 20% of the stomata were open for an appreciable period. On a very warm day, when soil moisture was at the wilting point in the surface 2 feet of dry plots there was almost no opening of stomata in the dry plots. Under irrigation, practically 100% of the stomata were open at the beginning of the day and 40% were still open at noon.

Sitton (34) found that stomata of Hicaria pecan leaves from trees growing in a soil whose moisture content was near the wilting point closed as early as 10:00 A.M. and remained closed the rest of the day.

Wormer and Ochs (41) showed that transpiration of oil palms remained constant at soil moisture values between field capacity and a certain critical content which varied with climatic conditions particularly with evaporating power of the air. With decreasing soil moisture content between the critical value and the wilting point, transpiration decreased steadily, the final rate being almost zero. Stomatal opening was related in the same way to decreasing soil moisture.

Alvim (2) found that stomatal opening, photosynthesis, transpiration, vegetative growth and hence yield of cacao were progressively reduced when available soil moisture fell below 60 to 70 per cent. A mixture of 60% medicinal paraffin oil and 40% kerosene was recommended as an indicator for water deficiency below 50 per cent available moisture in the soil.

Khan (20) working with sugar beets in Lebanon found that when the leaves of sugar beet did not absorb a mixture of 70% paraffin and 30% kerosene during the first half of the growth period, and a mixture of 60% paraffin and 40% kerosene during the second half, the plants started wilting.

Halevy (12) in his experiment on moisture relations in gladiolus, used an infiltration method with a series of eleven liquids which were mixtures of odorless kerosene and medicinal paraffin oil resulting in a range of viscosities. The degree of stomatal opening of the leaves was determined by applying mixtures of decreasing viscosity to the median portion of leaves. The most viscous liquid that would penetrate within five seconds was recorded as representative of the degree of stomatal opening of the plant leaf and each recorded figure was the average of ten such readings. From this study Halevy reported that if an infiltration mixture of 65% kerosene and 35% paraffin oil did not penetrate within five seconds into at least half of the plants examined, then irrigation was necessary.

MATERIALS AND METHODS

Experimental Design

In order to study the effect of irrigation interval on seasonal behavior of stomata and yield of corn and potato, a greenhouse pot experiment was made in Beirut and a field experiment was established at the Agricultural Research and Education Center, in the Beka'a (Latitude 33° 55.50' and longitude 36° 4.50'), Lebanon. A randomized block design was utilized for the field experiment. Treatments were weekly, biweekly, and triweekly irrigation of the crops and were referred to as M_1, M_2 and M_3, respectively, and were quadreplicated. Statistical analyses were made according to the analysis of variance method of Panse and Sukhatme (25). Linear regression and correlation coefficients were calculated for yield, degree of stomatal opening and soil moisture conditions.

Pot Experiment Procedure

Twelve pots each containing 5 kg. of air dry soil were planted to corn and potatoes on February 27, 1963. Three treatments and two replications were imposed. Treatments were irrigation with measured volumes of water, added to the pots whenever the soil moisture dropped to 28, 24 and 20 per cent (field carrying capacity was 32% and the permanant wilting point was 16%), as indicated through periodic weighing of the pots. On March 21, 1963, the corn was replanted in order to get a uniform growth. Because of unexpected hail on May 1, 1963, the experiment was discontinued and the weight of tubers and stalks were measured. The degree of stomatal opening was determined by the oil drop technique and the corresponding values for absorbed grades of oil by the leaves, temperature and water loss were recorded.

Field Procedure

The experimental area was surveyed and plants were laid out in such a way that a uniform application of water was possible. The treatments were assigned at random to the different plots within each block. Each plot was a basin consisting of five rows and was 8 meters long and 3.75 meters wide, with a 75 cm. space between the rows.

On March 29, 1963, seed potatoes of the Bintje variety were planted 30 cm. apart in the rows. This amounted to a population of approximately 44,400 plants per hectare. 300 kg. of N and 200 kg. of P per hectare were applied partly at planting time and the balance as side dressing. The carriers were ammonium nitrate for N, and concentrated superphosphate for P. During the course of the study the potatoes were sprayed against leaf hoppers with metacystox. On September 2, 1963, potatoes of the middle 7 meters of the three central rows of each plot were harvested and the yields of different grades, specific gravity, and the presence of chocolate spot in the tubers of each treatment plot were determined.

On April 19, 1963, seeds of the corn variety, Indiana 620 A were drilled with a hand seed planter on the ridges of each row. Fertilizer application was the same as for the potatoes. The seedlings were thinned to approximately 66,665 plants per hectare on June 2, 1963. The corn was harvested on September 26, 1963, and grain and stover yields of the middle 6 meters of the three central rows of each treatment plot were measured.

Irrigation

The method of the irrigation was the furrow system with gated pipe and according to the schedules (tables 1 and 2) given below. A flow meter was used to measure the flow of the water and the total amount of water applied to each plot was about the same for each crop regardless of treatment. The irrigation treatments started from June 14, 1963 and lasted for 11 and 15 weeks for potatoes and corn, respectively. Previous to starting the treatments, both crops were irrigated weekly by sprinklers.

Table 1. Irrigation Schedule for Corn.

Treatments	Irrigation Interval, Days	Required Time for Irrigation, Minutes	Number of Irrigations	Total Depth of Water Applied, Inches
M_1	7	60	15	32
M_2	14	120	8	32
M_3	21	180	6	32

Table 2. Irrigation Schedule for Potatoes

Treatments	Irrigation Interval, Days	Required Time for Irrigation, Minutes	Number of Irrigations	Total Depth of Water Applied, Inches
M_1	7	60	11	23
M_2	14	120	6	23
M_3	21	180	4	23

Stomatal Opening

A series of eleven liquids were used for measurement of stomatal opening. These liquids were mixtures of kerosene and medicinal paraffin oil (table 3), from grade 1 (pure liquid paraffin, highest viscosity, 6.16 compared to water) to grade 11 (pure kerosene, lowest viscosity, 0.613 compared to water). In between, the grades differed from each other by steps of 10% by volume.

Table 3. Oil Mixtures (paraffin + kerosene)

Grade	Paraffin, %	Kerosene, %
1	100	0
2	90	10
3	80	20
4	70	30
5	60	40
6	50	50
7	40	60
8	30	70
9	20	80
10	10	90
11	0	100

The greater the degree of stomatal opening of the leaves, the more viscous the liquid (lower the grade) that can be absorbed and vice versa. The mixture of decreasing viscosity was applied to the median portion of the full grown leaves for determining the degree of stomatal opening. The lowest grade of oil which was absorbed within five seconds when applied to the lower surface of full grown leaves and the average of ten plants were reported as representative of the degree of stomatal opening.

Soil Moisture

In the potato trial, gypsum blocks were buried at the 12 and 24-inch depths in one biweekly and at the 20-inch depth in one triweekly irrigated plot. In the corn plots, the gypsum blocks were buried at 12 and 24-inch depths in one biweekly and at the 24-inch depth in one triweekly irrigated plots. Soil moisture readings were made by means of a Bouyoucos meter whenever infiltration tests on stomata of the leaves were underway.

To measure the soil moisture content directly, soil samples were taken by auger from 8, 16 and 24-inch depths of each treatment plot whenever leaves of both crops began to absorb pure kerosene (relatively closed) and whenever they did not absorb it.

RESULTS AND DISCUSSION

A randomized block design was used to study the effect of irrigation interval on the stomatal behavior and yield of corn and potatoes. In the discussion that follows the term "highly significant" will be used to denote an effect with a probability of 0.99 or more of being true, while "significant" will be used for a probability of 0.95 to 0.99 of being true. The terms, moisture tension and soil moisture stress, have been used interchangeably in this paper since it was assumed that the osmotic pressure of the soil solution in the experiment was negligible.

Soil and Water Analyses

The soil pH at a 1:2.5 dilution was 8.2 and the calcium carbonate concentration was 39.3 per cent indicating a highly calcareous soil (table 4). The total nitrogen of the soil was found to be 0.131 per cent indicating a relatively low supply of N. The organic matter content was also low, 1.29 per cent by the wet combustion method. The cation exchange capacity and the exchangable calcium, magnesium, potassium and sodium were 42.36, 26.80, 13.34, 1.02 and 1.20 m.e./100 g. of soil, respectively. The water was considered to be of good quality. The soil is classified under the category of Light Chestnut. Although the mechanical analysis (table 4) indicated that soil has a clay texture, the permeability of the soil to water as observed in the field was good, and this may be explained by the high calcium saturation of the colloidal complex which imparts desirable flocculation to the soil.

Table 4. Results of chemical and mechanical analyses of the surface soil for the experimental plots and of the irrigation water.

Soil Analysis		Water Analysis (14)	
pH (1:2.5)	8.2	Sodium	0.282 m.e./liter
Calcium carbonate, %	39.3	Calcium	0.705 "
Organic matter, %	1.29	Magnesium	0.833 "
Total nitrogen, %	0.131	Potassium	0.056 "
Cation Exchange Capacity,		Sulfur	0.125 "
m.e./100 g.	42.36	Chlorine	0.318 "
Exchangeable Cations,			
m.e./100 g.		Electrical Conductivity	
Calcium	26.80	0.155 m. mho/cm.	
Magnesium	13.34		
Potassium	1.02		
Sodium	1.20		
Soil Texture			
Sand, %	15.9		
Silt, %	40.1		
Clay, %	44.0		

Soil Moisture Characteristics

The amount of moisture held by the soil at different tensions were determined by Richards pressure membrane method (27) (figure 1). The soil moisture sorption curve depicts that the available water holding capacity of the soil was about 16 per cent and that half of this moisture was held at a tension of more than 2.2 atmosphere. The Bouyoucos meter readings were always higher than actual soil moisture content by about 7 per cent of available soil moisture except for the 20-inch block of triweekly irrigated potatoes which was discarded because of incompatible values with actual soil moisture content.

Stomatal Behavior of Potato

There was a direct positive relationship between the grade of oil absorbed, and the soil moisture tension for the three indicated ranges of time (figure 2, tables 8, 9 and 10), with (r^2) values of 0.70, 0.67, and 0.84 for T_1, T_2, and T_3, respectively. This suggests that 67% to 84% of the differences in stomatal closure were accounted for by differences in soil moisture tension (table 5).

Table 5. Correlation coefficients (r), (r^2) and linear regression equations for the degree of stomatal opening of potato vs. absorbed grade of oil during the indicated ranges of time as found in a green house pot experiment.

Time	$(r)^{(1)}$	(r^2)	linear regression equations
T_1 (8 A.M. - 11 A.M.)	0.84	0.70	$Y = 0.23\,x + 0.25^{+}$
T_2 (11 A.M. - 4 P.M.)	0.82	0.67	$Y = 0.25\,x - 0.16$
T_3 (4 P.M. - 5 P.M.)	0.92	0.84	$Y = 0.27\,x - 0.19$

\+ Y is soil moisture tension in Atmospheres and x is grade of oil

1\. All the correlation coefficients were highly significant.

