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Response of Peanuts to Irrigation Management at Different Crop Growth Stages

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IMPROVED WATER AND NUTRIENT MANAGEMENT THROUGH HIGH-FREQUENCY IRRIGATION

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Volume 2: Response of Peanuts to Irrigation Management at Different Crop Growth Stages

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ABSTRACT

Past irrigation research on peanuts has shown that when the plant is exposed to soil moisture stress at different crop growth stages, different responses seem to exist between the Spanish and the Florunner peanut varieties. The Spanish peanuts appear more susceptible to soil moisture stress during the blooming and pegging stage, while the Florunners seem more susceptible during the late maturation stage.

The objective of this experiment was to determine the optimum irrigation schedule for peanuts at different crop growth stages for the Spanish and the Florunner varieties. The yield of the two varieties was evaluated under seven different irrigation treatments including a "no stress" check treatment and a dryland treatment. Each treatment had a different schedule of either irrigating or stressing the peanut plant during one or more of three crop growth stages. The three crop growth stages were: (1) pegging; (2) early maturation; and (3) late maturation. Rainfall during the vegetative and blooming stage ensured adequate moisture for both of the crop growth stages.

Evapotranspiration was monitored throughout the life cycle for both peanut varieties. The evapotranspiration was determined using a soil moisture balance equation.

Plant growth in the form of dry matter accumulation and leaf area index was also studied for the Spanish variety. No significant differences in the leaf area index existed between the treatments. The dry matter growth analysis showed that an irrigation during the pegging stage resulted in a faster pod weight accumulation during the early maturation stage than if no irrigation occurred during that stage.

The yield and evapotranspiration results showed that differences existed between the two peanut varieties. First, for the Spanish variety, the results indicated that soil moisture is needed during the pegging stage to obtain near maximum yields. Treatments with an irrigation during the pegging stage had a greater evapotranspiration and larger yields, than the treatments without an irrigation during this stage. Second, if an irrigation is made during the pegging stage, an additional irrigation during the early maturation stage is unnecessary. Third, an irrigation during the late maturation stage will increase yield if dry climatic conditions normally exist during this stage. In the case of the Florunner variety, the yield results indicated that moisture stress should occur in no more than one of the crop growth stages if yield reductions are to be minimized. Also, an adequate supply of soil moisture during the late maturation stage is absolutely necessary in order to obtain maximum yields for Florunner peanuts. Treatments which had an irrigation during the late maturation stage had a steady evapotranspiration rate during this crop growth stage and had near maximum yields. Treatments which showed a decrease in the evapotranspiration rate during the late maturation stage produced a significantly lower yield.

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INTRODUCTION

Presently many agricultural regions with a large irrigation demand are faced with dwindling water supplies. Furthermore, with increased energy cost for pumping water, there is a greater incentive to conserve water. One method of conserving water is to use irrigation management techniques such as irrigation scheduling. An important factor in irrigation scheduling is to know which crop growth stages are most sensitive to drought. For most crops the plant cannot undergo any stress during certain crop growth stages if yield losses are to be held to a minimum (Salter and Goode, 1967). Some crop growth stages are more sensitive to moisture stress than others. Water can be conserved by not irrigating during the less critical growth stages. Good crop yields and increased water use efficiencies are obtained by allocating limited water supplies to the more sensitive growth stages.

Several irrigation scheduling techniques are available which consider the sensitivity of crop growth stages to moisture stress. One such irrigation scheduling method is the Stress Day Index (SDI) concept developed by Hiler and Clark (1971). Using the SDI concept, the crop stage sensitivity of several crops has been quantified. For peanuts the crop susceptibility was evaluated by Bausch (1971). With the sensitivity values or susceptibility values determined from the

SDI method,it is possible to predict the effect on crop yield if irrigation water is not applied during any one of the crop growth stages. It would be useful to know the effects on crop yield if an irrigation were withheld from more than one crop growth stage. Possibly higher water use efficiencies could be obtained if irrigation water were withheld from more than one crop growth stage. Also it would be interesting to know the effect of irrigating or not irrigating the peanut plant during certain crop growth stages on evapotranspiration and plant growth. Therefore a research project on peanuts (Arachis hypogaea l.) was undertaken.

The objective of this research was to determine the optimum irrigation schedule for peanuts at different crop growth stages. The yield of two varieties of peanuts was evaluated under seven different irrigation treatments including a "no stress" check treatment plus a dryland treatment. The two varieties of peanuts studied were Spanish and Florunners. Plant growth in the form of dry matter accumulation and leaf area index was also studied for the Spanish variety. Relative yield versus relative evapotranspiration and yield versus water application was evaluated. Relative yield was defined as the ratio of a treatment yield to the maximum treatment yield and relative evapotranspiration was defined as the ratio of the evapotranspiration of a treatment to the maximum evapotranspiration from any of the treatments.

LITERATURE REVIEW

Peanut irrigation research has mainly consisted of: (1) irrigation timing studies, using soil moisture tension as a timing indication; (2) fixed frequency irrigation schedules; and (3) the effect of stressing the peanut plant during certain crop growth stages.

Matlock et al. (1961) conducted a four year study (1956-1959) in Oklahoma on irrigation scheduling using several soil moisture tension levels as a guide for timing. They showed that the highest return per centimeter of irrigation water applied occurred when the soil moisture tension was allowed to reach 6 atmospheres before irrigation. The soil moisture content dried to a level where the soil moisture tension reached 6 atmospheres only two times per growing season. A study using five alternative, but fixed, irrigation schedules was made on peanuts by Mantell and Goldin (1964) in Israel. The optimum treatment with respect to yield and quality occurred when the peanuts were irrigated on a 30 day interval. Stansell et al. (1976) did a water stress study on peanuts grown in the southeastern United States under controlled soil water conditions. They studied the yield and quality responses of peanuts to six different irrigation treatments. Different wetting depths and soil moisture tension levels were used as timing indiciations. Among the treatments with the highest crop yield, the treatment with small, frequent irrigations (the top 30 cm of the soil was wetted whenever the soil moisture tension reached 0.2 atm) had the least amount of water applied.

Some studies have been made on the effect of soil moisture stress on crop yield during certain growth stages. Whitt and Van Bavel (1955) found that water requirements are the most crucial during flowering and pod development. In two separate studies in Taiwan, Su and Lu (1965) and Su et al. (1964) found that the peak flowering and early fruiting stages were the most susceptible periods to moisture deficiency for Spanish peanuts. The maturation stage showed the least effect on yield due to moisture deficiency. In an international review of peanut irrigation, Klepper (1973) reinforced the idea that the period of greatest sensitivity to stress, in terms of a reduction in yield, was the flowering period.

Hiler and Clark (1971) studied the sensitivity of moisture stress during six different growth stages on the yield of a Spanish peanut. The six growth stages were: (1) vegetative; (2) peak flowering and early pegging; (3) peak pegging; (4) early nut development; (5) intermediate nut development; and (6) late nut development. In terms of the greatest reduction in yield, they found that the growth stage most sensitive to stress was the peak flowering and early pegging stage. Hiler and Clark (1971) used soil moisture tension as a timing guide for irrigation. Only one growth stage was stressed during the growing season, with water readily available during the rest of the growing season.

In a similar study, Bausch (1971) divided the development of a Spanish peanut into three periods or growth stages and studied the sensitivity of crop yield to water stress during each growth stage.

The three stress periods were: (1) from the vegetative stage to early pegging; (2) from pegging to nut development; and (3) maturation. Unlike many other irrigation studies, this one used plant water potential as an irrigation timing guide. It was found in this study that the vegetative stage to early pegging stress period was the most sensitive to stress in terms of the greatest reduction in yield.

In an eight year study of irrigation stress on peanuts (1971-1978) Newman (1978, 1979) used six different irrigation treatments or schedules to observe the effect of moisture stress during certain crop growth stages on crop yield. The six different irrigation schedules were: (1) one irrigation at 45 days after planting or the blooming stage, and then no more irrigations for the rest of the growing season; (2) two irrigations during the growing season, one at 45 days and one at 66 days after planting or the blooming and pegging stage; (3) two irrigations during the growing season, one each at 66 and 87 days after planting or the pegging and maturation stage; (4) one irrigation at 66 days after planting; (5) three irrigations during the growing season, one each at 45, 66, and 87 days after planting; and (6) 53 mm every eight days, for a check treatment. From this study it was found that failure to irrigate peanuts during the flowering stage resulted in the greatest yield reduction, while irrigating at least once during each of the flowering, pegging and maturation growth stages resulted in yields nearly equal to the fully irrigated treatment.

Pallas et al. (1979) conducted an irrigation stress study on

Florunner peanuts in which the growth period was divided into four different growth stages. Six different irrigation treatments were used. The effects of stressing the plant during one or more crop growth stages were evaluated by observing changes in leaf water potential, leaf diffusion resistance, and crop yield. The four crop growth stages were: (1) from 0 to 35 days after planting (vegetative); (2) from 36 to 70 days after planting (blooming); (3) from 71 to 105 days after planting (pegging and early maturation); and (4) from 105 to 145 days after planting (late maturation). In all treatments, the plants were never stressed during the vegetative stage. The treatment with moisture stress during stage 3 and again during stage 4 resulted in significantly lower yields. The treatment with moisture stress during stage 2 and again during stage 3 had the second lowest yield. Of the treatments with only one stress period, the treatment with moisture stress during crop growth stage 4 had the lowest yield. Generally the later the drought period, the more it reduced crop yield. This seems to differ from the findings of Su and Lu (1963), Su et al. (1964), Hiler and Clark (1971), Bausch (1971), and Newman (1978, 1979), but this contradiction could be due to the varietal differences between Spanish and Florunner peanuts.

Peanut irrigation management research has consisted of three approaches. One of the objects in each approach was to find a guide for irrigation management which would result in using the least amount of irrigation water while maintaining high crop yields. One of the approaches was to study the effect of stressing the peanut plant during certain crop growth stages. When the crop susceptibility of certain crop growth stages was evaluated, different responses seem to exist between the Spanish and the Florunner varieties. For the Spanish peanuts Su and Lu (1963), Su et al. (1964), Hiler and Clark (1971), Bausch (1971) and Newman (1978, 1979) showed that soil moisture stress during the peak flowering or the pegging crop growth stage caused the greatest reduction in yield. For the Florunners however, Pallas et al. (1979) showed that soil moisture stress during the late maturation crop growth stage caused the greatest reduction in yield. The possible varietal differences in peanut response to irrigation management at different crop growth stages needs investigation and clarification.

TEST AREA, EQUIPMENT, AND PROCEDURE

Seven different irrigation treatments for the Florunner and Spanish peanuts were used including a check treatment to provide well watered conditions for the plants. Furthermore there was a dryland (no irrigation) treatment. Each irrigation treatment plus the dryland treatment was replicated three times. The irrigation treatments were randomly assigned within each replication.

Test Area

This study was conducted in a field plot at the Texas Agricultural Experiment Station at Stephenville, Texas. The field layout is shown in Fig. 1. The total area was 2.7 ha (6.7 acres). Each replication occupied a 228 m (750 ft.) by 27 m (90 ft.) area. Rows ran lengthwise from north to south. Each irrigation treatment occupied a 15 m (50 ft.) by 27 m (90 ft.) area with one-half of the area occupied by the Spanish variety and the other half occupied by the Florunner variety. The varieties were randomly assigned within each treatment.

Between each irrigation treatment a 15 m (50 ft.) by 27 m (90 ft.) border plot was used to eliminate interference between adjacent irrigation treatments. The two areas between the three replications occupied a 228 m (90 ft.) by 18 m (60 ft.) area and were planted with Spanish peanuts. These two areas were also used as a dryland check. Four rows, 0.9 m (30 in.) wide were used for each variety.

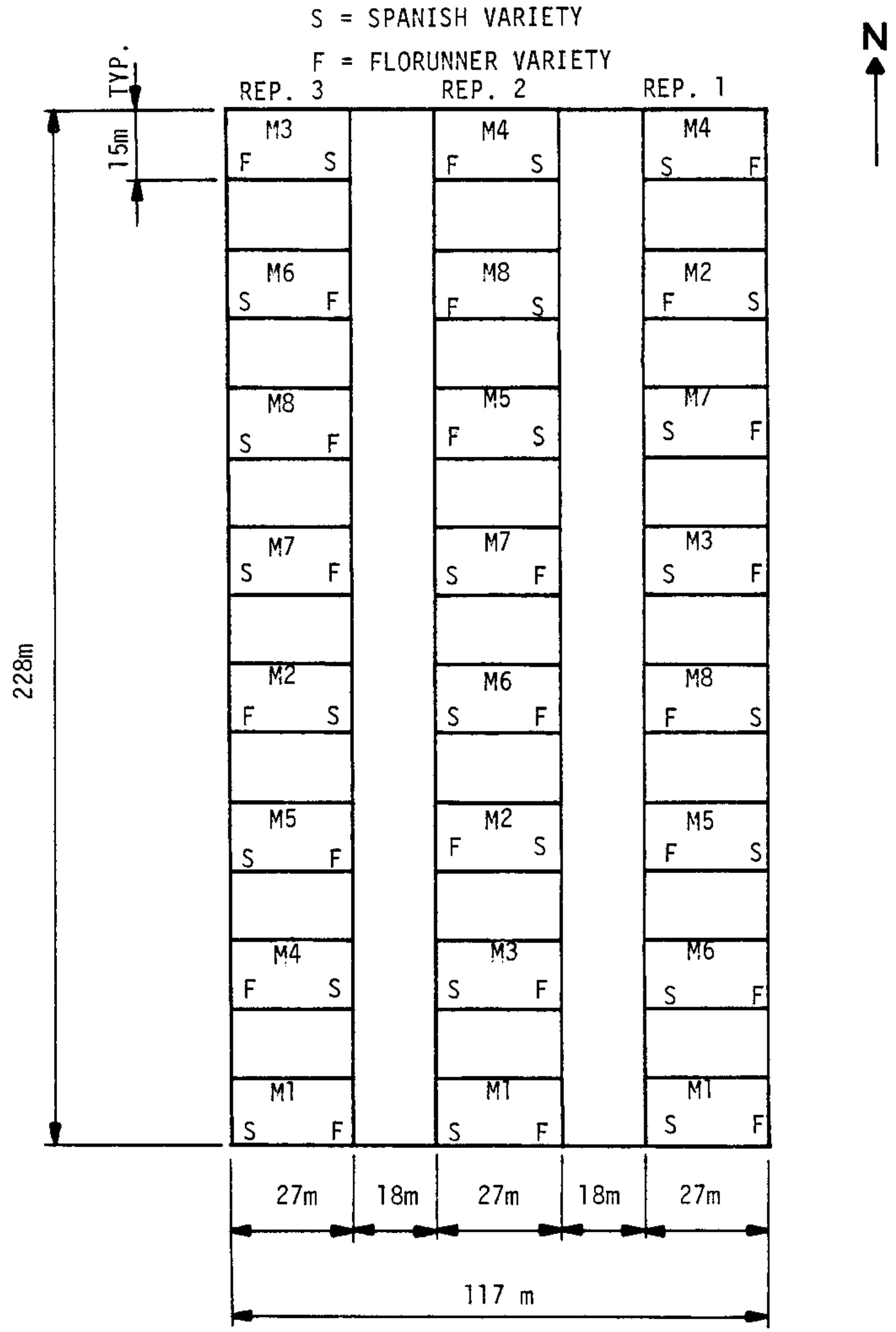

FIG. 1 PLOT LAYOUT

The soil in the area was of the Windthorst fine sandy loam series with an A horizon consisting of fine sandy loam to a depth of 25 cm (10 in.) and a B horizon of red sandy clay (Stahnke et al., 1980). On the north side of the study area, the soil surface was slightly sloping.

Equipment

The equipment used in this study included a sprinkler irrigation system, several meteorological instruments, soil tensiometer and a soil moisture measurement unit.

Irrigation System

The irrigation system was a solid set sprinkler system. Each irrigation treatment had two 7.6 cm (3 in.) diameter aluminum laterals, one on each side of a treatment plot. Three sprinklers were used per lateral. The laterals were spaced 15.24 m (50 ft.) apart, and the sprinklers were spaced 9.14 m (30 ft.) apart. Each sprinkler was attached to a 46 cm (18 in.) riser and had a nozzle diameter of 0.40 cm (5/32 in.). The pressure at the nozzle was 345 KPascals (50 psi). The laterals were attached to bonnet valves which in turn were attached to a 10.16 cm (4 in.) aluminum main pipe. An electric pump with an automatic shut-off timer was used to deliver the water.