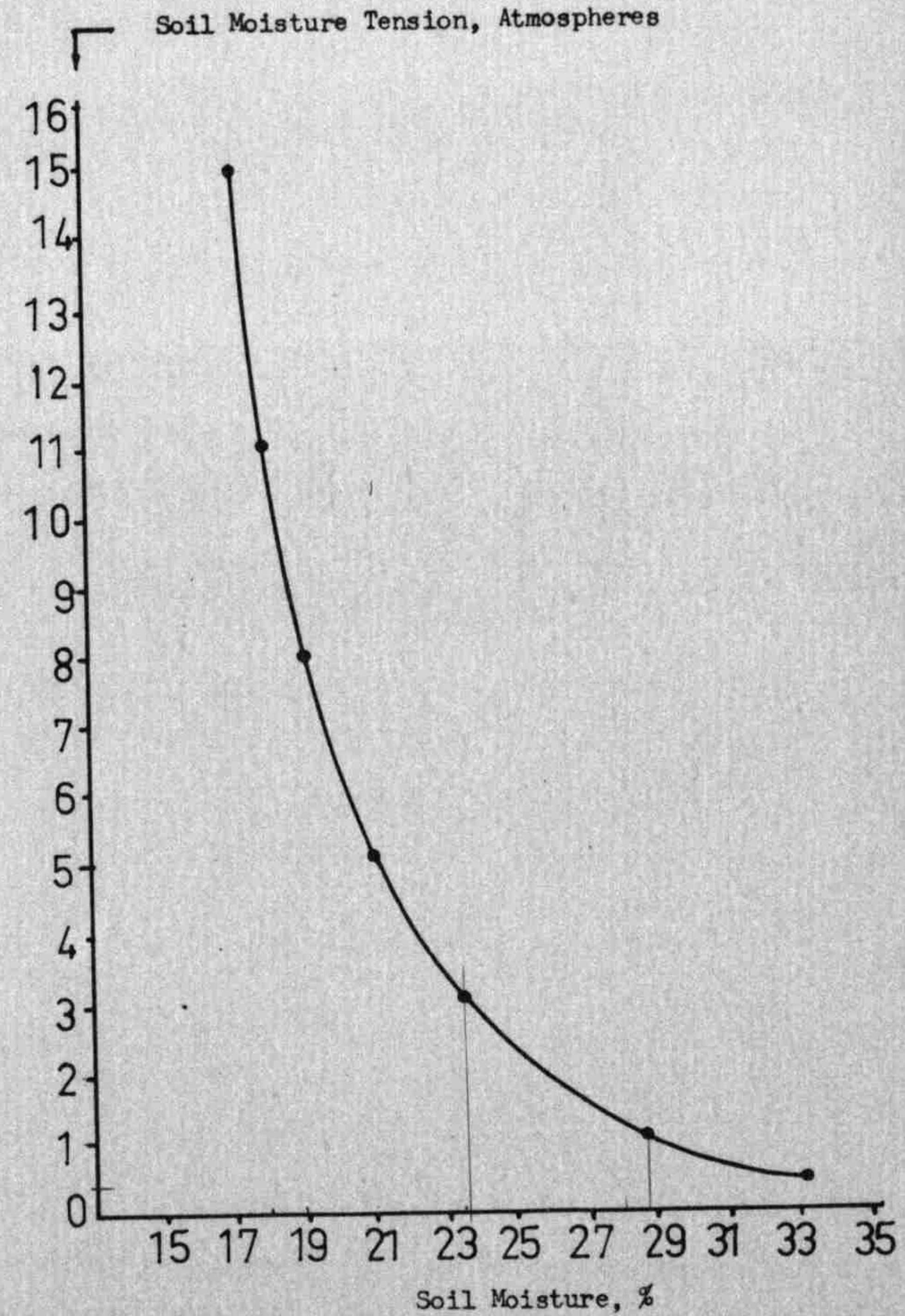

Figure 1. Relation between the soil moisture tension and the moisture content of the soil.

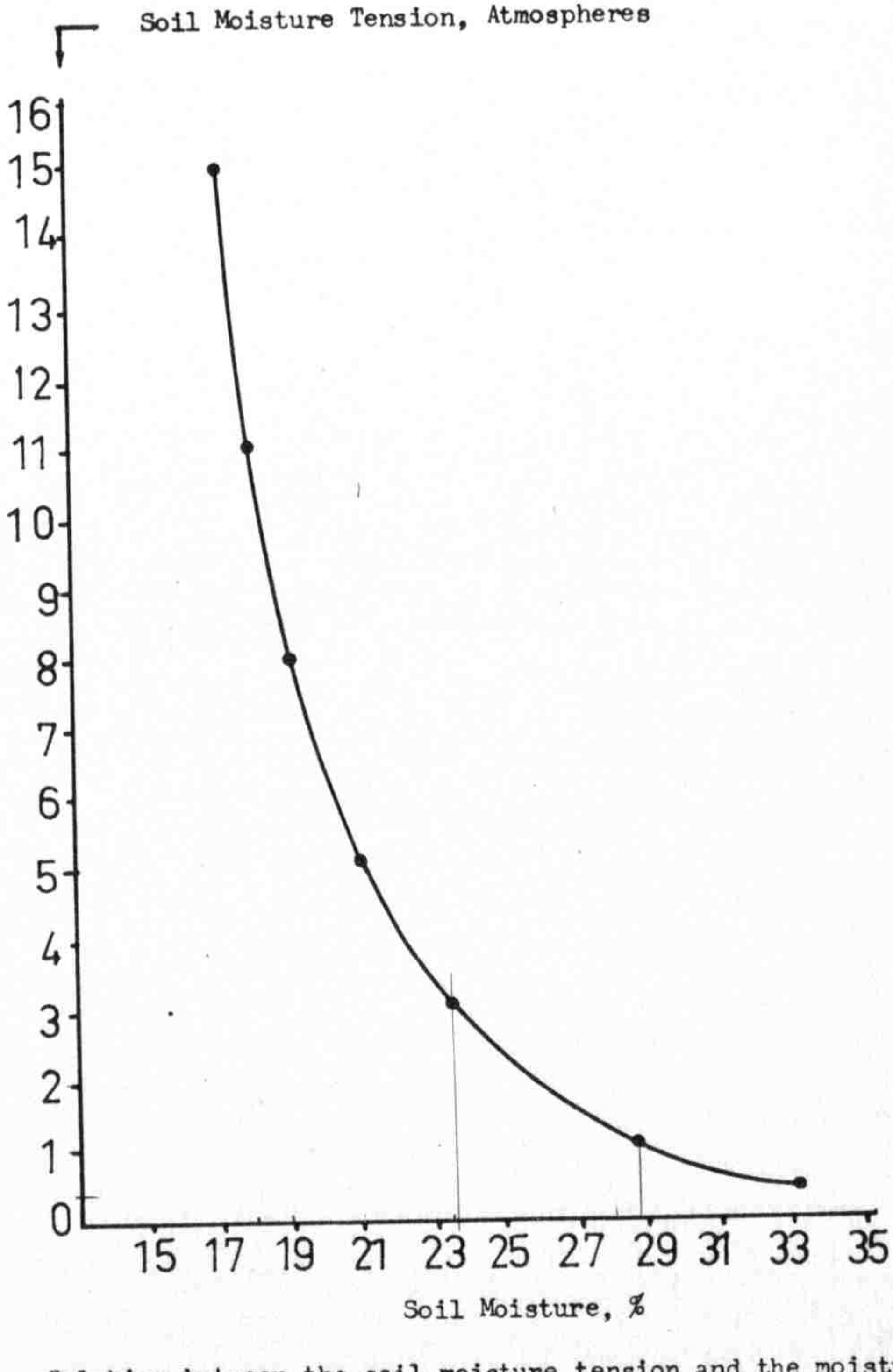

Figure 1. Relation between the soil moisture tension and the moisture content of the soil.

Effect of Irrigation Interval on The Stomatal Opening of Potato

An attempt was made to relate the degree of stomatal opening to length of the time since irrigation or the degree of soil moisture stress. The degree of stomatal opening was determined by noting the most viscous grade of oil (mixture of paraffin oil and kerosene, table 3) which could be absorbed by the leaves within five seconds between 8 and 11 o'clock each day. There was a gradual increase in the grade of absorbed oil with the lapse of time (figure 3, tables 11, 12, 13, and 14). The changes of the degree of stomatal opening were almost identical for weekly, biweekly and triweekly irrigation intervals and the trend did not change during the course of the experiment. This suggests that the long irrigation interval had no permanent effect on subsequent stomatal behavior. In the triweekly irrigated plots, the potato leaves began absorbing pure kerosene (grade 11) 14 days after irrigation and continued the absorption of this grade to the end of the third week. The relationship was direct and soil moisture tension increased from 1/3 atmosphere at the 12" and 24" depths to 7.2 and 3.3 atmospheres, respectively, after 14 days, with a concomittant increase in grade of oil from 4 or 5 to 11. In the triweekly irrigated plots a similar trend in changes of absorbed oil grades was observed. Direct soil sampling from depths of 8", 16", and 24" when the stomata began to absorb grades 10 and 11 (relatively closed) suggested that at 0.95 true probability level, the soil moisture tension varied from 4.35 to 5.25, 2.35 to 3.25, 1.08 to 1.52 atmospheres at 8", 16", and 24" depths, respectively and this occurred on the average, 12 days after irrigation (figure 4, table 15). It is evident that moisture depletion was greater in the surface 8 inches with over 75% of the available mois-