Meteorological Instruments

The meteorological instruments used to measure climatic parameters included an anemometer, evaporation pan, rain gauge, maximum and minimum thermometer, and pyranometer. All the meteorological instruments were located at a weather station on the Experiment Station Farm approximately 100 meters away from the center of the experiment plot. The meteorological instruments were:

(1) Anemometer. Daily wind run measurements were made using a 3-cup totaling anemometer. The anemometer was mounted 0.46 cm (18 in.) above the evaporation pan.

(2) Evaporation Pan. Daily pan evaporation measurements were made from a U.S. Weather Bureau class A evaporation pan.

(3) Rain Gauge. Daily rainfall totals were measured with a standard U.S. Weather Bureau 20.32 cm (8 in.) rain gauge.

(4) Pyranometer. Solar radiation measurements were made using an Epply Black and White* pyranometer (Model 8-48). The pyranometer was attached to a Licor LI-510 integrator. The pyranometer was mounted 1.37 m (4.5 ft.) above the ground.

Soil Moisture Measurement Unit

Soil moisture measurements were made at various depths through an access tube using a Troxler neutron soil moisture gauge and scalar.

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* Trade names are used in this publication solely for the purpose of providing specific information. Mention of a trade name does not constitute a guarantee or warranty of the product by the Texas A&M University System or an endorsement by the University over other products not mentioned.

The neutron soil moisture gauge consists of a probe, a cable, and a safety shield and standard. The probe consisted of a radioactive source, detector tube which sensed slow moving neutrons, and a preamplifier. The output of the probe was recorded by the scalar in terms of counts per time unit. The scalar used was a Troxler Model 600. Aluminum tubing with an inside diameter of 4.13 cm (1.625 in.) and a wall thickness of 0.09 cm (.035 in.) was used for an access tube.

Procedure

The seven irrigation treatments, the type of data collected and the method of data collection will be discussed in this section. The data collected were: (1) irrigation amount; (2) climatic data; (3) soil moisture; (4) leaf area; (5) dry matter accumulation; and (6) crop yield.

Each irrigation treatment was based on a combination of either irrigating or stressing the peanuts during certain crop growth stages. The peanuts were planted on June 8th and emerged on June 15th. A herbicide (Treflan) was applied at 1.12 kg/ha (1 lb/acre) immediately after planting. The peanut's life cycle was divided into five crop growth stages. The five crop growth stages and the approximate duration and dates of occurrence are shown in Table 1.

TABLE 1

Peanut Crop Growth Stage Duration

Planting Date: 6-8-79

Crop Stage	Duration	Date
(1) Vegetative	0 - 30 days	6/8 - 7/8
(2) Blooming	30 - 55 days	7/8 - 8/2
(3) Pegging	55 - 85 days	8/2 - 8/31
(4) Early Maturation	85 - 105 days	8/31 - 9/20
(5) Late Maturation	105 - 126 days (1) 105 - 140 days (2)	9/20 - 10/11 (1) 9/20 - 10/25 (2)

(1) Spanish peanuts
(2) Florunner peanuts

In this study, crop growth stages 3, 4 and 5 were used to design the seven irrigation treatments. It was originally planned that the blooming, pegging and early maturation growth stages (2, 3 and 4) would be used in eight irrigation treatments, and that spring precipitation would be sufficient to fulfill the moisture requirements during the vegetative stage. However, 68 mm (2.7 inches) of rainfall during the blooming period eliminated all treatments with a drought period planned during the blooming stage. When it became apparent that dry conditions would persist throughout September, the late maturation stage, was added to the crop growth stage scheme and two other irrigation treatments were added. The final seven irrigation treatments plus the dryland treatment are shown in Table 2. All three replications of each treatment were irrigated simultaneously. In

TABLE 2

Irrigation Schedule

Treatment	Pegging (August 21-22)	Early Maturation (September 5-7)	Late Maturation (September 26-27)
D.A.P.	75, 76	91, 92, 93	111, 112
1	0	0	0
2	I	0	0
3	0	I	0
4	I	0	I
5	0	I	I
6	I	I	0
7	I	I	I
8	Check 53 mm every 8 days starting on August 7.		

I = Irrigation Application

0 = Drought Period

D.A.P. = Days after planting an irrigation occurred his eight year study, Newman (1979) established that an irrigation of 53 mm every eight days was the optimum frequency for a well watered treatment. A treatment using this criterion was established to provide a well watered check treatment. The check treatment received its first irrigation on August 7 and the last irrigation on September 16.

The sprinkler system was evaluated on two separate occasions. This was necessary because the pump at the well operated at different well pressures during the growing season due to a drawdown of the water table. The pump pressure was 345 KPascals (50 psi) for those treatments that were irrigated during the pegging stage and 179 KPascals (26 psi) for those treatments irrigated during the early maturation stage. During the late maturation stage the pump pressure had increased to 345 KPascals. During the early maturation period, flow measurements from several sprinklers were made. For an operation time of 13 hours, the average sprinkler output was 71.12 mm (2.80 inches). Flow measurements from several sprinklers were made again during the late maturation stage and with an operation time of 8 hours, the average sprinkler output was 64 mm (2.53 inches). Furthermore, from application depth measurements made during this period, an 81% application efficiency was found. Knowing the application efficiency, the amount of water applied was calculated by multiplying the application efficiency by the sprinkler output. Since fairly similar weather conditions existed during all irrigation periods, an 81% application efficiency was used for all of the irrigation applications. Since the pump pressure was the same during both the pegging stage and the late maturation irrigations, the same application depth was used for both periods. The irrigation application depth and the climatic conditions for each irrigation are summarized in Table 3.

To determine the daily potential evapotranspiration, daily climatic measurements were made. Also daily pan evaporation was measured for comparison with the calculated potential evapotranspiration. The daily climatic measurements consisted of maximum and minimum temperatures, wind run and solar radiation. Potential evapotranspiration was calculated using both the Penman and Van Bavel combination methods.

Evapotranspiration was computed for each treatment using the following water balance equation:

$$ET = P + I - dSM$$

where ET = actual evapotranspiration depth over a time period, P = effective precipitation depth; I = irrigation depth, and dSM = change in soil moisture content to a certain depth over time. The time period in which evapotranspiration was determined was usually a week. Since the plots had only a slight slope with an underlying slowly permeable subsoil, deep percolation, lateral flow, and capillary flow were considered negligible. The precipitation amount was corrected for runoff using the Soil Conservation Service method (Schwab et al., 1966). For both varieties the original weekly ET values (for several periods during the middle of the growing season) were adjusted for

TABLE 3

Climatic Conditions During Irrigation Applications

Date	Max. Temp. °C	Anemometer Windspeed km/hr	Net Radiation mm/day	Treatments Irrigated	Application Depth mm
8-7	32.8	3.44	6.61	TM 8	53
8-15	32.8	3.14	6.68	TM 8	53
8-21	35.6	7.13	5.52	TM 4, TM 2	51
8-22	30.6	3.04	6.57	TM 7, TM 6	51
8-23	32.2	2.69	5.18	TM 8	53
8-31	34.4	2.92	5.49	TM 8	53
9-5	33.9	3.00	6.88	TM 3	55
9-6	32.2	3.44	5.37	TM 5, TM 7	55
9-7	32.8	3.44	5.00	TM 6	55
9-8	29.4	3.43	4.62	TM 8	53
9-16	27.8	3.31	4.84	TM 8	53
9-26	33.3	4.60	5.12	TM 4, TM 5	51
9-26	37.8	4.39	5.24	TM 7	51

some runoff from the well-watered treatment (treatment 8). The well-watered treatment was adjacent and slighly uphill from treatment 5 in the first replication (Fig. 1). The runoff was estimated using the Soil Conservation method (Schwab et al., 1966). The amount of runoff and the calculated curve number are shown in Appendix Table A4. The estimated runoff from treatment 8 was subtracted from the soil moisture balance of treatment 8 and added to the soil moisture balance of treatment 5. The curve number used was for leveled agricultural land with good hydrologic conditions. Unless the soil was either very wet or dry, antecedent moisture condition two was used.

The change in soil moisture was evaluated by weekly measurements of soil moisture using the neutron scatter method. Soil moisture measurements were made on one replication of each treatment for both of the peanut varieties. Soil moisture was measured to a depth of 150 cm, with 10 cm increments used to a depth of 50 cm and 20 cm increments used from 50 to 150 cm. An individual treatment plot with access tubes is shown in Fig. 2.

The soil moisture content was determined as follows. At each specified soil depth, a neutron count over a one minute interval was read from the scalar. Standard counts, taken with the probe inside the shield were obtained before and after each soil profile was measured. Count ratios for each soil depth were calculated by dividing the neutron count by the average of the standard counts. These count ratios could then be translated into soil moisture content

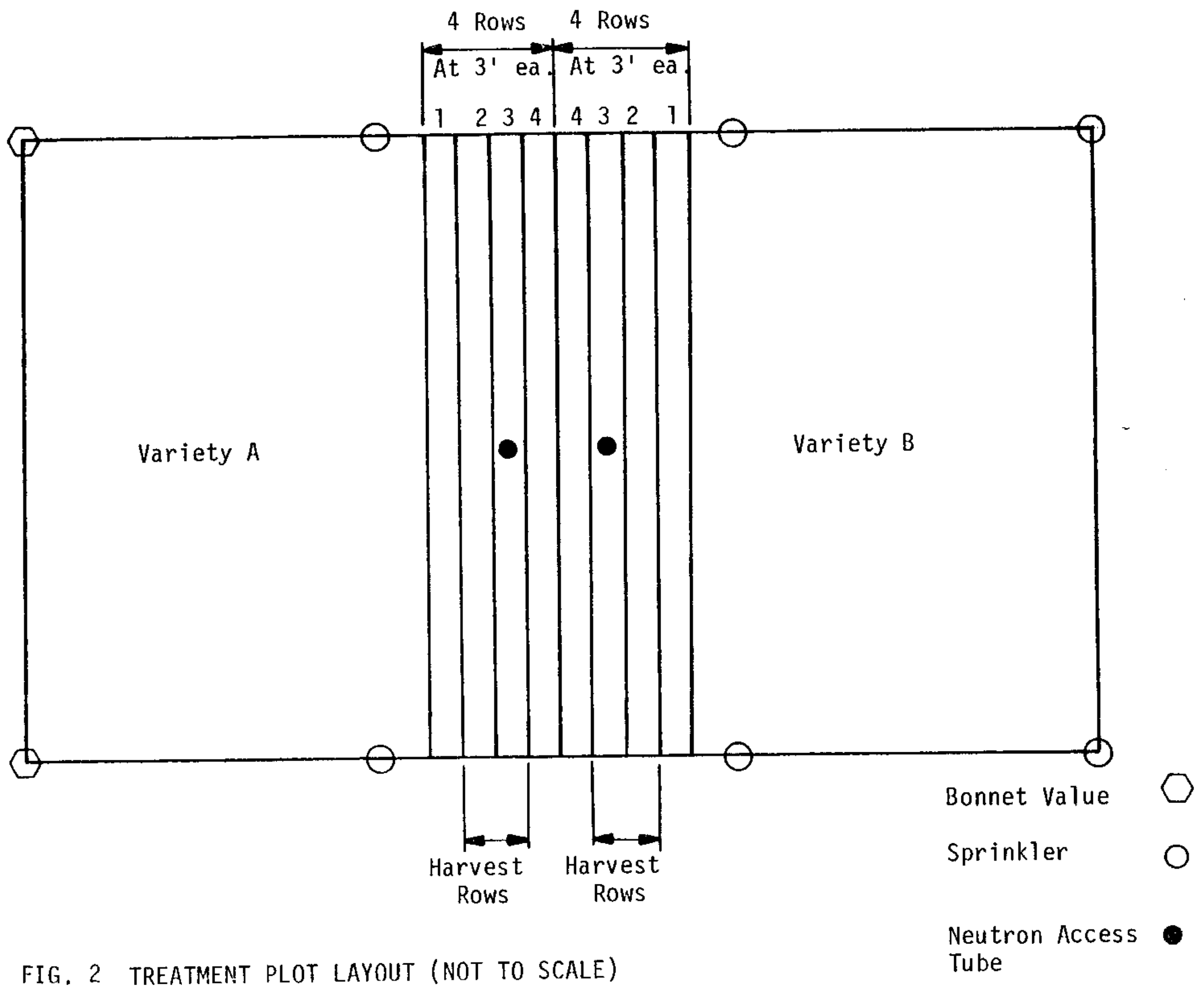


FIG. 2 TREATMENT PLOT LAYOUT (NOT TO SCALE)

values using the calibration curves in Fig. 3. A linear relationship existed between the count ratio and volumetric soil water content. Two separate linear relationships were used, one for the top 20 cm of the soil profile and one for the bottom 130 cm of the soil profile. The two linear relations are shown in Fig. 3. Also shown in Fig. 3 is a standard reference linear relationship whose slope can be compared with the linear relationship of soils below 20 cm. The linear relationships were obtained by correlating gravimetric soil moisture content with the count ratios. The gravimetric soil moisture content was determined from field samples at the same depths that the count ratios were obtained. The total water depth in the soil profile was obtained by multiplying each volumetric moisture content by the soil layer thickness and summing the water depth for each interval in the soil profile. The change in soil moisture over a time period was taken as the difference between the total soil moisture content at the beginning and end of the time period.

Calculation of evapotranspiration amounts using the measured changes in soil moisture required several assumptions. An assumption made in the use of the calculated ET data is that the ET determined for the first replication is applicable to the other two replications. This is not a bad assumption if: (1) the soil moisture content in the zone of influence of the neutron probe is representative of the soil moisture content of the plot; and (2) the change in soil moisture content of the measured plot is representative of the other replications. These two assumptions imply that: (1) the root distribution

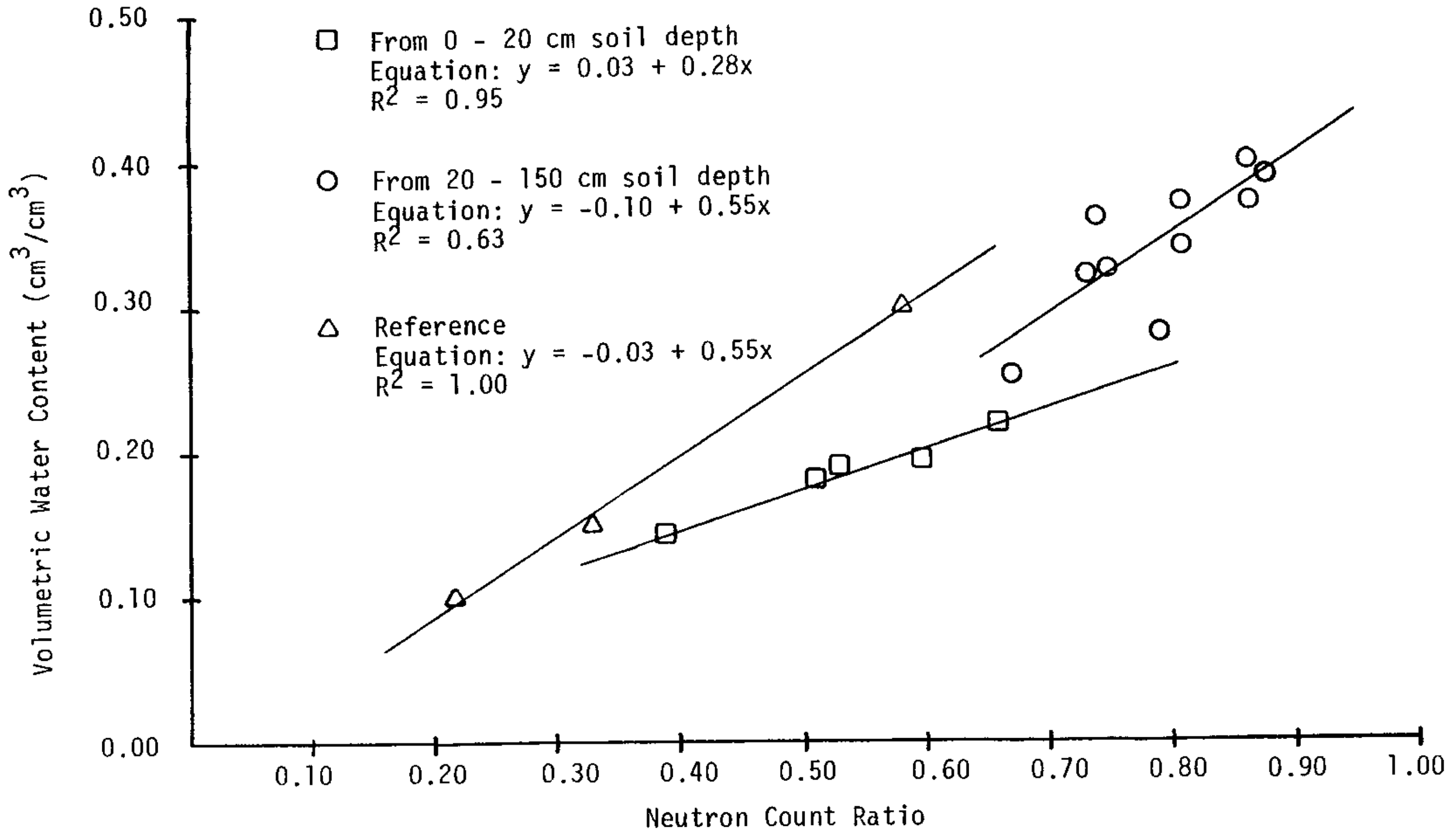


FIG. 3 VOLUMETRIC WATER CONTENT VERSUS NEUTRON COUNT RATIO

and depth around the access tube is approximately representative of that plot and of the other replication areas; and (2) that the soil type in each replication is approximately the same.

Sources of error also exist in the use of the soil moisture balance equation;

$$ET = P + I - dSM.$$

The main problem was the determination of effective precipitation. As was discussed previously, the SCS method (Schwab, 1966) was used to determine the runoff from precipitation. The runoff calculated was subtracted from the rainfall amount. Also, as was previously discussed, the irrigation application for treatment 8 (the well-watered treatment), was adjusted for runoff onto treatment 5. The irrigation application of the other treatments had a slow application rate of 5.84 mm/hr (0.23 in/hour), and occurred infrequently. Therefore, the irrigation application of treatments 1 through 7 were not adjusted for runoff.

Another source of error is that some deep percolation could have occurred during very wet soil conditions. Miller and Aarstad (1971) showed that less water for deep percolation was available during periods of large evapotranspiration and the assumption that deep percolation is negligible is very good. When small ET rates occur, a hazard exists in ignoring deep percolation. In this experiment, the potential evapotranspiration was large enough to utilize the applied irrigation water and it is unlikely that any significant amounts of deep percolation occurred. Furthermore, there was a heavy clay at a depth of 90 cm underlying the soils of this experiment. The soil moisture was measured to a depth of 150 cm (for most treatments). Thus, water lost from the root zone was mainly from ET and was accounted for by the change in soil moisture measurements. A third source of error in the model is that some subsurface lateral flow could have occurred under a slightly sloping land during extremely wet conditions, but this is expected to be very small.

Basically the neutron scatter method is a satisfactory method for estimating the change in soil moisture content. A review of the advantages of using the neutron scatter method and some of the problems with its use was given by Visvalingham and Tandy (1972). Kristensen and Jensen (1975) used the neutron scatter method to determine seasonal evapotranspiration in a soil moisture balance model and obtained satisfactory results. Bowman and King (1965) used the neutron scatter method and a soil moisture balance model to estimate evapotranspiration. They concluded that it was a satisfactory method, but several problems existed. A major source of error in the neutron scatter technique is the existence of non-uniform soil conditions around the probe. Other error sources include: (1) instrumental properties such as aging components; (2) soils containing organic matter; and (3) presence of water infiltrated on the sides of the access tube (Visvalingham and Tandy, 1972).

Leaf area and dry matter determinations were made on the Spanish variety of each treatment for all three replications. Leaf area index was defined as the total leaf area divided by the soil area covered by the canopy or over a standard size area for the case of a row crop. According to Sivakuna (1978), leaf area index can be an important input in the characterization of crop growth. Kramer (1963) wrote that a reduced transpiration rate of plants will among other things reduce photosynthesis and plant growth. Therefore the leaf area index and dry matter accumulation can be helpful in detecting the effects of moisture stress during certain crop growth stages. Leaf area and dry matter determinations were made at the beginning of the irrigation treatments or 55 days after planting, and were then determined approximately every 10 days until harvest.

The leaf area index was determined using several representative peanut plants, chosen from a border plot. The leaves from each plant were counted and photo copied. The total leaf area for each plant was then determined by planimetering the outline of each leaf on the photo copy. The average area per leaf was determined by dividing the total leaf area per plant by the number of leaves per plant (LA/NL). From each treatment in each replication, a group of plants within a 15 cm (6 in.) row length were selected and the number of plants and leaves counted. From these determinations the average number of leaves per plant was determined (NL/NP). From the product of the average area per leaf and the average number of leaves per plant, the average leaf area per plant was determined. Basically this approach assumes that the total leaf area of a plant was linearly related to the number of leaves per plant. The number of leaves correlated well with the total leaf area ($r^2 = 0.96$). By knowing the plant density within each treatment NP/A (number of plants/treatment area), the leaf area index was calculated using the following equation:

$$LAI = LA/NL \times NL/NP \times NP/A.$$

The dry matter accumulation was determined as follows. In particular treatments, the plant picked for the LAI determination was divided into three parts; the leaves, stems and roots, and pods. Each plant was oven dried at 70°C for 48 hours and then weighed. From this the difference in dry matter accumulation for the different treatments was identified.

The average yield was determined in the following manner: The center two rows of the four rows in each treatment, and in each replication were harvested. The peanut plants were dug with an inverter peanut digger, left in the field for a period of time to dry and then thrashed and combined with a Benthal sacking combine. The Spanish peanuts were dug on October 12 and were combined on October 18th. The florunners were dug on October 26 and combined on November 27th. The peanuts were dried in the sack, weighed and processed for grade.

RESULTS AND DISCUSSION

The results of the crop yield, evapotranspiration, leaf area index, and dry matter accumulation evaluations for all treatments will be discussed in this chapter. Relative yield versus relative evapotranspiration will be used to compare the effectiveness of each treatment. The water use efficiency for each treatment will also be discussed. Relative yield is the yield of a certain treatment divided by the maximum yield from all treatments for the same variety and relative evapotranspiration is the cumulative evapotranspiration at the end of the growing season divided by the maximum cumulative evapotranspiration from all treatments for the same variety. The differences in evapotranspiration during certain crop growth stages of the different treatments are related to the differences in yield. The difficulties encountered in this study and the assumptions made during data analysis will be discussed.

Crop Yield

The reported yields for both peanut varieties were obtained by averaging the yields from the three replications. For both the Spanish and the Florunner varieties, significant differences in crop yield were obtained between several treatments. Also differences existed between the two varieties in the crop yield response for some treatments. Duncan's multiple range test with a significance level of 10% was used to test which of the treatments had significantly different yields. The actual yield, the relative yield and Duncan's multiple range test grouping are shown in Table 4 for the Spanish peanut and in Table 5 for the Florunner peanut. In the grouping column, yield values with the same letter are not significantly different. As expected for both the Spanish and the Florunner variety, treatment 8 (the well-watered treatment) produced the maximum yield and treatment 1 (the dryland treatment) produced the minimum yield.

From the yield results, different conclusions on the effect of irrigating during certain crop growth stages can be made for the Spanish and Florunner peanuts. For both varieties, the importance of the blooming stage was not tested, but numerous experiments such as those of Bausch (1971), Hiler and Clark (1971), Newman (1978, 1979), Su et al. (1964) and Su and Lu (1963) have asserted the importance of having adequate moisture during the blooming stage.

For the Spanish peanuts, the yield results indicated that both pegging and the late maturation stages are crucial stages to have soil moisture. Treatment 4, which had an irrigation during the pegging and another during the late maturation stage, produced the second highest yield. According to Duncan's test, treatment 4 could be ranked among the top yielding treatments.

The importance of the pegging and late maturation stages is also demonstrated by treatments 5 and 6. Treatment 5 which had a drought period during the pegging stage, and treatment 6, which had a drought period during the late maturation stage, were both ranked among the lower yielding treatments.

Treatment 7, which had an irrigation during each crop growth

TABLE 4

Yield of the Spanish Peanut Variety

Treatment	Yield kg/ha	Relative Yield	Duncan's Test Grouping
8 (check)	3168.3	1.00	A
4 (101)*	2625.2	0.83	A B
7 (111)	2614.5	0.83	A B
2 (100)	2438.7	0.77	C B
5 (011)	2342.9	0.74	C B
6 (110)	2279.0	0.72	C B
3 (010)	2044.7	0.65	C B
1 (000)	1874.3	0.59	C

TABLE 5

Yield of the Florunner Peanut Variety

Treatment	Yield kg/ha	Relative Yield	Duncan's Test Grouping
8 (check)	3056.4	1.00	A
4 (101)*	2933.7	0.96	A B
5 (011)	2832.8	0.93	A B C
7 (111)	2822.1	0.92	A B C
3 (010)	2300.3	0.75	D B C
6 (110)	2247.0	0.74	D C
2 (100)	2183.1	0.71	D C
1 (000)	2130.0	0.70	D

* Numbers in parenthesis refer to an irrigation (1) or no irrigation (0) during pegging, early maturation and late maturation crop growth stages, respectively.

stage, did not yield any better than treatment 4 (drought period during the early maturation stage). An irrigation during the early maturation stage seems to have had little effect as seen by treatments 3, 5, 6 and 7.

Comparing the treatments with two drought periods, treatments 2 and 3, the treatment with an irrigation during the pegging stage (treatment 2) had a 12% greater relative yield than the treatment with only an irrigation during the early maturation stage (treatment 3). But Duncan's test did not indicate the two treatments significantly different statistically.

In the case of the Florunners, it can be seen from this experiment that it is important to have an adequate soil moisture supply during the late maturation stage. The treatments with two irrigations, but one of them occurring in the late maturation stage, treatments 4 and 5, had near maximum yields (96% and 93%, respectively). It did not matter if the earlier irrigation was applied either during the pegging or the early maturation growth stages. The treatments with two drought periods, treatments 2 and 3, did not have significantly greater yields than the dryland treatment.

The yield results of this study conflicts with the findings of several past investigators. Bausch (1971), Hiler and Clark (1971), Newman (1978, 1979), Su et al. (1964) and Su and Lu (1963) found the pegging and the blooming stages to be very sensitive to moisture stress. They also found that moisture stress during the maturation stage produced only a slight decrease in yield. In this experiment, however, an irrigation during the late maturation stage helped improve yields for both varieties of peanuts. In the studies of Bausch (1971) and Newman (1978, 1979), the maturation stage corresponded with a high rainfall period (Newman and Woodard, 1979), which made it difficult to determine the sensitivity of that period to moisture stress. During this experiment, however, the early and late maturation stage was very dry with high temperatures. Furthermore, the four mentioned experiments tested only the Spanish peanut variety. The Florunner variety, as demonstrated in this experiment, responded differently to moisture stress than the Spanish variety. In an irrigation study on Florunners, Pallas et al. (1979) found results similar to those in this experiment in which the late maturation stage was found to require an adequate supply of soil moisture.

In comparing the effectiveness of the different irrigation treatments, the quality of the yield is an important factor. Combining yield quality and the quantity of the yield can be accomplished by computing a market value in dollars per hectare for each treatment. The quality, expressed as the average "percent sound mature kernels" (%SMK), and the average dollar per hectare produced from each treatment are shown in Table 6.

Potential Evapotranspiration

The potential evapotranspiration during each crop growth stage was determined by: (1) Van Bavel's modified combination equation; (2) Penman's combination equation; and (3) Class A pan evaporation. Results from these three determinations are shown in Table 7. Daily

TABLE 6

Peanut Quality and Gross Income

	Spanish		Florunner	
Treatment	% SMK	$/ha	% SMK	%/ha
1	69.7	881.22	76.4	1055.94
2	70.9	1140.00	76.1	1082.13
3	69.6	935.06	75.5	1140.40
4	71.8	1213.52	76.5	1463.03
5	70.8	1087.99	74.0	1374.13
6	70.0	1046.23	75.3	1103.29
7	69.6	1207.14	76.7	1415.17
8	70.6	1475.24	75.4	1495.55

TABLE 7

Potential Evapotranspiration During Each Crop Growth Stage

Duration:	6/8 - 8/2	8/2 - 8/31	8/31 - 9/20	9/20 - 10/11	
	Vegetative & Blooming mm	Pegging mm	Early Maturation mm	Late Maturation mm	Season Total mm
Van Bavel	320	207	167	164	858
Penman	245	159	88	116	608
Class A Pan	288	202	138	200	828

potential evapotranspiration is shown in Appendix Table A7.

A roughness factor of 2 cm (0.79 in.) was used in the Van Bavel combination equation. This value was also used in earlier peanut studies by Bausch (1971) and Hiler and Clark (1971). Since a roughness factor for peanuts has never been experimentally determined to the author's knowledge, it is uncertain what the correct roughness factor is. Dr. Van Bavel (personal communication, 1980) believes that a value of 2 cm should be the minimum value used for the roughness factor.

Seasonal Evapotranspiration

Evapotranspiration was calculated using the soil moisture balance equation. The final cumulative evapotranspiration was calculated by summing up the ET's from each period in which soil moisture measurements were taken. The relative ET and the final cumulative ET for each treatment are shown in Table 8 for the Spanish variety and in Table 9 for the Florunner variety. In almost all treatments the Florunners had a higher seasonal ET than the Spanish, the exceptions being treatments 5 and 7.

Water Use Efficiency

A method of evaluating the effectiveness of irrigation treatments is to compare the water use efficiency of each treatment. Water use efficiency is the yield produced per unit of evapotranspiration. Water use efficiency can also be defined as the yield produced per

TABLE 8

Seasonal Cumulative Evapotranspiration of the Spanish Variety

Treatment	Seasonal Cumulative ET (mm)	Relative ET
7 (111)*	437	1.00
8 (check)	423	0.97
4 (101)	390	0.89
5 (011)	362	0.83
2 (100)	352	0.81
6 (110)	351	0.80
3 (010)	337	0.77
1 (000)	261	0.60

TABLE 9

Seasonal Cumulative Evapotranspiration of the Florunner Variety

Treatment	Seasonal Cumulative ET (mm)	Relative ET
8 (check)	500	1.00
7 (111)*	437	0.87
4 (101)	401	0.80
2 (100)	383	0.77
3 (010)	381	0.76
6 (110)	366	0.73
5 (011)	362	0.72
1 (000)	271	0.54

* Numbers in parenthesis refer to an irrigation (1) or no irrigation (0) during pegging, early maturation and late maturation crop growth stages, respectively.

unit depth of applied water. Applied water includes precipitation and irrigation water. Water use efficiency gives an indication of how well a plant produces a yield for a certain amount of available water or applied water. Efficiencies calculated for both peanut varieties are shown in Table 10.

TABLE 10

Water Use Efficiency

	Yield per Unit Depth of Applied Water		Yield per Unit Depth of Evapotranspiration	
Treatment	Spanish kg/(ha-cm)	Florunner kg/(ha-cm)	Spanish kg/(ha-cm)	Florunner kg/(ha-cm)
1 (000)	97.4	110.6	69.2	78.6
2 (100)	98.4	88.1	69.3	57.1
3 (010)	82.6	92.9	60.7	60.4
4 (101)	87.8	98.1	67.3	73.2
5 (011)	78.4	94.8	64.7	78.4
6 (110)	75.3	74.2	64.9	61.3
7 (111)	73.9	79.7	59.8	64.7
8 (check)	59.2	57.1	74.9	59.2
Avg	81.6	86.9	66.4	66.6

Comparing the water use efficiency of the treatments of the Spanish variety in terms of yield per unit depth of applied water, treatment 2 and the dryland treatment used their applied water the most efficiently, which emphasizes the importance of water availability early in the growing season. A second irrigation during the late maturation stage after one during the pegging stage lowered the efficiency (treatment 4) but it was still relatively high. Treatments

7 and 8, the well-watered treatments, used their applied water the least efficiently.

Looking at water use in terms of yield per unit of evapotranspiration for the Spanish variety, the check treatment had the largest yield response to the amount of water consumed. Treatment 8 had a large water use efficiency in terms of evapotranspiration because it used only a portion of the applied irrigation water for evapotranspiration. Treatment 7 had the lowest water use efficiency. For its available water, treatment 7 should have produced a much higher yield.

For the Florunners, the dryland treatment (treatment 1) had the highest water use efficiency, both in terms of evapotranspiration and applied water, but was followed closely by treatments 4 and 5 which had two irrigations, but one of them occurred during the late maturation stage. Treatment 8 had either the second lowest or the lowest water use efficiency in terms of evapotranspiration or applied water, respectively.

Water use efficiency does not indicate the profitability of a certain irrigation treatment. In the case of the Spanish variety, treatment 7 produced a much higher gross income than the dryland treatment (treatment 1) as Table 6 indicates. However, as the cost of pumping increases, water use efficiency becomes much more important. The increase of yield due to larger water applications might not be economical anymore.