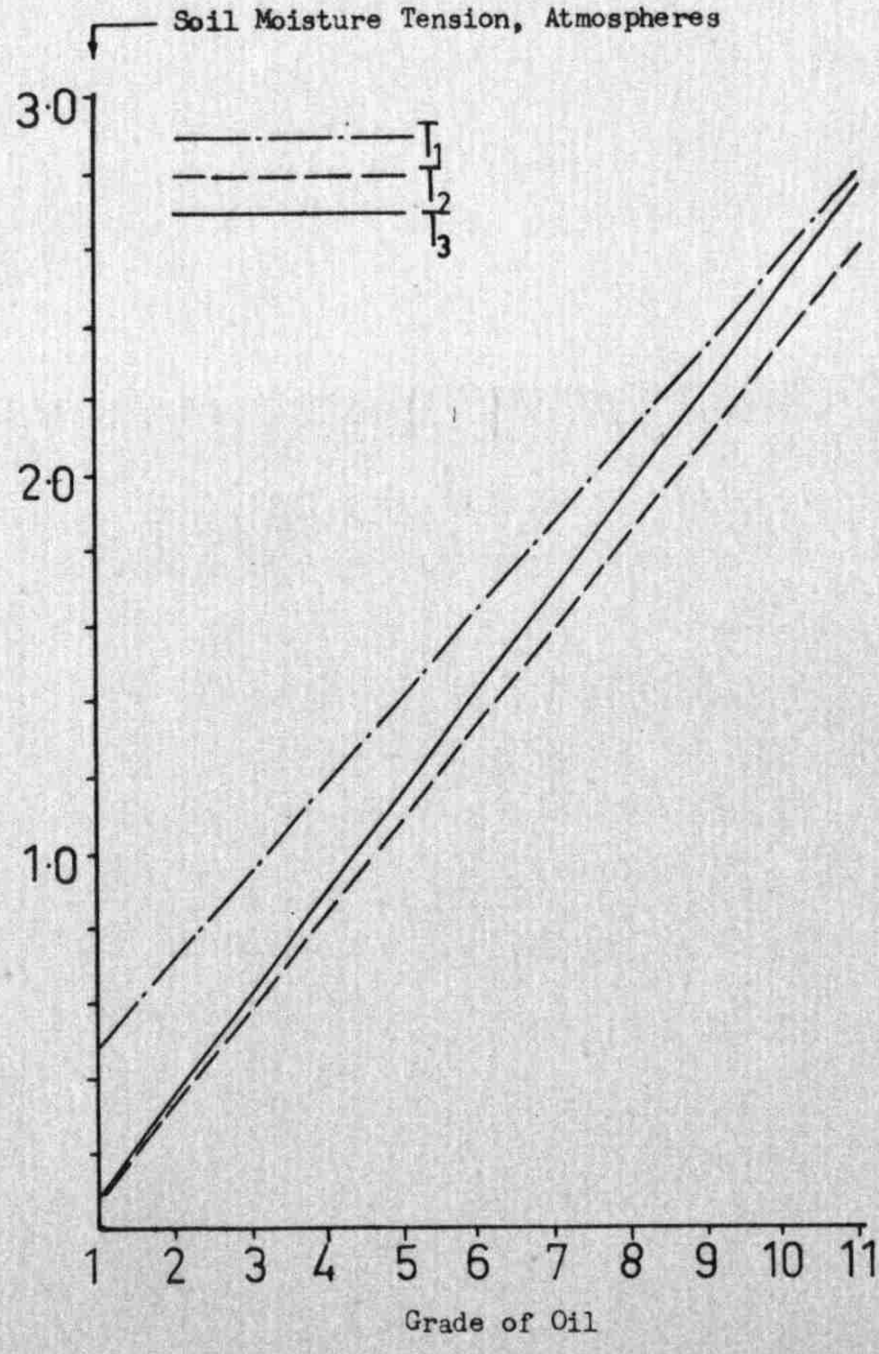

Figure 2. Relationship between grade of oil absorbed by potato leaves and soil moisture tension calculated from the regression equations.

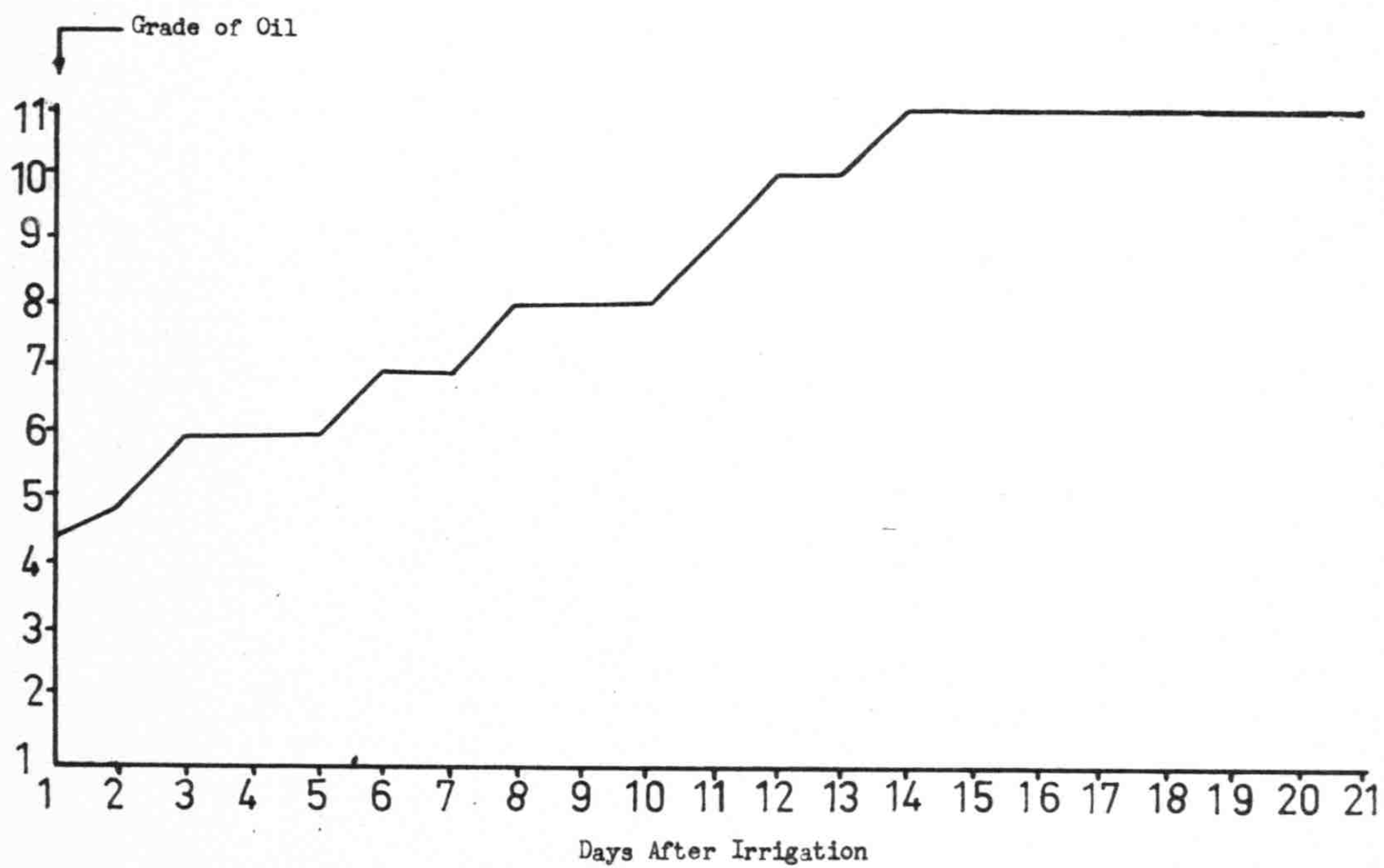

Figure 3. Relationship between grade of oil and number of days after irrigation for potato plants for the period of June 27 - July 18, 1963.

ture used, and that moisture content at the 24-inch depth remained relatively untapped after twelve days with less than 25 per cent of the available soil moisture used.

Effect on Potato Yield

Increasing irrigation interval had a negative effect on total and grade 1 potato yields ($r = -0.96$) although treatments were started on June 20 when tubers had already set to some extent. This was in agreement with the results of the several workers (4, 11, 18, 29, 33) who had similar experiments. The analysis of variance (table 6) indicates that the difference between weekly and biweekly intervals was not significant, but the triweekly irrigated plots differed significantly from the weekly irrigated ones.

Table 6. Analysis of variance for the total yield of potatoes as affected by irrigation interval.

Source	d.f.	S.S.	M.S.	F
Treatment	2	278.62	139.31	8.72+
Replication	3	27.82	9.27	0.58
Error	6	95.79	15.96	-

\+ Statistically significant at 0.05 level.

L.S.D. at 0.05 level was 6.83 tons.

Average yield of potato in m.tons/ha.

Treatments	M_1(1wk.)	M_2(2wk.)	M_3(3wk.)++
	44.0	37.9	32.2

++ Means joined with a solid line are not significantly different at the 0.05 level.

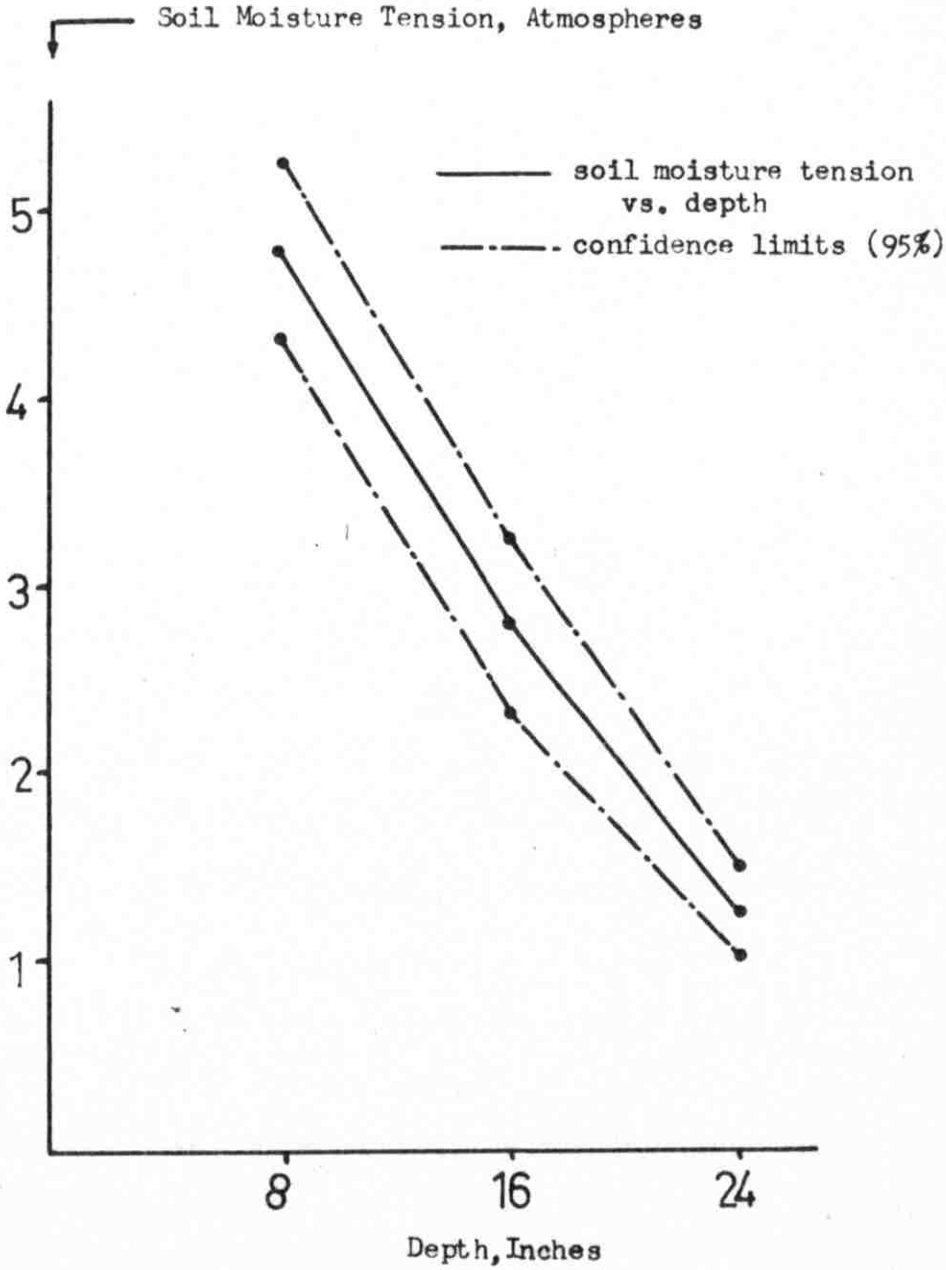

Figure 4. Soil moisture tension at different depths of soil, when the potato stomata no longer absorbed grade 9, about 12 days after irrigation.

The specific gravity of potatoes, which is correlated with the starch and dry matter content, was determined by the salt solution method (24) but there was no trend or significant difference among treatments (table 16).

The economic analysis of the data indicated a significant difference among the three treatments with the maximum return from weekly irrigation (figure 5). Also, the increased cost of more frequent irrigation was negligible compared to the increased yield.