Relative Yield versus Relative Evapotranspiration

By comparing relative yield versus relative seasonal evapotranspiration for all the treatments, the effect on yield of having different amounts of evapotranspiration can be observed. The relative yield versus relative seasonal evapotranspiration relationship is shown in Fig. 4 for the Spanish variety and in Fig. 5 for the Florunner variety. For the Spanish variety a linear relationship exists between relative ET and relative yield ($r^2 = 0.88$). Both treatments 4 and 7 had a higher relative yield and seasonal ET than the other treatments with one drought period or more. Treatment 7, which had a higher relative seasonal ET than treatment 4, did not produce a higher yield than treatment 4. Part of the seasonal ET of treatment 7 then was not effectively used to produce an increased yield. Treatments 2, 3, 5 and 6 had approximately the same relative ET (ranging from 0.77 to 0.83), even though treatments 2 and 3 received only one irrigation while treatments 5 and 6 received two irrigations. Treatment 2 had the largest relative yield of the four treatments, while treatment 3 had by far the lowest. However, referring back to the Duncan's test (Table 4) all four treatments were not statistically significantly different in yield. The dryland treatment (treatment 1) had the smallest relative yield and smallest relative seasonal ET. The difference in relative evapotranspiration between treatment 1 and the other treatments in Fig. 4 is greater than the difference in relative yield.

For the Florunners, there are two distinct groupings in the

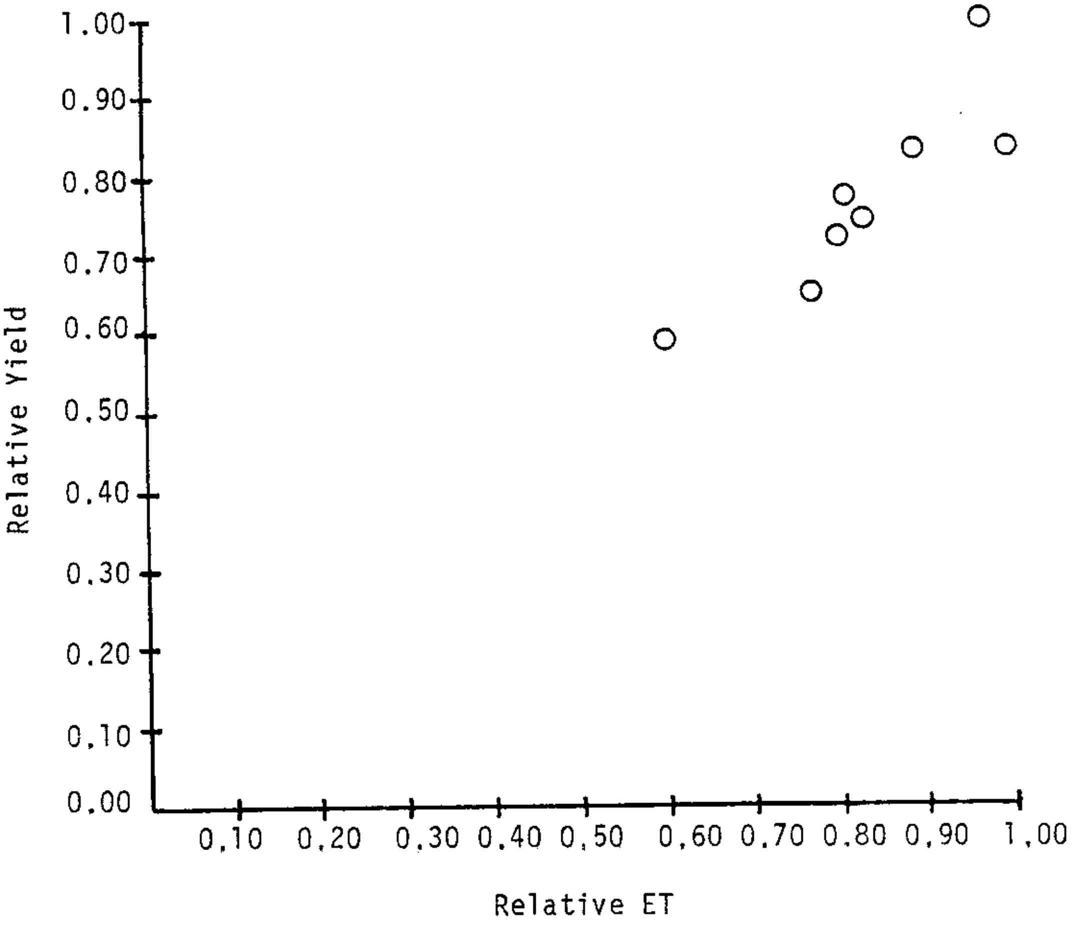


FIG. 4 RELATIVE YIELD VERSUS RELATIVE ET FOR THE SPANISH VARIETY

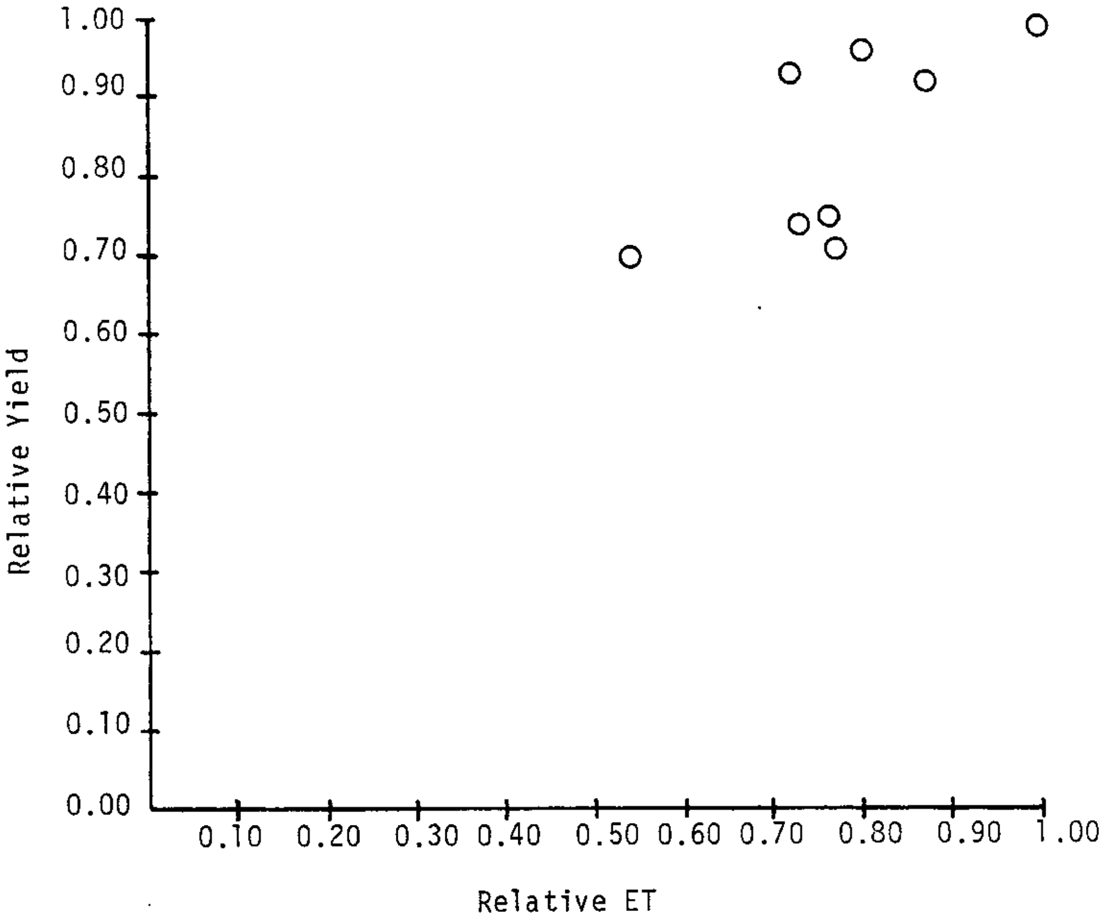


FIG. 5 RELATIVE YIELD VERSUS RELATIVE ET FOR THE FLORUNNER VARIETY

positioning of treatments in Fig. 5; each group having approximately the same relative yield. The top group included all treatments with an irrigation during the late maturation stage (treatments 4, 5, 7 and 8). Within each group however, great differences in relative seasonal evapotranspiration existed. A greater seasonal evapotranspiration does not necessarily produce a higher yield. Also for a narrow range of seasonal evapotranspiration values, great differences in crop yield can exist. This was less true for the Spanish peanut because, as shown in Fig. 4, there was much less scatter in the data than for the Florunner peanut shown in Fig. 5. However for both varieties, the evapotranspiration during certain crop growth stages could explain the reason that some treatments produced a larger yield.

Using the original scheme of dividing the growing season into stages (shown in Table 1), the cumulative ET during each crop growth stage for each treatment was determined. Since soil moisture measurements were made early in the season on a weekly basis, weekly ET quantities will be shown for each treatment as cumulative ET over time graphs. The cumulative ET versus time curves are shown in Fig. 6 through Fig. 13 for both varieties.

Cumulative ET versus Time

The ET curves for treatment 1 (Fig. 6) of both varieties tracked each other closely. Both curves basically consisted of two parts. From June to mid August, both curves showed a fairly constant and high ET rate, but starting in mid August, the ET rate decreased.

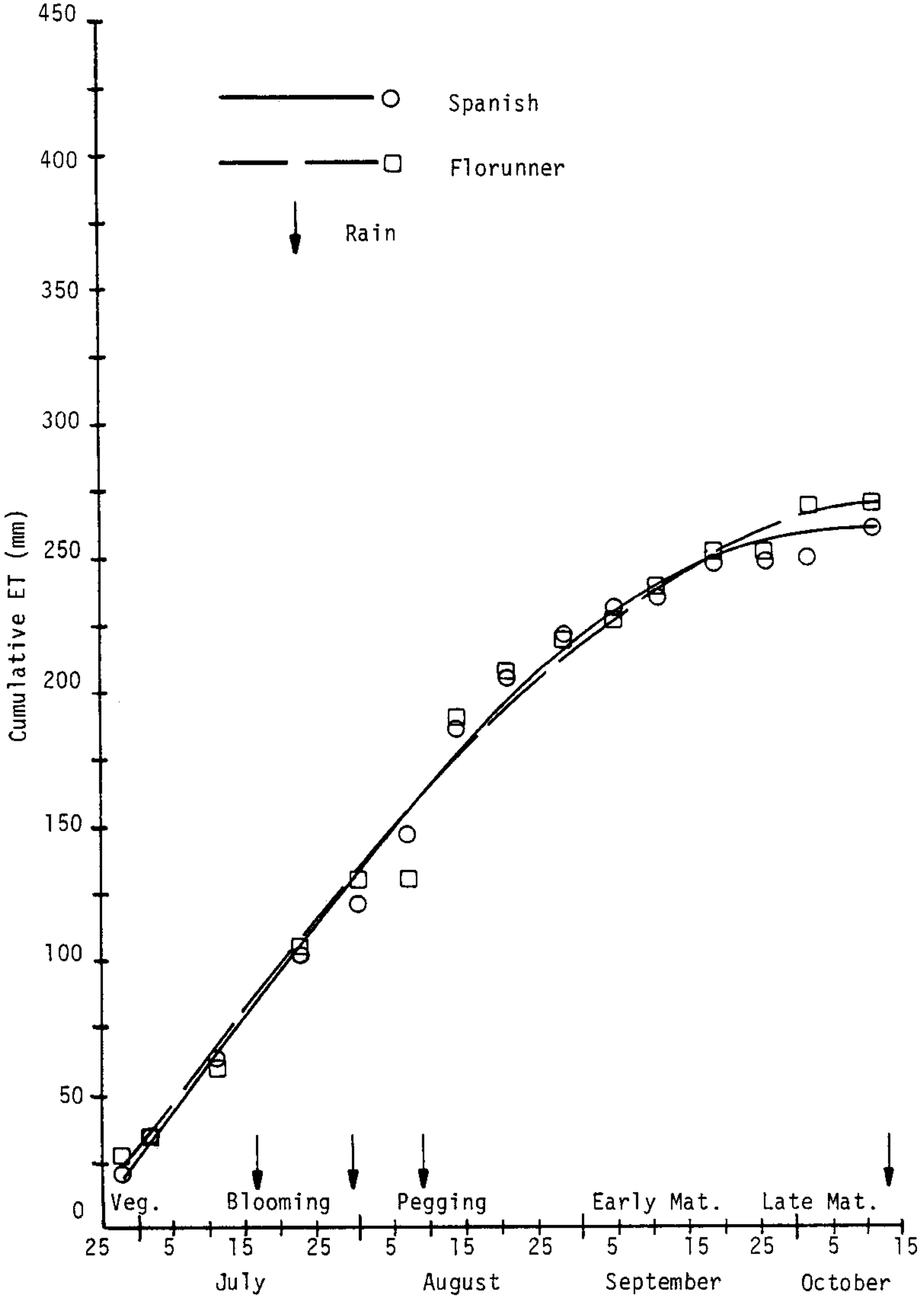


FIG. 6 CUMULATIVE ET OVER TIME FOR TREATMENT 1

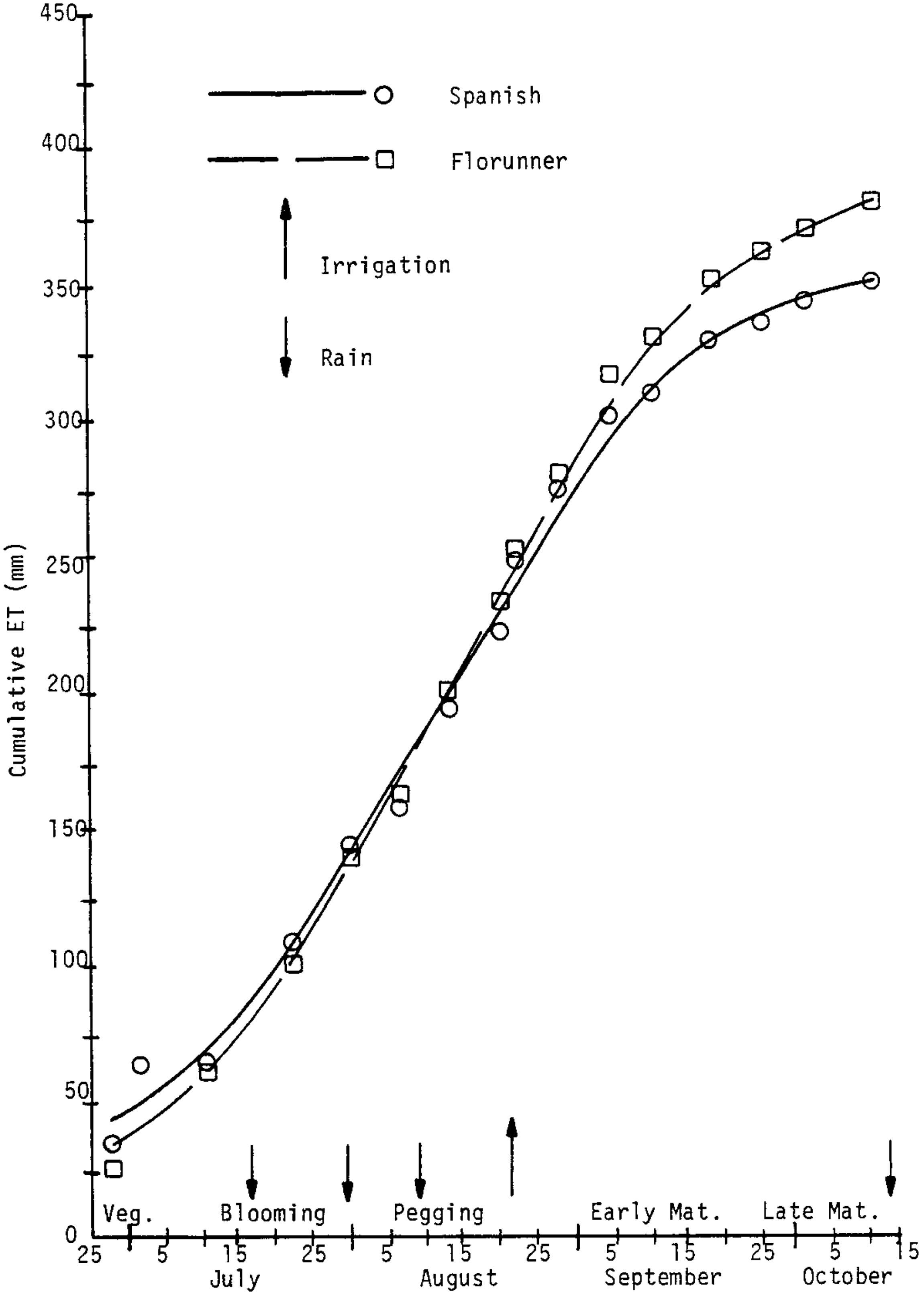


FIG. 7 CUMULATIVE ET OVER TIME FOR TREATMENT 2

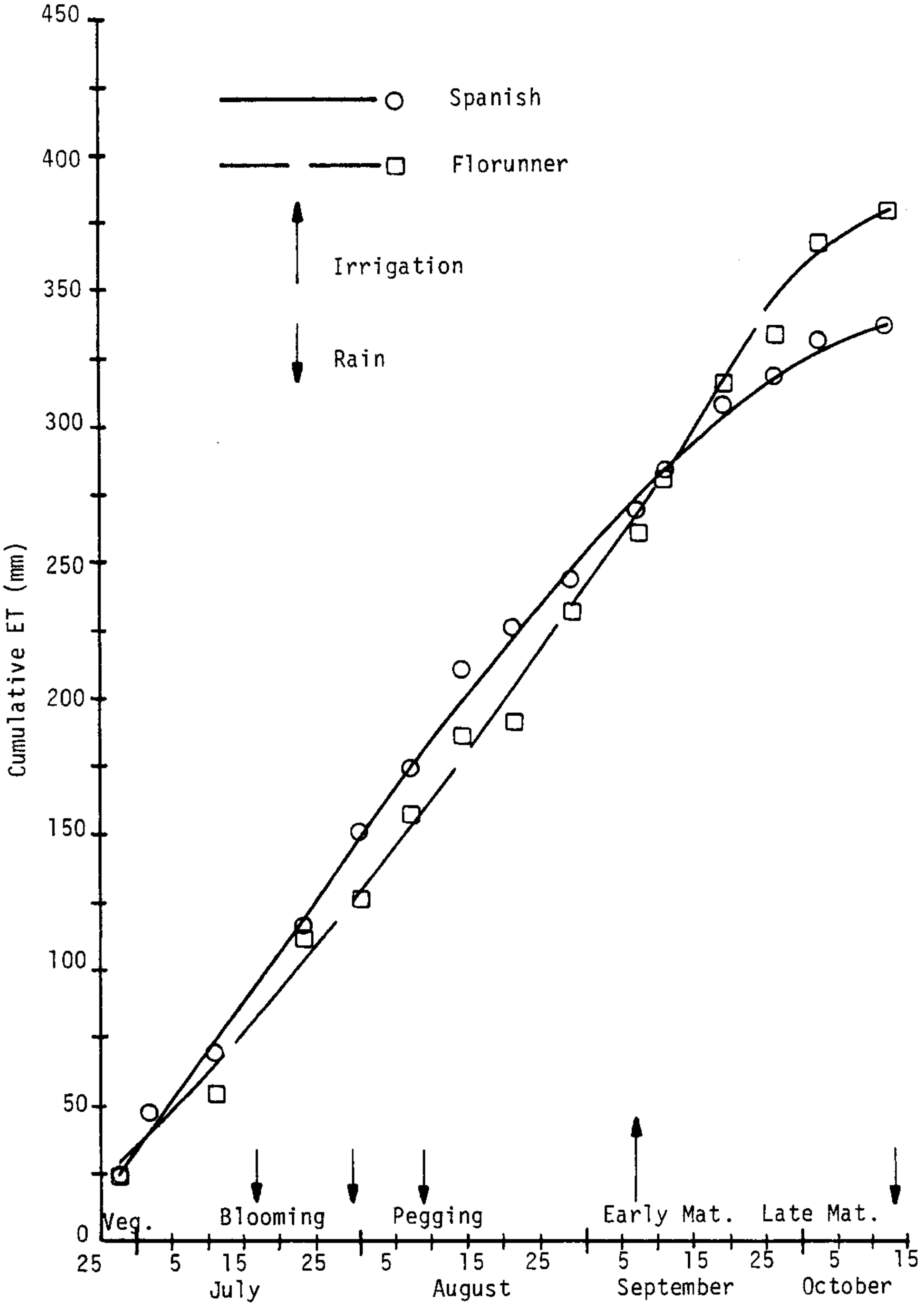


FIG. 8 CUMULATIVE ET OVER TIME FOR TREATMENT 3

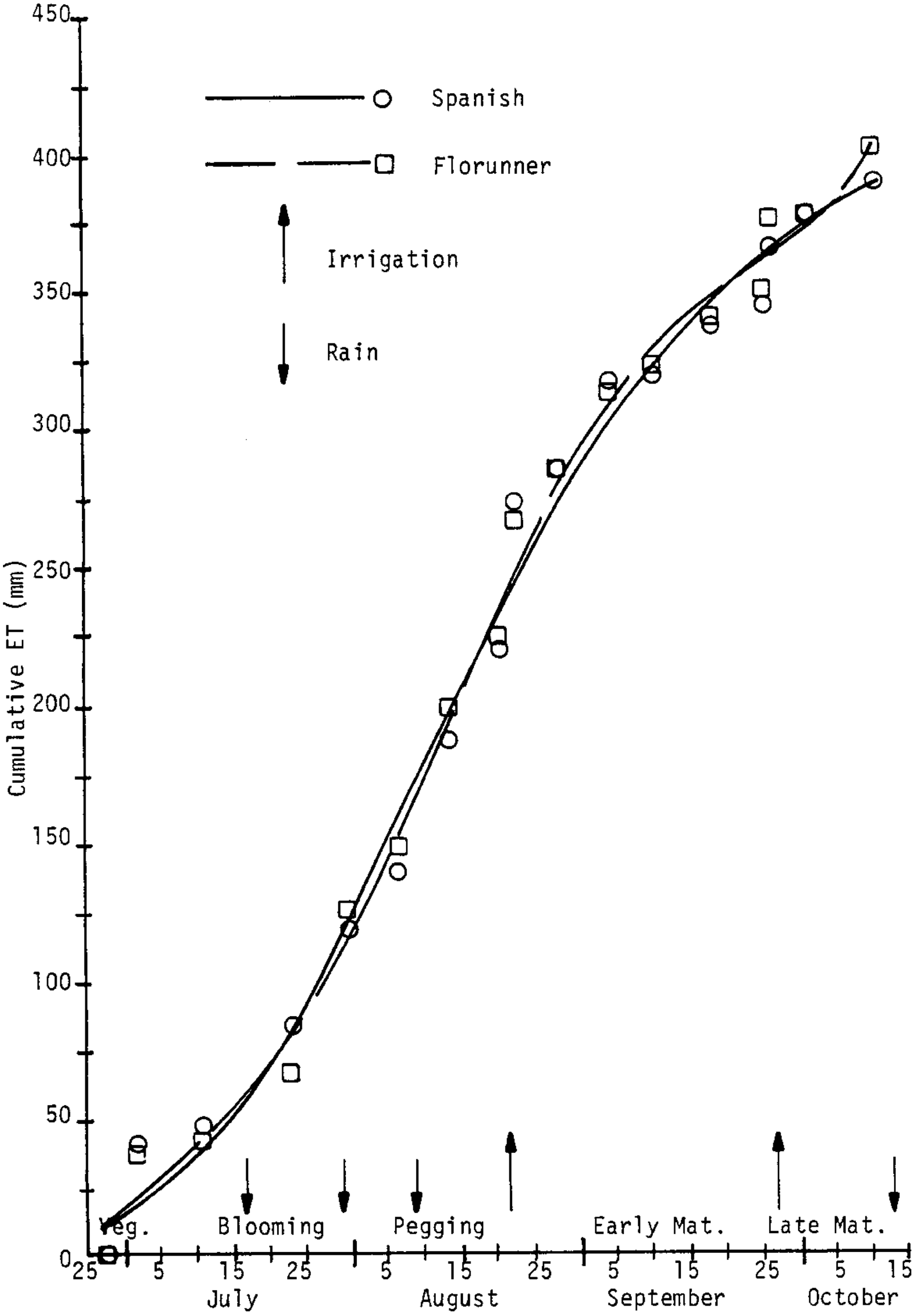


FIG. 9 CUMULATIVE ET OVER TIME FOR TREATMENT 4

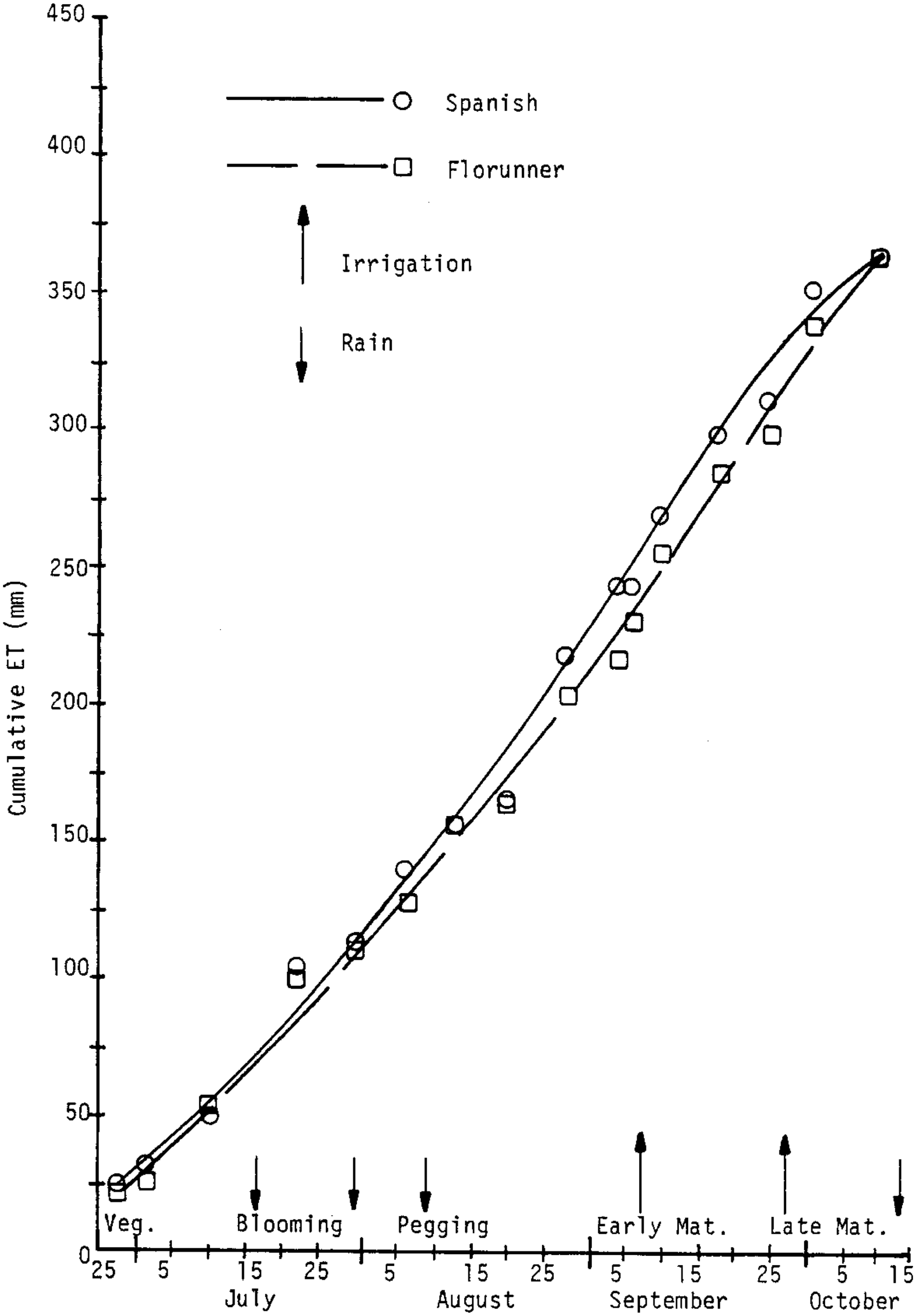


FIG. 10 CUMULATIVE ET OVER TIME FOR TREATMENT 5

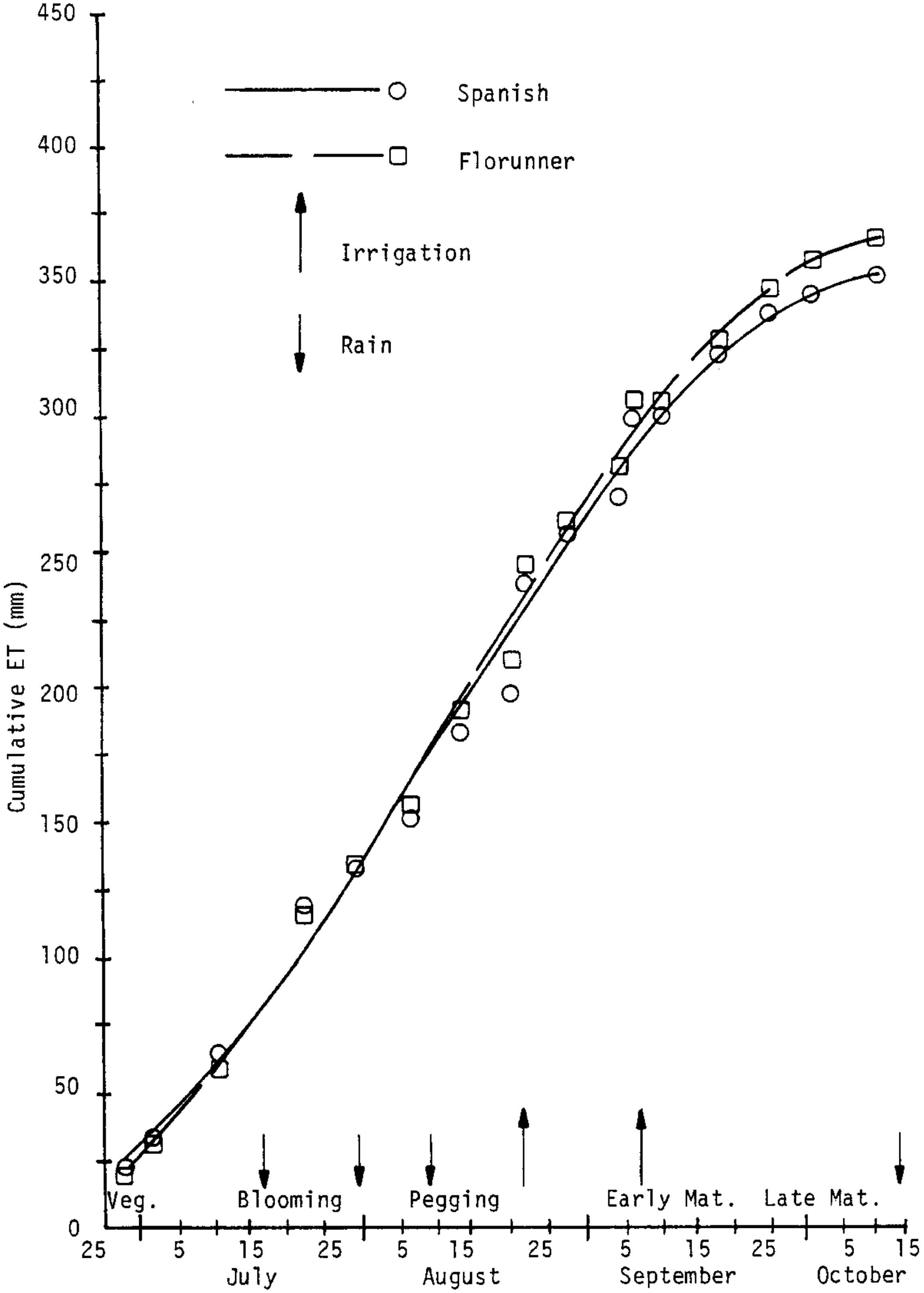


FIG. 11 CUMULATIVE ET OVER TIME FOR TREATMENT 6

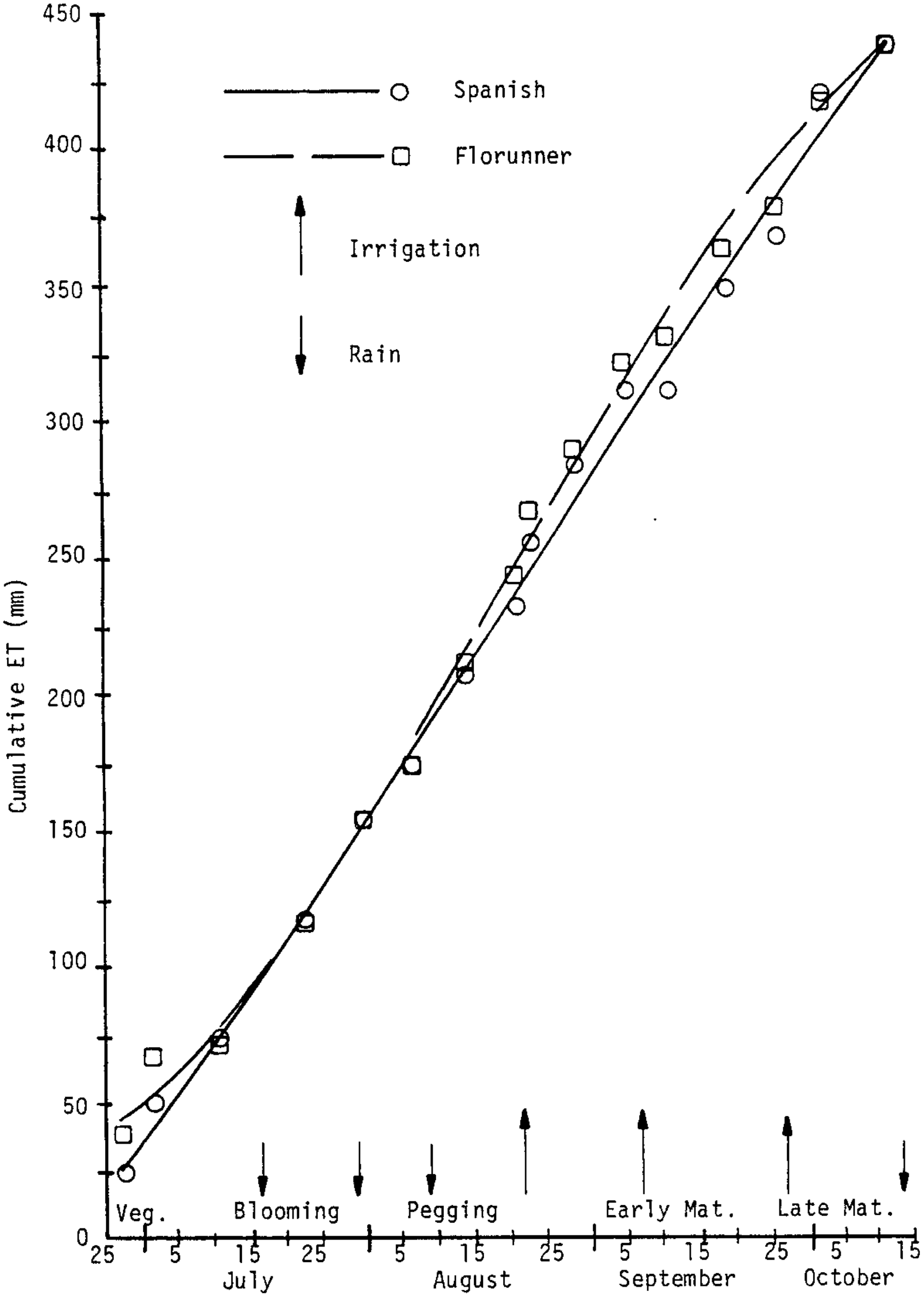


FIG. 12 CUMULATIVE ET OVER TIME FOR TREATMENT 7

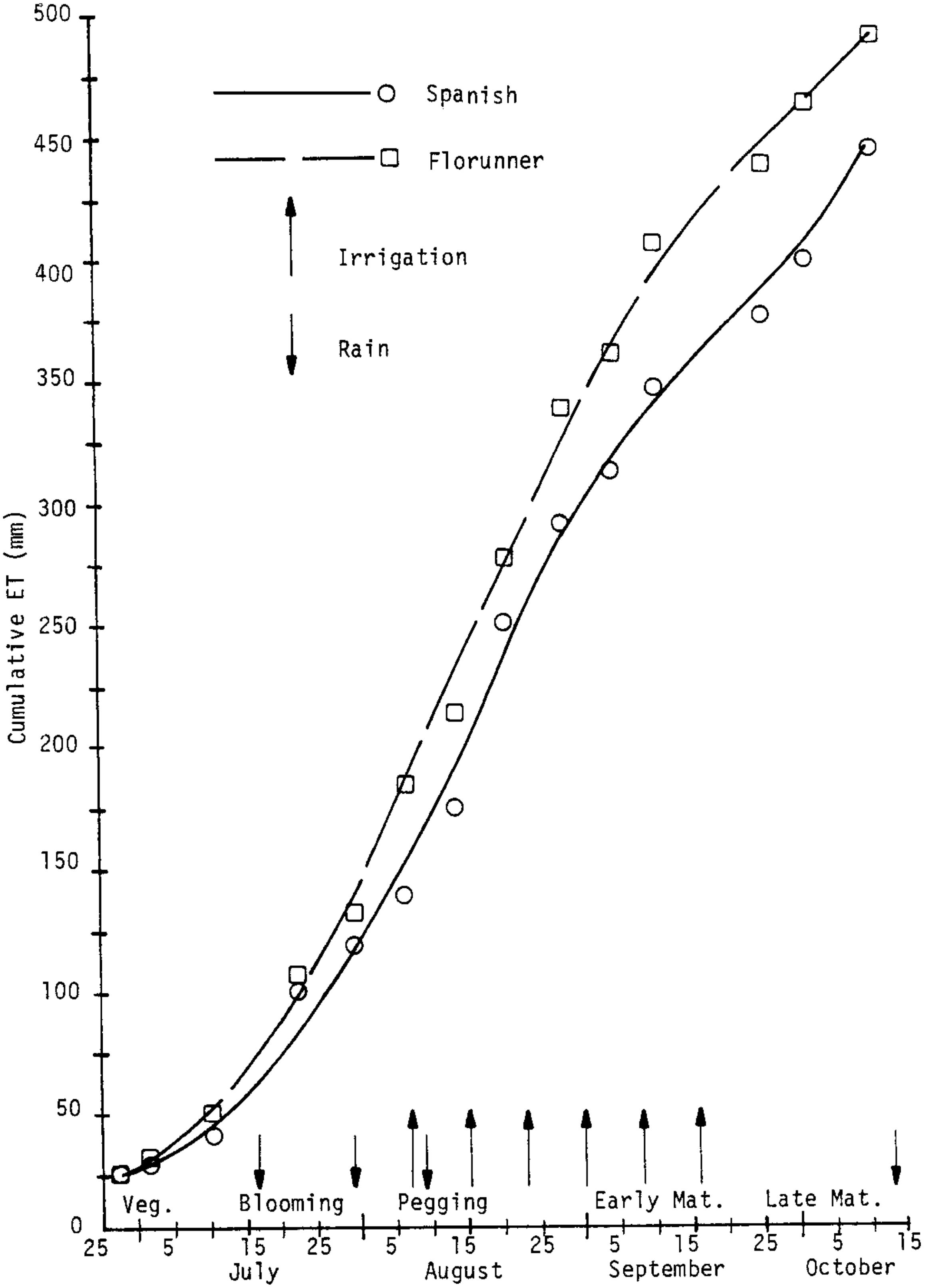


FIG. 13 CUMULATIVE ET OVER TIME FOR TREATMENT 8

In treatment 2 (Fig. 7), both varieties had an erratic beginning, but both exhibited a similar water use pattern having a high ET rate throughout the blooming and pegging stages and then decreasing. After early September when the Florunners had a greater ET rate than the Spanish, the smallest ET rate for both varieties was during the late maturation stage.

In treatment 3 (Fig. 8), the Florunners had a slower ET rate than the Spanish until the last 10 days of the pegging stage when they had a consistently large ET rate, which lasted until the last week. The ET rate for the Spanish peanut was fairly constant until the latter half of the pegging stage where a decrease in the ET rate occurred. The ET rate continued decreasing through the early and late maturation stage.

In Fig. 9, the ET curves for treatment 4 were somewhat erratic, but the ET curves for both varieties were very similar. Both varieties had relatively high ET rates throughout the pegging stage. After the first week of the early maturation stage, the ET rate decreased, but it increased again following an irrigation in the late maturation stage.

In treatment 5 (Fig. 10), both varieties had a relatively low ET rate from the beginning of the vegetative stage until the last week of the pegging stage (August). Throughout the pegging stage, the Spanish peanut had a larger ET rate than the Florunner peanut. After the pegging stage the ET rate of both varieties increased slightly, but the ET rate of the Spanish peanut decreased in the last week of the maturation stage. For the Florunners, the larger ET rate lasted throughout the early and late maturation stage.

In treatment 6 (Fig. 11), the ET rate for both varieties increased in the early part of the pegging stage and remained fairly constant throughout the pegging stage and early maturation stage. During the late maturation stage, the ET rate for both varieties decreased sharply.

Generally, treatment 7 (Fig. 12) shows a smooth and almost linear curve for both varieties. After September 7 a slight decrease in the ET rate of the Spanish variety was observed.

In treatment 8 (Fig. 13), the greatest differences existed between the two varieties, with the Florunners having the largest ET rate during the growing season. The Spanish peanut had a decrease in the ET rate during the early maturation stage. The calculated ET values were reduced to compensate for runoff, as was discussed earlier.

Evapotranspiration During Each Crop Growth Stage

The importance of an adequate ET rate during critical crop growth stages can be demonstrated by relating the yield of the treatments with the amount of ET during certain crop growth stages. The amount of ET during each crop growth stage is shown in Table 11 for the Spanish variety and in Table 12 for the Florunner variety.

During the vegetative and blooming stages, some of the treatments had relatively large ET values (154 mm being the largest), and some treatments had much smaller ET values (112 mm being the smallest).

TABLE 11

ET (mm) During Each Crop Growth Stage for the Spanish Variety

Duration:	6/8-8/2	8/2-8/31	8/31-9/20	9/20-10/11	
Treatment	Vegetative & Blooming	Pegging	Early Maturation	Late Maturation	Total Seasonal
TM 1 (000)	122	100	26	13	261
TM 2 (100)	145	130	54	23	352
TM 3 (010)	151	93	64	29	337
TM 4 (101)	119	167	52	52	390
TM 5 (011)	112	104	81	65	362
TM 6 (110)	141	116	65	29	351
TM 7 (111)	154	130	65	89	437
TM 8 (check)	115	184	74	59	432

TABLE 12

ET (mm) During Each Crop Growth Stage for the Florunner Variety

Duration:	6/8-8/2	8/2-8/31	8/31-9/20	9/20-10/11	
Treatment	Vegetative & Blooming	Pegging	Early Maturation	Late Maturation	Total Seasonal
TM 1 (000)	132	89	32	18	271
TM 2 (100)	141	141	72	29	383
TM 3 (010)	128	106	84	63	381
TM 4 (101)	125	161	55	60	401
TM 5 (011)	108	95	81	78	362
TM 6 (110)	138	124	67	38	367
TM 7 (111)	153	136	74	75	438
TM 8 (check)	130	208	82	75	500

It should be noted that all treatments received approximately the same amount of water during these two periods.

For the Florunners there was also a spread in the ET quantities. All treatments had ET values lower than the potential ET, which was due to the fact that a full crop canopy had not yet developed. The difference in the ET values during the first two crop growth (vegetative and blooming) stages for both varieties evidently did not have a great effect on yield because some of the treatments with small ET values during this period had the largest relative yields. For example, treatment 4 (Spanish) and treatment 5 (Florunners) both had relatively small ET values during this period, but had large relative yields.