Effect of Degree of Stomatal Opening on Potato Yield

The stomatal apertures began to close and the leaves absorbed less viscous grades of oil gradually and regularly with increasing time after irrigation (figure 3). When the stomata were relatively open, oil of grades 4 and 5 infiltrated the leaves in the specified time, while at the end of the irrigation intervals, especially in triweekly, the stomates were relatively closed and absorbed only grade 11 (pure kerosene) or grade 10. There was a high positive correlation ($r = 0.99$) between the number of the days the stomata were relatively open (the leaves absorbed grades less than 10) and the total yield (figure 6), the high correlation coefficient and almost straight line relationships justifies the adoption of arbitrary "relatively open" and "relatively closed" limits at oil grade 10.

Irrigation Interval, Stomatal Behavior and Corn Yield

Depletion of soil moisture had a direct effect on the degree of stomatal opening. The initial absorbed grade of oil was 7, indicating a smaller aperture size for the stomata of corn as compared to potatoes.

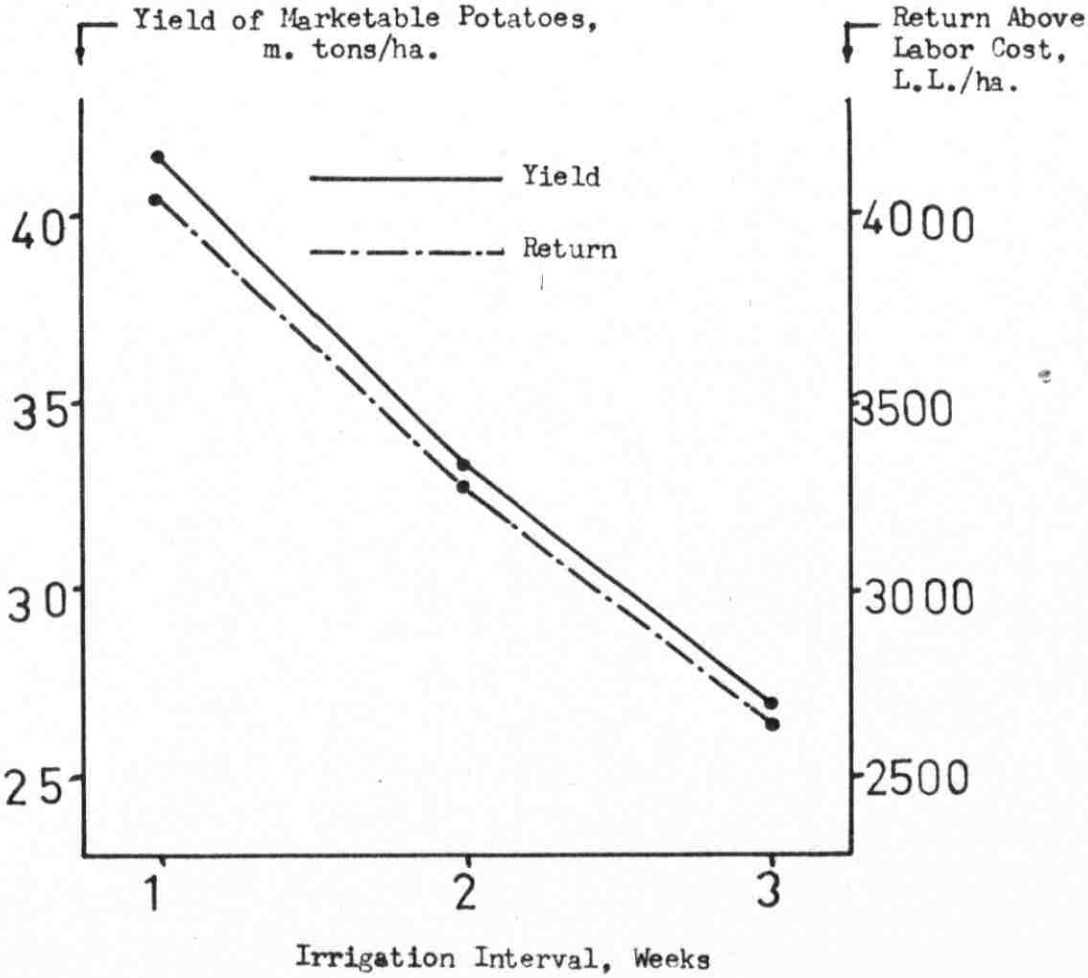

Figure 5. Effect of irrigation interval on marketable yield (potatoes longer than 4 cm. in diameter) and on return above labor cost based on the following prices: marketable potatoes, L.L. 100 per m. ton, and L.L. 10 per hectare per irrigation as labor cost.

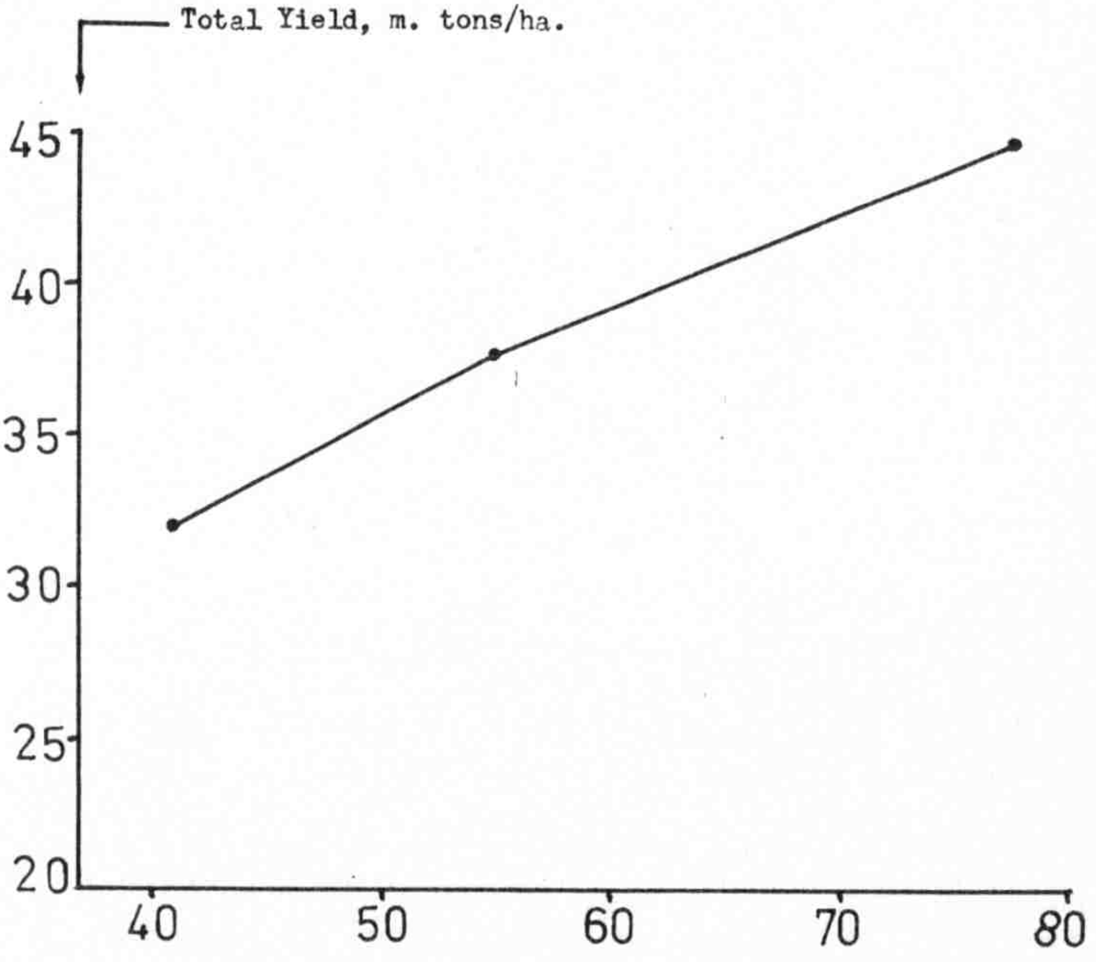

Figure 6. Relationship between total yield of potatoes and total number of days the stomata were relatively open during the eleven weeks of the irrigation experiment. The leaves absorbed grades of oil less than 10 throughout the period when they were presumably open.

The tendency of gradual closure of stomata with the lapse of time after irrigation was found to be almost identical for weekly, biweekly, and triweekly intervals and the trend did not change during the course of the experiment. The leaves of corn began absorbing only pure kerosene (became relatively closed) 5 or 6 days after irrigation and ceased to absorb even pure kerosene after 12 days since irrigation both in biweekly and triweekly irrigated plots, suggesting that a further reduction of oil viscosity below that of pure kerosene was required to trace the three week irrigation cycle (figure 7). The soil moisture tension rose from 1/3 to 8.4 atmospheres at the 12-inch depth after 12 days, leaving the top one foot of soil with less than 15 per cent of available soil moisture. The commencement of the adsorption of pure kerosene corresponded to a soil moisture tension of 1.15 and 0.55 atmospheres at 12 and 24 inches respectively, in biweekly irrigated plots, while in triweekly irrigated corn the tension was 0.64 atmospheres at 24 inches (tables 17, 18, 19 and 20).

Similar results were obtained through the analysis of soil moisture data where soil samples were taken from the depths of 8, 16, and 24 inches when the leaves began and when they ceased to absorb grade 10 and pure kerosene (figure 8). The beginning of relative stomatal closure, or the absorption of grade 10 (90% kerosene and 10% paraffin) and grade 11 (100% kerosene) usually occurred on the average, 4 days after irrigation in all treatments (table 21) and the soil moisture tension, with 95% of true probability level, varied from 1.4 - 2.6, 0.71 to 0.93, and 0.59 to 0.71 atmospheres at the 8, 16 and 24-inch depths, respectively. This suggests that when about 50 per cent of available soil moisture at 8