ET during the pegging, early, and late maturation stages and its effect on yield will be discussed for the Spanish variety first. With the exception of treatment 6, the treatments which received an irrigation during the pegging stage, (treatments 2, 4, 6, 7 and 8), had an ET at least 26 mm (1.02 in.) larger than the treatments which received no irrigation during the pegging stage. During this crop growth stage, treatment 6 had an ET only 12 mm (0.47 in.) higher than treatment 5. Treatment 5 had a relatively low ET amount only during the pegging stage, it was also ranked among the lower yielding treatments. Treatment 8, which had 3 irrigations during the pegging stage had the largest ET which was somewhat smaller than the potential ET calculated from Van Bavel's equation (Table 7). The yields for the treatments which received an irrigation during the pegging stage (except treatment 6) were larger than for the treatments which received no irrigations during this stage.

During the early maturation stage, only treatment 1 had a very low ET amount. Treatments 2 and 4 (no irrigation during the early maturation stage) did not have a much lower ET amount than treatment 3 (irrigation during the early maturation stage). An irrigation during the early maturation stage does not necessarily increase yields. Of the treatments which received an irrigation during this stage, treatments 3, 5, 6, 7 and 8, treatments 3 and 6 had the smallest yields.

Treatments which had an irrigation during the late maturation stage (treatments 7, 5 and 4), had an ET amount at least 23 mm (0.93 in.) greater than the non-irrigated treatments. Treatment 8 (the well-watered treatment), had its last irrigation on September 16 and was an exception. It apparently had enough soil moisture throughout the late maturation stage to provide all its water needs. During this stage treatment 8 had a slightly larger ET than treatment 4. During the late maturation stage, treatments 1, 2, 3 and 6 (no irrigation during late maturation stage) suffered a large decrease in ET rates. The effectiveness of an irrigation during the late maturation stage can be seen by comparing the yields of treatment 4 (Table 4). A greater amount of available water for evapotranspiration during the late maturation stage will help increase yields.

The actual ET values for all the treatments were considerably less than the values of calculated potential evapotranspiration as shown in Table 7.

The Florunner peanut responded differently than the Spanish peanut to irrigations during certain growth stages. For the Florunner, an irrigation during the pegging stage is apparently not as important as for the Spanish peanuts. Treatment 5 had no irrigation and a low ET amount during the pegging stage. However, the yield from treatment 5 was among the largest. A possible reason that the pegging stage was not crucial in this experiment is the fact that a 33 mm (1.3 in.) rainfall occurred on August 8 early in the pegging stage. This could have provided enough moisture for the Florunner peanut. Also, Florunner peanuts grow much more horizontally and less vertically than the Spanish. Thus pegs have a smaller distance to travel and require less water. Treatment 8 (well-watered) had the highest cumulative ET during the pegging stage, which was equal to the potential ET as determined by the Van Bavel equation, slightly greater than the pan evaporation, and much greater than the potential ET calculated using Penman's equation as shown in Table 7.

In comparing the ET values of the Florunner peanut for the early maturation stage, only the dryland treatment (treatment 1), had an extremely small ET value (Table 12). Treatments 2 and 4 which were not irrigated during the early maturation stage, had ET values not much lower than the irrigated treatments. Both treatments 2 and 4 were irrigated during the pegging stage. The early maturation stage does not seem to be crucial for yield because treatment 4, which was not irrigated during this stage, had one of the largest yields, while treatment 3, which received its only irrigation during this stage, had one of the smallest yields.

All treatments (4, 5 and 7) irrigated during the late maturation stage had the largest ET rates. Treatment 8 (well-watered) also had a large ET value for this crop growth stage. Of those treatments irrigated during this period, treatments 4, 5 and 7 had the largest yield. The treatments not irrigated (treatments 1, 2, 3 and 6), had the smallest yields. Except for treatment 3, these treatments also had relatively low ET rates during this crop growth stage (Table 12). For the Florunner peanut, ET rates during the late maturation stage should not be reduced if high yields are to be maintained.

Leaf Area Index

Leaf area and leaf are index measurements were determined for the Spanish peanut in an effort to explain the difference in yield response between treatments. (Leaf area index over time is shown in Fig. 14 and 15). However, no trends in evapotranspiration or yield were found with treatments having a larger or smaller leaf area index over time.

Leaf area index is a function of the leaf area, the number of leaves and plant density. Some differences in plant density within treatments existed (Appendix Table A6). As plant density increased, the leaf area index also increased. As mentioned earlier, a high or low plant density could affect plant yield.