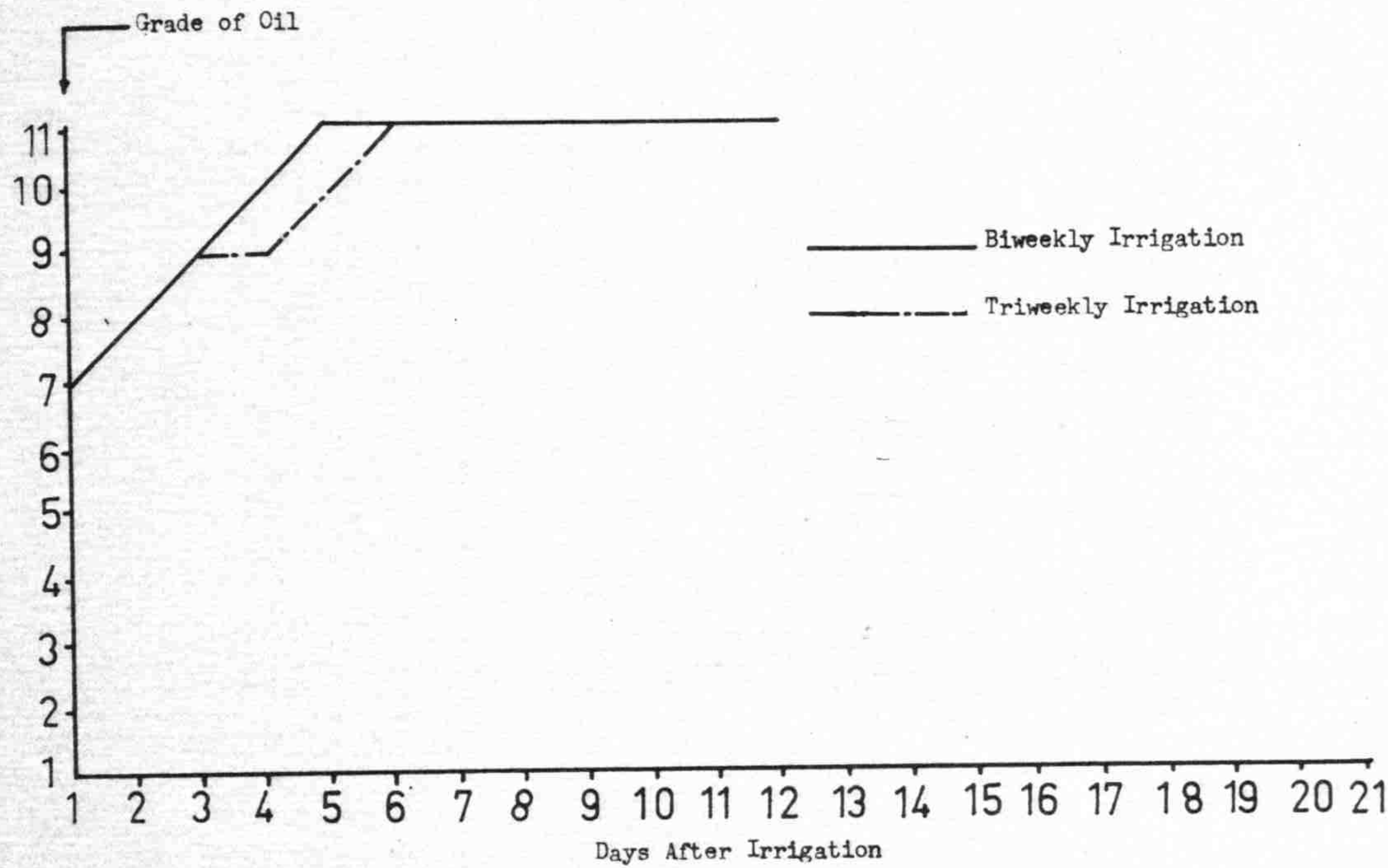

Figure 7. Relationship between grade of oil absorbed and number of the days after irrigation for corn plants, for the period of June 27 - July 18, 1963.

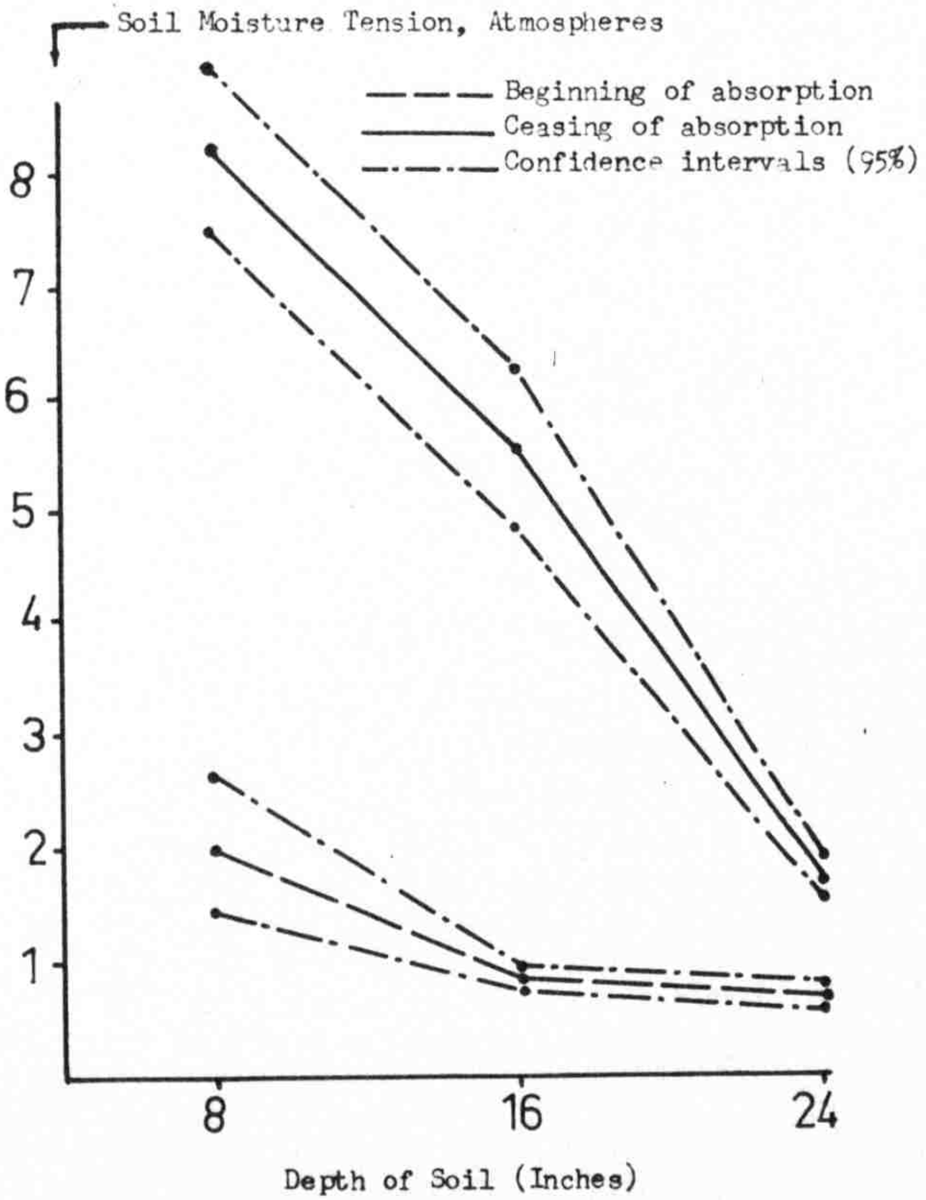

Figure 8. Soil moisture tension at different depths of soil when the corn stomata began, and then ceased to absorb grade 10 and pure kerosene.

inches and about 20 per cent at 16 inches was depleted, the leaves began to absorb only grades 10 and 11. The soil moisture tension was increased gradually and regularly with time until the leaves no longer absorbed pure kerosene. Usually this occured about 11 days after irrigation at which time the soil moisture tension ranged from 7.50 to 8.94, 4.89 to 6.21 and 1.49 to 1.83 atmospheres at the 8, 16 and 24-inch depths respectively (table 22). It was found that at this time less than 15 per cent of available soil moisture was present in the top 8 inches of the soil and increased only to about 20 per cent at the 16-inch depth.

Increasing irrigation interval significantly affected the grain yield negatively ($r = -0.96$). The grain yield differed significantly from one treatment to the other, and the yield difference between biweekly and triweekly irrigated plots was highly significant (table 7). The average weight of corn ears and the grain-stover ration decreased significantly as the irrigation interval was lengthened from one week to three weeks (table 23). The difference was not significant between weekly and biweekly irrigation intervals, while both differed significantly from the triweekly interval. The percent of moisture in the grain at harvest time was greatest for the least frequently irrigated plots (M_3) indicating that maturity was delayed under this irrigation regime, while percent of forage moisture remained the same in M_1 and M_3 with a slight decrease in M_2 which was not statistically significant. Forage weight was highest for M_2 although it did not differ significantly from the others. The shelling percentage tended to be decreased with an increase in irrigation interval, but the differences were not statistically significant (figure 9).

The reduced yield due to lengthened irrigation interval has been confirmed by many workers (8, 9, 15, 21, 33, 39). The economic analysis indicates that tripling the irrigation interval (while the total applied volume of water remains the same) reduced the gross return to less than one-third (figure 10).

Table 7. Analysis of variance for the grain yield of corn (at 15.5% moisture) as affected by irrigation interval.

Source	d.f.	S.S.	M.S.	F
Treatment	2	110.2	55.1	39.9++
Replication	3	0.5	0.16	0.01
Error	6	8.3	1.38	-

++ significant at 1% level

L.S.D. at 0.05 was 2.00 tons

L.S.D. at 0.01 was 3.03 tons

	Average grain yield (m. tons/ha.)		
Treatments	M_1(1 wk.)	M_2(2 wk.)	M_3(3 wk.)
	10.25	5.25	3.00

If it is assumed that when the corn stomata absorbed only pure kerosene they were relatively closed, it can be shown (figure 11) that the total number of days stomata were presumably open (absorbed grades less than 11) affected the gfain yield positively (r = 0.96).

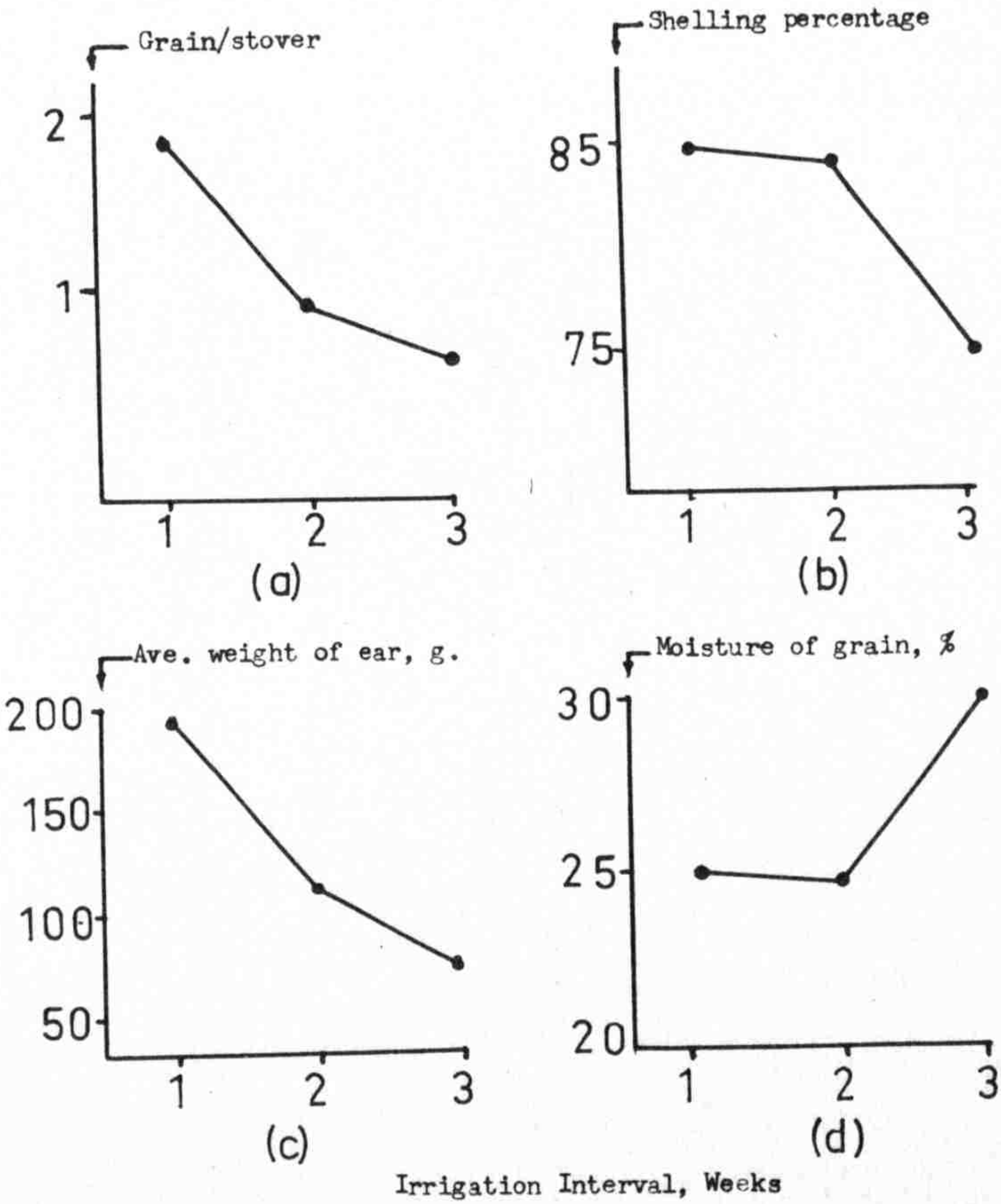

Figure 9. a) Relationship between grain/stover (grain at 15.5% moisture and stover at the oven dry level) and irrigation interval. b) Shelling percentage (grain at 15.5% and cobs at 20% moisture content) as affected by irrigation interval. c) Average weight of ear at corrected moisture levels and d) percent moisture of grain at harvest time as influenced by different treatments.

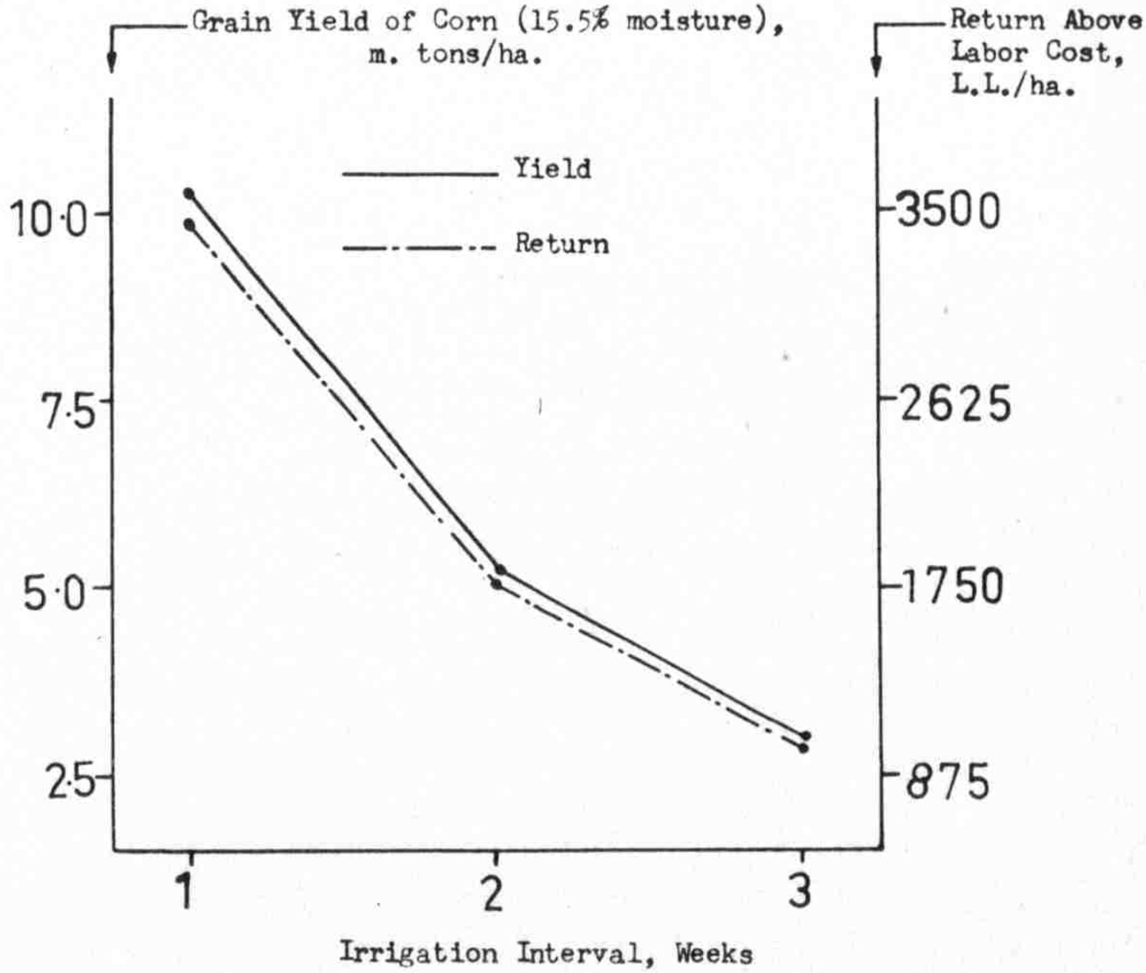

Figure 10. Effect of irrigation interval on grain yield of corn (at 15.5% moisture) and on return above labor cost. Prices used were L.L. 350 per m. ton of grain yield and L.L. 10 per hectare per irrigation as labor cost.

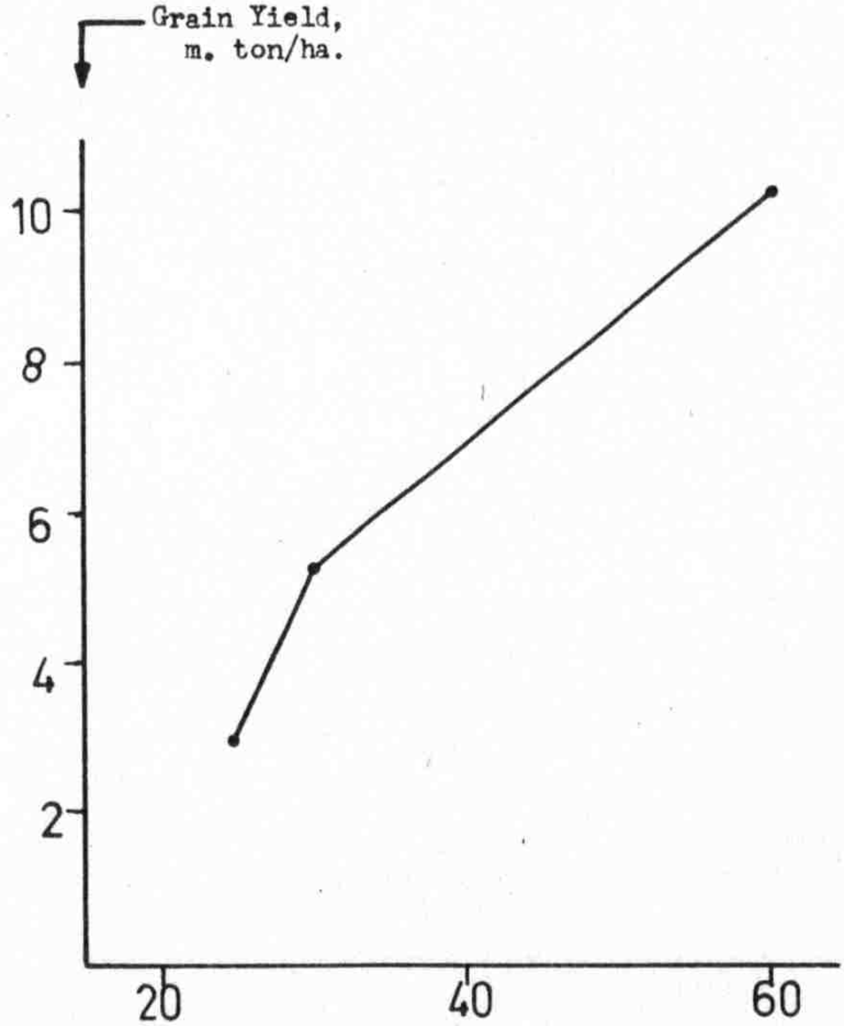

Figure 11. Relationship between grain yield of corn and total number of the days stomata were presumably open (absorbed grades less than 11) during the fifteen weeks of the irrigation experiment.

SUMMARY AND CONCLUSIONS

The effects of various irrigation intervals on stomatal behavior and yield of corn and potatoes were studied. The oil drop penetration method as an indicator of the degree of stomatal opening was related to the degree of soil moisture tension.

The stomatal opening technique worked well as a method for field determination of soil moisture status showing a gradual closure with depletion of soil moisture in both crops. The long irrigation interval had little effect on the subsequent behavior of stomata and the leaves regained their turgidity when irrigated. In these two species, the onset of wilting was too late as an indicator of irrigation need. The method must be calibrated with each species of plant because of difference in the stomatal size. In order to trace the complete 3-week irrigation cycle for corn a less viscous fluid than kerosene would be required because of the small stomatal size.

Increasing the irrigation interval tended to decrease the yield of the corn and potatoes. Economic analyses showed a wide range and highest return above labor cost was obtained from weekly irrigation for both corn and potatoes. The yield difference was statistically significant and of considerable magnitude for corn, indicating sensitivity of the corn plant to prolonged soil moisture stress. The potato irrigation interval treatment started late but there was a significant difference in yield between weekly and triweekly irrigated plots. As a tentative recommendation, corn and potatoes should be irrigated when the leaves of the plants no longer absorb grades 10 (10% paraffin and 90% kerosene) and 7, (40% paraffin and 60% kerosene), respectively.

LITERATURE CITED

1. Al-Ali, A.S. The life history of potato tuber moth and its control in storage. M.S. Thesis. American University of Beirut. 1963.

2. Alvim, P. Det. Stomatal opening as practical indicator of moisture deficiency in cacao. Phyton. 15 : 79-89. 1960. (Hort. Abstr. 31 : 3267. 1961).

3. Blake, G.R., Brill, G.D. and Campbell, G.C. Studies on supplemental irrigation on potatoes in New Jersey. Am. Potato J. 32 : 327-331. 1955.

4. Corey, G.L., and Meyers, Victor I. Irrigation of Russet Burbank potatoes in Idaho. Idaho Agr. Expt. Sta. Bull. 246. 1955.

5. Darrow, Geo. M. and Dewey, Geo. W. Studies on the stomata of strawberry varieties and species. Amer. Proc. Hort. Sci. 32 : 440-447. 1934.

6. FAO - Production Yearbook. 14 : 74. F.A.O., U.N. - Rome. 1960.

7. Fulton, J.M. Irrigating early potatoes in southwest Ontario. Publ. 1028 Can. Dep. Agric., Ottawa, 1958. (F. Crops Abstr. 12 : 1844. 1959).

8. Gard, L.E. Moisture used by corn on a silt pan soil in Southern Illinois. Ill. Res. 1, No. 4. 1959. (F. Crops Abstr. 13 : 1632. 1960).

9. Gertel, Karl., Thorfinnson, J.W., Thomas, T.S. and Ottoson, H.W. Adjusting to irrigation in the Loup river area in Nebraska. Nebr. Agr. Expt. Sta. Bull. 434. 1956.