A point of interest is that after the early maturation stage,

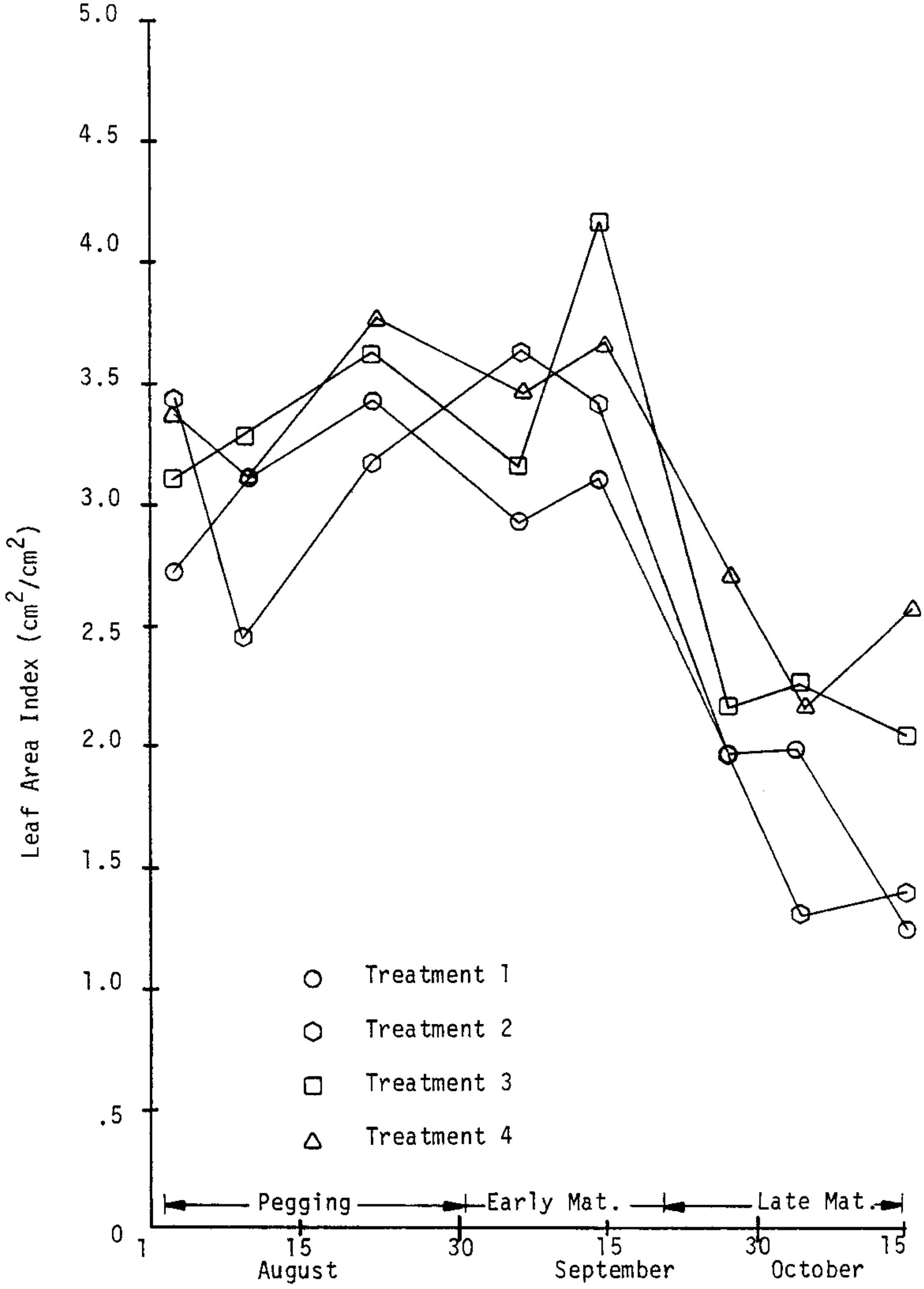


FIG. 14 LEAF AREA INDEX OVER TIME FOR TREATMENTS 1-4

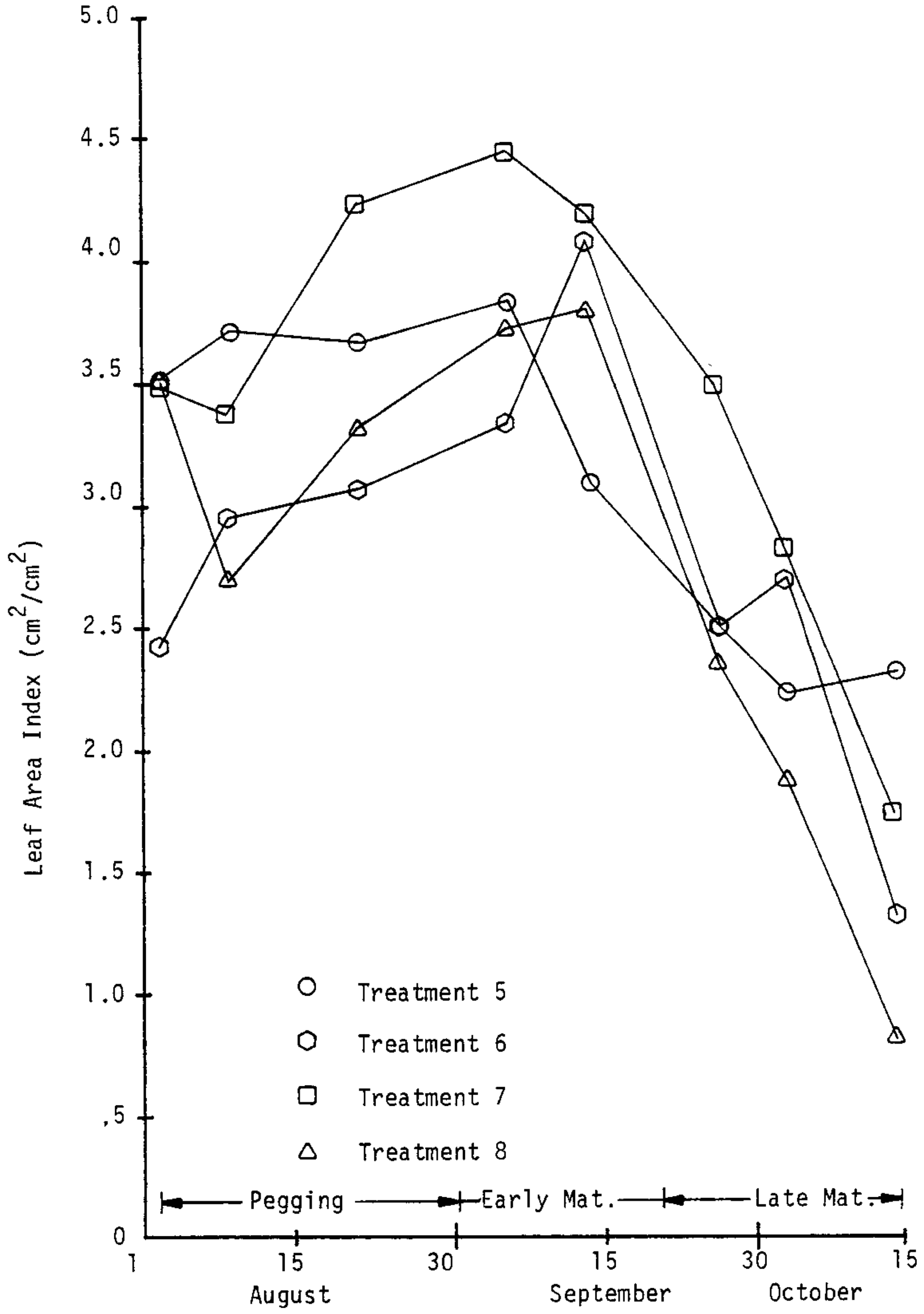


FIG. 15 LEAF AREA INDEX OVER TIME FOR TREATMENTS 5-8

the Spanish peanuts had a significant loss of leaf area. Treatment 8 (well-watered treatment) suffered from leaf spot disease and had an especially large loss in leaf area. Some experimental error was involved. When the plants were pulled from the soil for sampling, some leaves were lost and were thus not counted, so the final leaf area should probably be somewhat higher for all treatments. Nevertheless, there was a sharp reduction in leaf area index from the early maturation stage to harvest. This was reflected to a lesser degree in the reduced ET rates of the Spanish variety during the early and late maturation stages. Treatments 8, 6, 5, 3, 2 and 1 reflect a corresponding decrease in leaf area index and evapotranspiration rate. Only treatments 4 and 7, which had the same or more evapotranspiration during the late maturation stage than during the early maturation stage, exhibited a decrease in leaf area.

Dry Matter Accumulation

Dry matter accumulation for the Spanish peanut was also monitored. The dry matter accumulation analysis was separated into three parts, leaf, stem and pod weight accumulation. The leaf weight accumulation is discussed first and is shown in Figs. 16 and 17. The timing of the peak leaf weight accumulation for some treatments can be seen more clearly than the leaf area index. Treatments 5 and 1 (the dryland treatment) received no irrigation during the pegging stage, and had their peak leaf mass during the pegging stage. Treatments 2, 6, 7 and 8 had their peak leaf mass at mid September, or near the end

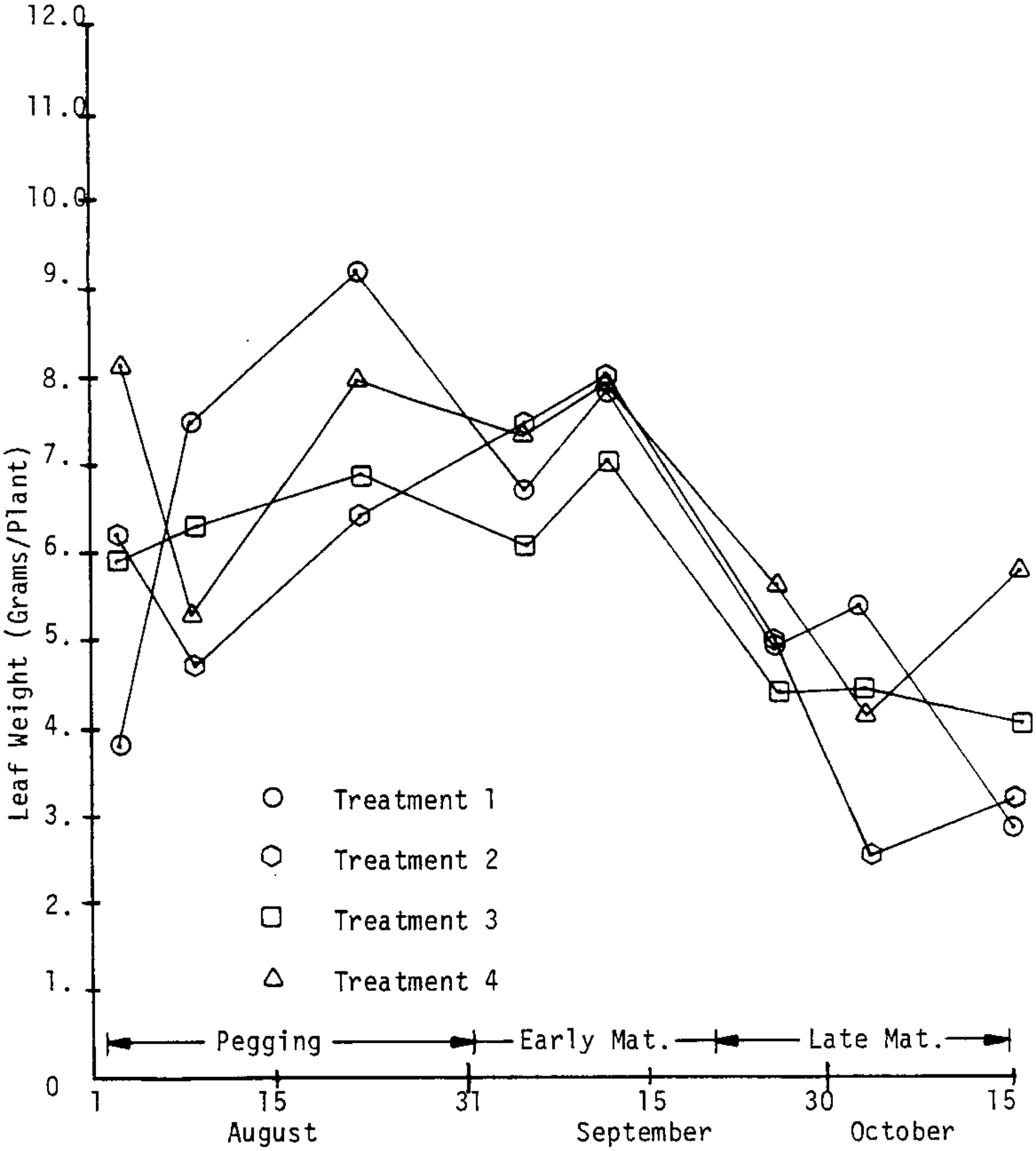


FIG. 16 LEAF WEIGHT CHANGE OVER TIME FOR TREATMENTS 1-4

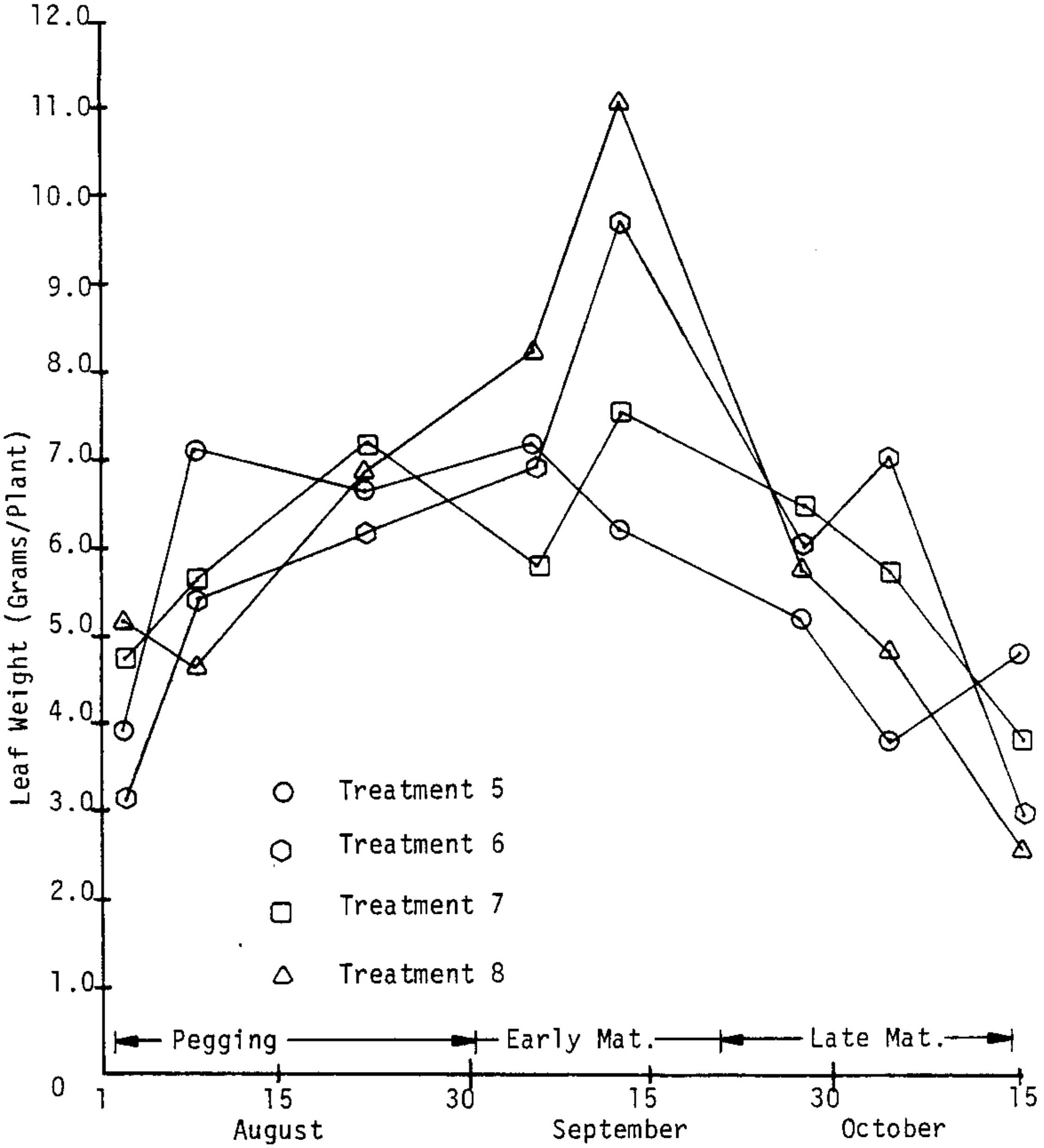


FIG. 17 LEAF WEIGHT CHANGE OVER TIME FOR TREATMENTS 5-8

of the early maturation stage. Treatments 3 and 4 had their peak leaf mass over a longer span of time, from the late pegging stage until the end of the early maturation stage.

After the blooming stage, the stem weight did not change significantly over time as can be seen in Figs. 18 and 19. Stem weight for all treatments oscillated within a band ranging from 4.0 to 7.0 grams/plant, except for one point in treatment 7.