10. Glover, J. The apparent behavior of maize and sorghum stomata during and after drought. J. Agr. Sci. 53 : 412-416. 1959.

11. Haddock, Jay L. The influence of irrigation regime on yield and quality of potato tubers and nutritional status of plants. Am. potato J. 38 : 423-433. 1961.

12. Halvey, A.H. The influence of progressive increase in soil moisture tension on growth and water balance of gladiolus leaves and development of physiological indicators for irrigation. Proc. Amer. Soc. Hort. Sci. 76 : 620-630. 1960.

13. Hampton, R.N., Murphy, R.G. and Hoff, P.R. Potato irrigation. Corn. Agr. Expt. Sta. Bull. 862. 1950.

14. Hashimi, M.A.A. Interrelationships of nitrogen, phosphorous sulfur, sodium and chlorine on the growth and composition of sugar beets. M.S. Thesis. American University of Beirut. 1963.

·15. Howe, O.W. and Rhoades, H.F. Irrigation practice for corn production in relation to stage of plant development. Soil Sci. Soc. Amer. Proc. 19 : 94-98. 1955.

·16. Israelson, O.W. Irrigation Principles and Practices 2nd. ed. pp. 332. John Wiley and Sons, Inc. New York. 1950.

17. Jacob, Walter C., Russell, M.B., Klute, A., Levine, G. and Grossman, R. The influence of irrigation on the yield and quality of potatoes on Long Island. Am. Potato J. 29 : 292-296. 1952.

18. Jones, Sam. T., and Johnson, W.A. Effect of irrigation at different minimum levels of soil moisture and of imposed droughts on yield of onions and potatoes. Proc. Amer. Soc. Hort. Sci. 71 : 440-445. 1958.

·19. Kellerman, G. Irrigation frequency experiments on maize in Central Viet-Nam. Agron. Trop. 4 : 531-536. 1949. (Soils and Fertilizers 13 : 243. 1950).

20. Khan, S.A. Effect of applied nitrogen and sodium and irrigation frequency on the development and yield of sugar beets. M.S. Thesis. American University of Beirut. 1964.

·21. Kiesselbach, T.A. Progressive development and seasonal variations of the corn crop. Neb. Agr. Expt. Sta. Bull. 166. 1950.

22. Magness, J.R., and Furr, J.R. Stomatal activity in apple leaves. Proc. Amer. Soc. Hort. Sci. 27 : 207-212. 1930.

·23. Maximov, N.A., and Zernova, L.K. Behavior of stomata of irrigated wheat plants. Plant Physiol. 11 : 651-654. 1936.

24. Murphy, H.J., and Goven, Michael J. Factors affecting the specific gravity of white potato in Maine. Maine Agr. Expt. Sta. Bull. 583. 1959.

25. Panse, V.G., and Sukhatme, P.V. Statistical Methods For Agricultural Workers. 2nd ed. Indian Council of Agricultural Research, New Delhi. 1961.

·26. Pittman, D.W., and Stewart, G. Utah Agr. Expt. Sta. Bull. 219. 1930. (Roe, H.B. Moisture Requirement in Agriculture. McGraw Hill Co. N.Y. 1950).

27. Richards, L.A. Diagnosis and Improvement of Saline and Alkali Soils. U.S.D.A. Handbook No. 60. 1954.

28. Robins, J.S. and Domigo, C.E. Some effects of severe soil moisture deficits at specific growth stages in corn. Agron. J. 45 : 618-621. 1953.

29. ________, and ________. Potato yield and tuber shape as affected by severe soil moisture deficits and plant spacing. Agron. J. 48 : 483-492. 1956.

30. ________, and Rhoades, H.F. Irrigation of field corn in the west. U.S.D.A. Leaf. No. 440. 1958.

31. Rosic, K. Irrigation of maize in Metobia. Arh. poljopr. Nauk. 8, 21 : 95-107. 1955. (Soils and Fertilizers 19 : 2114. 1956).

32. Sayegh, A. The Agricultural Guide of Lebanon. 1962. Samia Press. Lebanon.

33. Singleton, H.P. Soil, water and crop management investigations. The Columbia Basin Progject. Wash. State Agr. Expt. Sta. Bull. 520. 1950.

34. Sitton, B.G. Some observations on stomatal movements in Hicoria pecan. Proc. Amer. Soc. Hort. Sci. 29 : 80-82. 1932.

35. Somerhalder, B.R. Design criteria for irrigating corn. J. Agr. Engg. 43 : 336-339. 1962.

36. Stockton, J.R. Potato irrigation studies. Paper given at 12th. National Potato Utilization Conference. 1962.

37. Struchtemeyer, R.A., Epstein, E., and Grant, W.J. Some effects of irrigation and soil compaction on potatoes. Amer. Potato J. 40 : 266-270. 1963.

38. Struchtemeyer, R.A. Efficiency in the use of water by potatoes. Amer. Potato J. 38 : 22-24. 1961.

39. Trunov, N.P. Irrigation of maize in the Rostov. J. Agr. Sci. U.S.S.R. 6, No. 12 : 40-46. 1961. (F. Crops Abstr. 15 : 1301. 1962).

40. Vazquez, R. Effect of irrigation at different growth stages, and of N levels on corn yields in Lajas Valley, P.R. J. Agr. Univ. Puerto Rico 45 : 85-105. 1961. (Soils and Fertilizers 25 : 500. 1962).

41. Wormer, T.M., and Ochs, R. Soil moisture, stomatal opening and transpiration of oil palms and ground nuts. Oleagineux, 14 : 571-580. 1959. (Hort. Abstr. 30 : 169. 1960).

APPENDICES

Table 8. Relationship between soil moisture tension and grade of oil absorbed by potato leaves during 8 - 11 A.M. obtained from the greenhouse pot experiment.

Grade of oil	Temp. C.	Soil moisture tension, atm.	Grade of oil	Temp. C.	Soil moisture tension, atm.
5	31	1.0	3	20	1.0
6	32	1.8	4	28	1.2
4	32	1.2	10	32	2.3
5	29	0.7	10	32	2.4
4	32	1.0	7	20	1.8
3	32	1.2	8	24	2.1
11	23	2.0	8	32	2.0
3	36	1.0	10	32	2.3
5	25	0.7	9	31	2.3
5	32	0.6	9	25	2.1
5	20	1.1	9	20	2.4
3	28	1.1	9	24	2.1
4	30	1.2	10	32	3.4
3	32	0.6	10	31	3.2
4	29	0.7	5	25	2.8
4	32	0.9	11	32	3.5
3	30	1.5	11	28	3.4
3	30	1.1	10	31	2.7
3	32	0.8	3	35	1.0
9	23	2.0	4	25	0.9

Table 9. Relationship between soil moisture tension and grade of oil absorbed by potato leaves during 11 A.M. - 4 P.M. obtained from the greenhouse pot experiment.

Grade of oil	Temp. C.	% available soil moisture used	Soil moisture tension, atm.
8	28	26	1.2
3	35	20	0.9
9	28	44	2.6
3	35	22	1.0
8	28	40	2.2
5	32	28	1.4
9	35	40	2.3
8	28	39	2.3
7	32	34	1.8
10	33	47	2.6
9	28	44	2.6
8	22	29	1.5
8	24	37	2.0
5	22	38	2.1
9	22	57	3.7
10	28	44	2.6
10	27	43	2.5
6	27	36	2.0
3	29	20	0.9
8	27	29	1.5
3	29	18	0.8
10	27	48	2.8

Table 10. Relationship between soil moisture tension and grade of oil absorbed by the potato leaves during 4 - 5 P.M. obtained from the greenhouse pot experiment.

Grade of oil	Temp. C.	% available soil moisture used	Soil moisture tension, atm.
11	32	46	2.7
5	28	22	1.0
6	22	30	1.5
8	22	26	1.2
10	25	40	2.3
6	23	22	1.0
6	23	30	1.5
3	23	24	1.1
8	23	40	2.3
4	20	21	1.0
3	20	19	0.9
3	28	24	1.2
9	33	36	2.0
7	25	24	1.2
6	22	22	1.0
4	23	24	1.2
3	20	16	0.7
11	31	40	2.3
9	28	37	2.0
9	23	40	2.2
9	23	39	2.3
10	23	40	2.3
9	30	43	2.5
11	23	47	2.8
9	25	39	2.3
11	23	49	3.0
8	23	42	2.4
10	23	52	3.3

Table 11. The degree of stomatal opening of the potato plant as affected by soil moisture tension obtained from Bouyoucos meter readings in the field. June 28 - July 11. 1963.

Days after Irrigation	Grade of oil absorbed	% Available soil mois. at		Soil mois. tension, atm.		Max. day temp. C.	Max. day R.H.
		12"	24"	12"	24"		
1	4 & 5	100	100	0.33	0.33	34	74
2	5	100	100	0.33	0.33	34	70
3	6	97	100	0.42	0.33	34	83
4	6	95	100	0.50	0.33	28	86
5	6	90	100	0.55	0.33	26	99
6	7	82	95	0.72	0.50	27	99
7	7	71	89	1.2	0.60	29	94
8	8	56	80	1.25	0.75	27	99
9	8	50	78	2.00	0.82	28	99
10	8	44	76	2.45	0.85	29	88
11	9	39	65	3.00	1.25	29	64
12	10	33	58	3.60	1.50	29	68
13	10	27	43	4.50	2.50	30	68
14	11	15	35	7.2	3.3	32	70

Table 12. The degree of stomatal opening of the potato plant as affected by soil moisture tension, obtained from uncorrected Bouyoucos meter readings in the field. June 28 - July 18. 1963.

Days after irrigation	Grade of oil absorbed	% available soil moisture at 20"	Max. day Temperature C.	Max. day R.H.
1	4 & 5	107	34	74
2	4 & 5	107	34	70
3	6	107	34	83
4	6	102	28	86
5	6	102	26	99
6	7	102	27	99
7	7	102	29	94
8	7	100	28	99
9	7	97	29	99
10	8	95	29	88
11	8	93	29	64
12	9	90	29	68
13	10	80	30	68
14	11	77	32	70
15	11	74	33	58
16	11	69	33	70
17	11	60	32	62
18	11	54	31	66
19	11	39	29	68
20	11	32	31	70
21	11	25	29	76

Table 13. The absorbed grades of oil and the corresponding corrected Bouyoucos meter readings for biweekly irrigated potatoes. June - August 1963.

Date	Grade of oil absorbed	% Ava. moisture at 1 ft.	% Ava. moisture at 2 ft.	Date	Grade of oil absorbed	% Ava. moisture at 1 ft.	% Ava. moisture at 2 ft.
June 23	9	38	80	July 24+	11	12	18
24	9	34	71	27	6	95	100
26	10	27	67	28	6	90	100
+ 27	11	24	36	31	7	66	87
28	4 & 5	100	100	August 1	7	58	80
29	5	100	100	2	8	50	78
30	6	97	100	3	8	44	78
July 1	6	95	100	4	8	38	69
2	6	90	100	5	9	27	46
3	7	82	95	+ 8	10 & 11	22	31
44	7	71	89	11	6	96	100
5	8	56	80	15	7	69	87
6	8	50	78	16	8	50	77
8	9	39	65	18	9	36	60
9	10	33	58	+ 22	11	15	29
10	10	27	43	23	4 & 5	100	100
+ 11	11	15	35	24	5	91	98
12	4	100	100	25	6	91	98
15	6	88	96	29	7	65	85

+ Irrigation

Table 14. The absorbed grades of oil and the corresponding uncorrected Bouyoucos meter readings for triweekly irrigated potatoes. June - August 1963.

Date	Grade of oil absorbed	% Available moisture at 20"	Date	Grade of oil absorbed	% Available moisture at 20"
June 23	6	102	July 18+	11	25
24	6	102	24	7	97
26	7	99	28	8	86
+ 27	7	97	31	10	77
28	4 & 5	107	August 1	11	77
29	4 & 5	107	2	11	73
30	6	107	3	11	68
July 1	6	102	4	11	62
2	6	102	5	11	55
3	7	102	+ 8	11	19
4	7	102	11	6	104
5	7	100	15	7	97
6	7	97	16	7	97
8	8	93	18	8	91
9	9	90	22	11	74
10	10	80	23	-	
11	11	77	24	-	
12	11	74	25	-	
14	11	60	29	-	
16	11	39			

+ Irrigation

Table 15. Relationship between soil moisture tension at different depths and the degree of the stomatal opening of potato plant when the leaves began to absorb grades 10 and 11.

Grade of oil	days after Irrigation	Soil moisture tension, atmosphere 8"	16"	24"
10	12	5.7	2.4	1.3
10	11	4.5	2.3	1.0
11	13	5.6	3.1	1.9
11	11	4.3	2.7	1.1
10	8	4.9	2.7	0.8
11	14	4.5	3.6	1.8
11	14	6.0	5.4	2.1
11	13	3.0	2.5	1.7
10	10	4.8	2.3	0.9
11	13	5.4	2.7	1.3
11	11	4.1	2.5	1.2
10	11	3.9	2.1	0.9
11	12	5.9	2.8	1.1
11	13	4.8	1.9	1.7
Average	12	4.8	2.8	1.3
confidence limits at 5% level		4.35 - 5.25,	2.35 - 3.25,	1.08-1.52

Table 16. Potato yield, grade and density as affected by irrigation interval.

Replication	Treatments	yield/ha. m. tons	% Grade + 1	% Grade 2	% Grade 3	Density
	M_1	52.4	53.7	40.5	5.8	1.070
1	M_2	36.1	43.3	46.3	10.5	1.068
	M_3	32.9	26.2	59.8	14.0	1.068
	M_1	41.4	55.7	39.5	4.9	1.072
2	M_2	40.2	37.4	50.3	12.3	1.070
	M_3	32.0	20.6	60.0	19.4	1.071
	M_1	42.0	55.1	39.7	5.1	1.068
3	M_2	36.3	39.3	48.2	12.5	1.072
	M_3	34.9	25.9	57.9	16.1	1.070
	M_1	40.4	52.1	41.9	6.1	1.072
4	M_2	39.1	33.4	53.3	13.3	1.068
	M_3	29.2	25.8	57.8	16.4	1.074
	M_1	44.0	54.1	40.4	5.4	1.070
Average	M_2	37.9	38.3	49.5	12.1	1.069
	M_3	32.2	24.6	58.8	16.4	1.070

+ % are on weight basis.
Grade 1 - potatoes larger than 7 cm. in maximum diameter
Grade 2 - " between 4 and 7 cm. in " "
Grade 3 - " smaller than 4 cm. in " "

Table 17. The degree of stomatal opening of corn plant as affected by soil moisture tension, obtained from Bouyoucos meter readings in the field. June 28 - July 11, 1963.

Days after irrigation	Grade of oil absorbed	% available soil moisture at		Soil moisture tension, atm.		Max. day Temp.	Max. day R.H.
		12"	24"	12"	24"	C.	
1	7	100	100	0.33	0.33	34	74
2	8	95	100	0.50	0.33	34	70
3	9	82	98	0.72	0.40	34	83
4	10	76	95	0.85	0.50	28	86
5	11	70	90	1.15	0.55	26	99
6	11	61	87	1.45	0.64	27	99
7	11	55	85	1.73	0.67	29	94
8	11	50	81	2.0	0.73	27	99
9	11	42	75	2.6	0.85	28	99
10	11	25	75	4.7	0.94	29	88
11	11	15	70	7.2	1.35	29	64
12	11	12	61	8.4	1.5	29	68
13	-	-	52	-	1.8	30	68
14	-	-	39	-	3.0	32	70

Table 18. The degree of stomatal opening of corn plant as affected by soil moisture tension, obtained from Bouyoucos meter readings in the field. June 28 - July 18, 1963.

Days after irrigation	Grade of oil absorbed	% available soil moisture at 24"	Soil moisture tension at 24" atmospheres	Max. day temp. °C.	Max. day R.H.
1	7	100	0.33	34	74
2	8	97	0.42	34	70
3	9	95	0.50	34	83
4	9	90	0.55	28	86
5	10	87	0.64	26	99
6	11	87	0.64	27	99
7	11	85	0.66	29	94
8	11	85	0.66	27	99
9	11	80	0.75	28	99
10	11	75	0.94	29	88
11	11	70	1.25	29	64
12	11	63	1.4	29	68
13	-	54	1.6	30	68
14	-	46	2.3	32	70
15	-	20	5.8	33	58
16	-	15	7.2	33	70
17	-	12	10.2	32	62
18	-	-	-	31	66
19	-	-	-	29	68
20	-	-	-	31	70
21	-	-	-	29	76

Table 19. The absorbed grades of oil and the corresponding corrected Bouyoucos meter readings for biweekly irrigated corn. June - September, 1963.

Date	Grade of oil absorbed	% Ava. moisture at 1 ft.	% Ava. moisture at 2 ft.	Date	Grade of oil absorbed	% Ava. moisture at 1 ft.	% Ava. moisture at 2 ft.
June 23	11	48	69	August 2	11	32	72
24	11	39	60	3	11	20	70
26	11	22	55	+ 8	-	-	30
+ 27	11	17	42	11	9	78	94
28	7	100	100	15	11	50	83
29	8	95	100	16	11	47	80
30	9	82	98	18	11	24	73
July 1	10	76	95	22	-	-	41
2	11	70	90	23	6 & 7	100	100
3	11	61	87	25	9	80	95
4	11	55	85	29	11	48	82
5	11	50	81	30	11	43	79
6	11	42	75	31	11	40	71
7	11	25	75	September 1	11	36	63
8	11	15	70	2	11	29	59
10	-	-	52	3	-	15	52
+ 11	-	-	39	4	-	12	48
12	7	100	100	+ 5	-	-	40
15	10	73	92	6	7	100	100
20	11	39	70	7	8	93	98
+ 24	-	-	43	8	9	90	95
27	8	100	100	9	10	86	91
28	9	91	96	10	11	80	89
31	11	59	83	12	11	67	82
August 1	11	47	81	+ 19	-	-	-

\+ Irrigation

Table 20. The absorbed grades of oil and the corresponding corrected Bouyoucos meter readings for triweekly irrigated corn. June - September, 1963.

Date	Grade of oil absorbed	% Available moisture at 24"	Date	Grade of oil absorbed	% Available moisture at 24"
June 23	9	97	August 1	-	44
24	9	92	2	-	37
26	11	90	3	-	15
+ 27	11	87	+ 8	8	95
28	7	100	11	11	79
29	8	97	15	11	60
30	9	95	16	11	54
July 1	9	90	18	-	47
2	10	87	22	-	32
3	11	87	23	-	15
4	11	85	24	-	-
5	11	85	25	-	-
6	11	80	+ 29	9	90
7	11	75	30	10	87
8	11	70	31	10	82
10	-	54	September 1	11	75
11	-	46	2	11	70
12	-	20	3	11	62
15	-	12	4	11	55
17	-	-	6	11	43
+ 20	8	96	8	-	31
24	11	83	9	-	27
27	11	77	11	-	18
28	11	73	12	-	12
31	--	49	19	-	-

+ Irrigation

Table 21. Relationship between soil moisture tension at different depths and the degree of the stomatal opening of corn plant when the leaves began to absorb only grades 10 and 11.

days after irrigation	Soil moisture tension, Atmospheres		
	8"	16"	24"
4	3	0.8	0.7
4	1.2	0.8	0.6
5	4.6	1.2	0.6
3	1.5	0.6	0.5
5	1.6	0.7	0.6
4	1.3	0.7	0.7
4	1.0	0.7	0.6
5	3.0	1.1	0.9
4	1.5	1.2	0.9
3	3.0	0.8	0.6
5	3.2	0.7	0.6
4	1.0	0.7	0.6
4	1.0	0.6	0.5
4	1.3	0.9	0.7
Average, 4	2.0	0.82	0.65
Confidence limits at 5%	1.4 - 2.6	1.71 - 0.93	0.59 - 0.71

Table 22. Relationship between soil moisture tension at different depth and the degree of stomatal opening of corn plant, when the leaves did not absorb grade 11 (pure kerosene).

days after irrigation	Soil moisture tension, Atmospheres		
	8"	16"	24"
11	8.1	5.4	1.7
10	5.4	3.6	1.1
12	9.6	6.7	1.6
11	7.8	4.9	1.5
12	10.1	7.2	1.9
11	7.5	5.1	1.4
11	7.9	5.6	1.8
12	9.8	6.3	1.9
11	7.3	3.9	1.7
10	5.9	3.2	1.3
11	7.3	5.4	1.6
12	9.2	6.9	2.1
12	9.7	6.7	1.9
11	8.1	5.3	1.1
12	9.6	7.1	2.3
Average 11	8.22	5.55	1.66
Confidence limits at 5%	7.5 - 8.94,	4.89 - 6.21,	1.49 - 1.83

Table 23. Yield and other characteristics of corn as affected by different irrigation intervals.

Repli-cation	Treat-ment	No. of ears/ha.	Ave. wt. of ear, g.	moisture of: shelled corn, %	cobs, %	forage %	Forage yield (at 20%), m. ton/ha.	Ear corn yield, m. ton/ha.	shelling at 15.5% mois.	ratio, grain/ stover
I	M_1	65950	161	21	49	70	6.8	10.6	85	1.67
	M_2	55575	133	22	42	67	6.5	7.4	85	1.22
	M_3	54835	76	27	42	73	5.4	4.2	79	0.77
II	M_1	68172	165	27	49	73	5.8	11.2	82	2.01
	M_2	61503	118	29	59	72	7.6	7.2	84	1.00
	M_3	57057	76	37	40	71	6.4	4.3	63	0.54
III	M_1	60021	213	29	42	74	6.9	12.8	85	1.98
	M_2	57798	92	17	55	63	7.3	5.3	78	0.71
	M_3	48165	67	23	55	71	5.8	3.3	80	0.56
IV	M_1	60762	229	21	42	72	6.7	13.9	83	2.24
	M_2	56316	97	29	53	68	7.2	5.5	80	0.77
	M_3	57798	72	33	53	73	6.0	4.2	78	0.69
Average	M_1	63724	192+	25	46	72	6.5	12.1+	84	1.97+
	M_2	57798	110	24	52	67	7.1	6.3	82	0.93
	M_3	54463	73	30	47	72	5.9	4.0	75	0.64

+ Significantly different at 5% level.