Differences in the pod weight accumulation within the treatments were quite evident as seen in Figs. 20 and 21. Variations existed within the pod weight accumulation over time but the trends are easily seen. For every treatment, the pods weighed less than one gram per plant early in the pegging stage. Until September 6, the pod weight for all treatments increased at approximately the same rate. After September 6, differences in pod growth rate between the treatments appeared. The dryland treatment (treatment 3) and treatment 5 (which was not irrigated during the pegging stage), had a slower pod weight accumulation than the other treatments. This could imply that a delayed effect of not irrigating during the pegging stage existed as time increased. The difference in pod growth rate increased between those treatments irrigated during pegging and those not irrigated during pegging. After September 6, treatment 8 had the largest pod weight of all treatments. The effect of irrigation during the early and late maturation stages could not be seen on the pod weight accumulation. The final ranking of pod weight did not correspond to the final ranking in yield of Spanish peanuts. Treat-

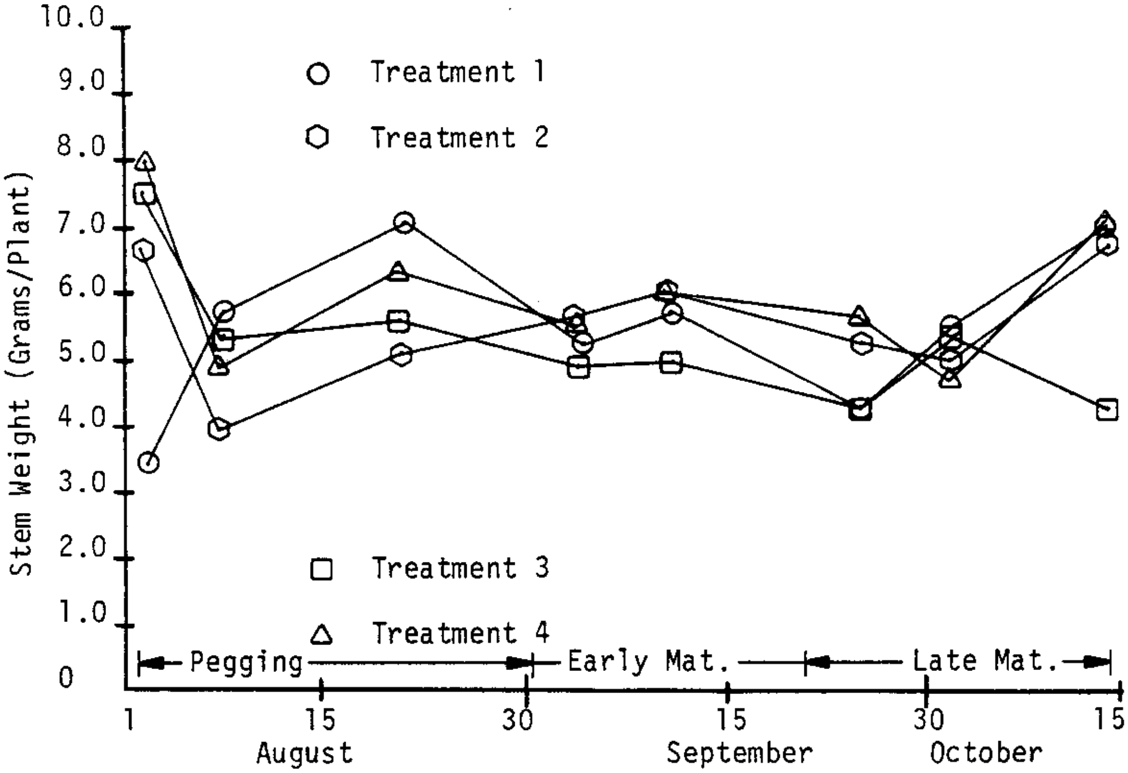


FIG. 18 STEM WEIGHT CHANGE OVER TIME FOR TREATMENTS 1-4

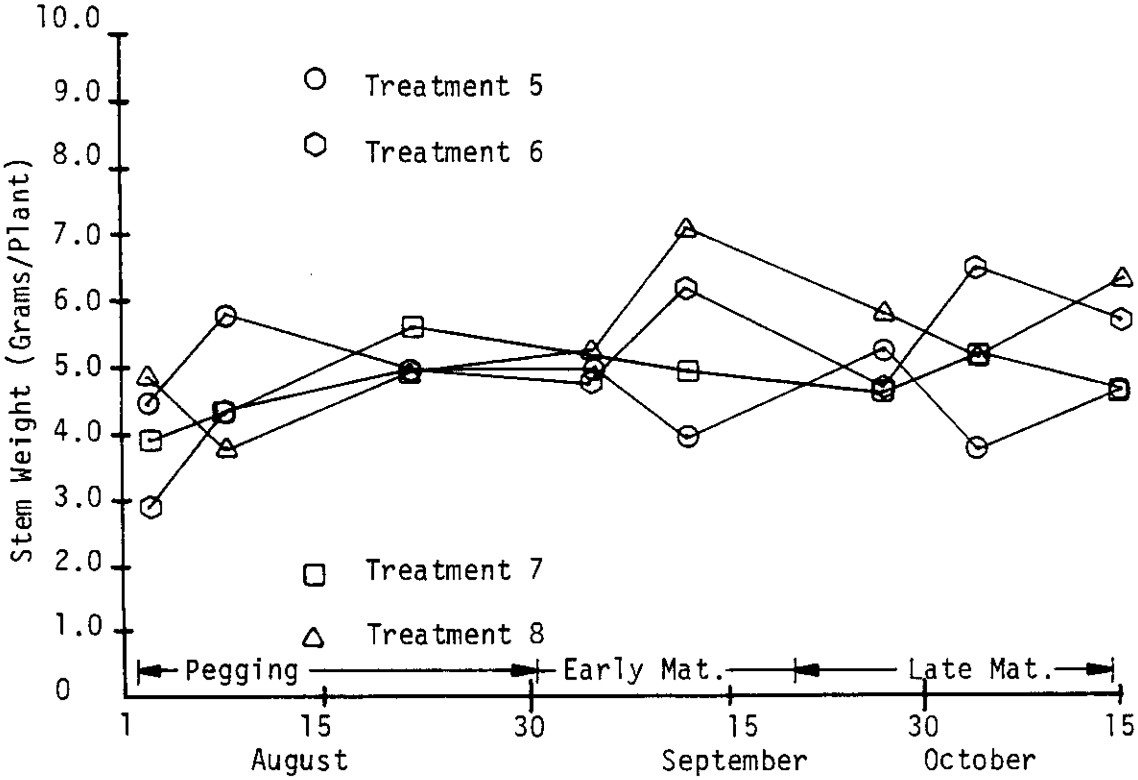


FIG. 19 STEM WEIGHT CHANGE OVER TIME FOR TREATMENTS 5-8

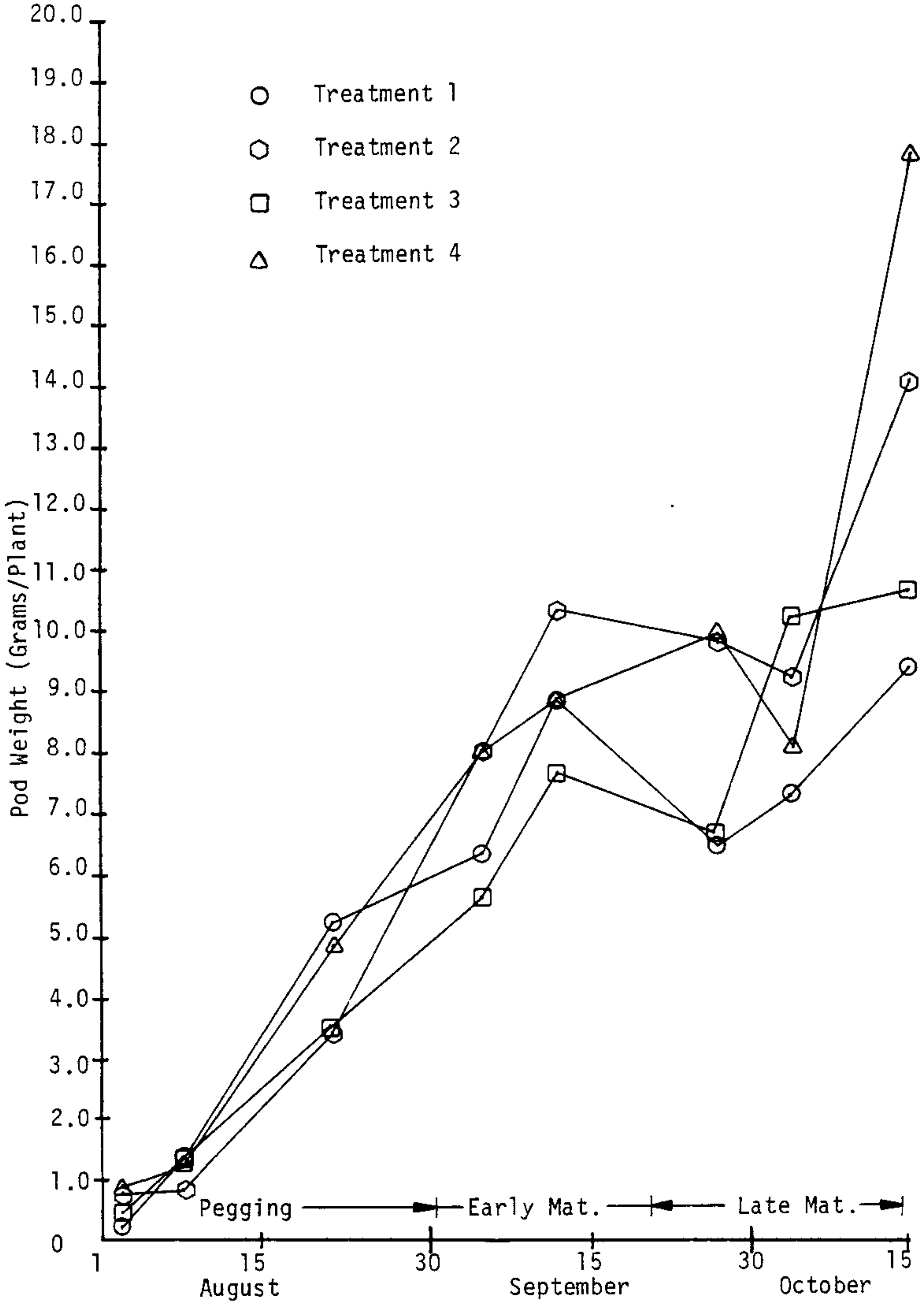


FIG. 20 POD WEIGHT CHANGE OVER TIME FOR TREATMENTS 1-4

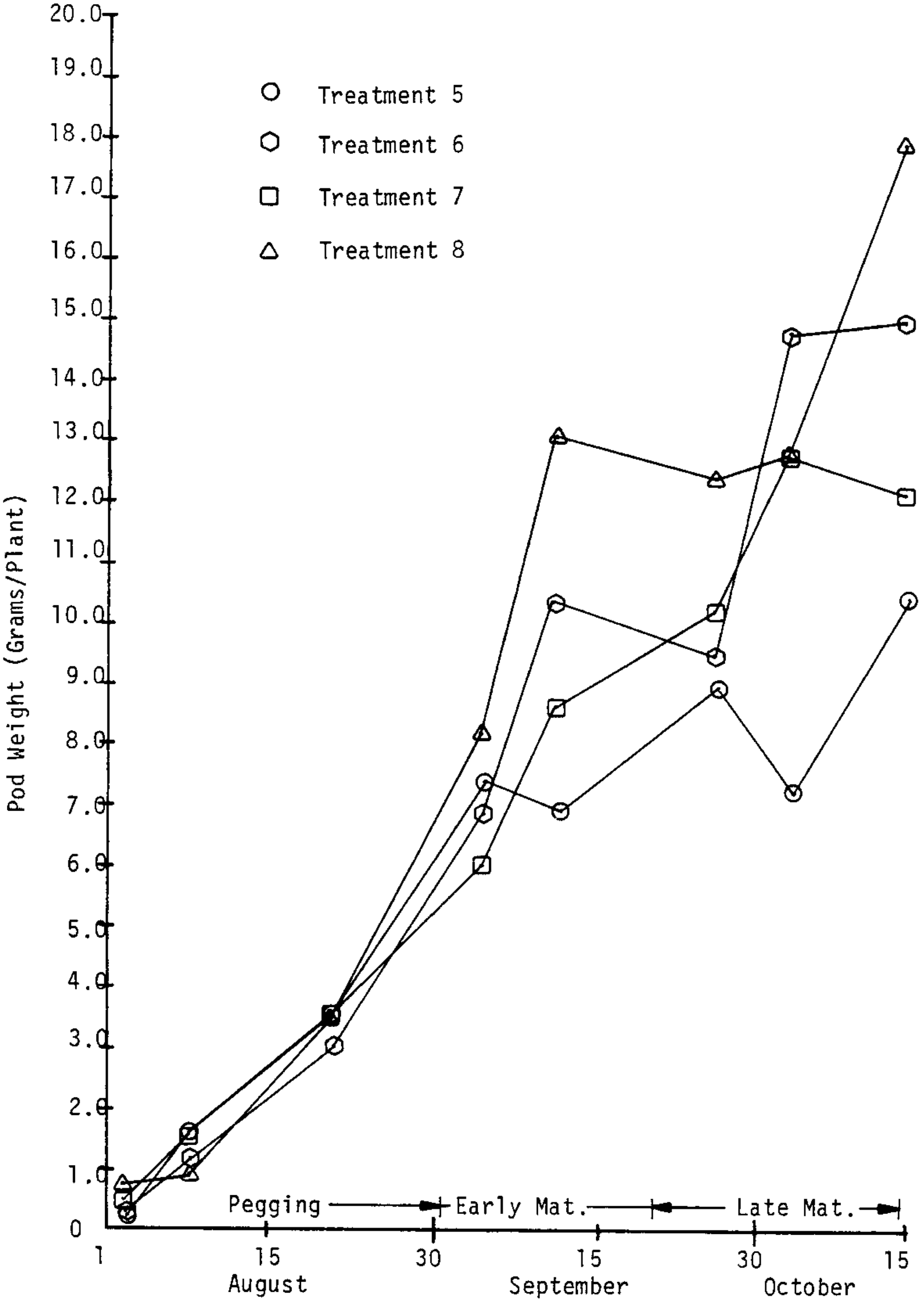


FIG. 21 POD WEIGHT CHANGE OVER TIME FOR TREATMENTS 5-8

ment 8, 4 and 1 had the same rank in the final pod weight as they had in the yield. However, treatment 6 had a higher rank in the final pod weight ranking than it had in the final yield ranking.

SUMMARY AND CONCLUSIONS

A peanut irrigation research project was conducted, and the effect on yield of withholding water during one or more crop growth stages was evaluated. The project was conducted at the Texas Agricultural Experiment Station at Stephenville, Texas, during the growing season of 1979. Eight irrigation treatments, replicated three times, were tested on two peanut varieties, the Spanish and the Florunner. Included among the irrigation treatments was a dryland treatment and a well-watered treatment. Each of the other six treatments had a different combination of either irrigating or stressing the peanut plant during the pegging, early maturation or late maturation crop growth stages. Precipitation during the vegetative and the blooming stage ensured adequate moisture for the first two crop growth stages.

Evapotranspiration was monitored throughout the growing season for both varieties. Leaf area and dry matter accumulation was also monitored for the Spanish variety only. No significant difference between treatments existed in the leaf area index. After the early maturation stage, a large decrease in leaf area occurred in all treatments (Spanish variety).

The dry matter growth analysis was separated into three parts, leaf, stem and pod weight accumulation. Generally, treatments without any irrigation during the pegging stage had their peak leaf weight earlier than treatments with an irrigation during the pegging stage.

After the blooming stage, the stem weight did not change significantly for any treatments. Pod weight accumulation showed that all the treatments had approximately the same pod growth rate during the pegging stage. However, during the early maturation stage, treatments with an irrigation during the pegging stage had a larger pod growth rate than treatments without an irrigation during the pegging stage. Treatments with an irrigation during the pegging stage also had the largest final pod weights, which is not in complete correlation with the final yield results. Generally, the pod weight accumulation study demonstrates the importance of an irrigation during the pegging stage.

Several points can be made about the yield and evapotranspiration results. First, for the Spanish variety, the yield results indicated that an adequate supply of soil moisture is needed during the pegging stage to obtain high yields. Treatments with an irrigation during the pegging stage had an evapotranspiration amount which was at least 25 mm (1 in.) greater than the treatments with no irrigation during this stage. These treatments also had higher yields. Furthermore, one of the treatments which had its only drought period during the pegging stage did not have a higher yield than the treatment which had its only irrigation during the pegging stage. The treatment which had its only irrigation during the pegging stage produced 394 kg/ha (351 lb/ac) more than the treatment which had its only irrigation during the early maturation stage. So if only one additional irrigation can be afforded after the blooming stage, that irrigation should occur during the pegging stage.

Secondly, an irrigation during late maturation will help increase yields if dry climatic conditions exist during the maturation stage. A treatment which received an additional irrigation during the late maturation stage plus one during the pegging stage produced 186 kg/ha (166 lb/ac) more than a treatment which received only an irrigation during the pegging stage. Also, a treatment which was irrigated once during the late maturation stage and once during the early maturation stage produced 298 kg/ha (266 lb/ac) more than a treatment which only received one irrigation during the early maturation stage.

Thirdly, if an irrigation application is made during the pegging stage, an additional irrigation during the early maturation stage is unnecessary. Treatment 6 which had an irrigation during the early maturation stage plus one during the pegging stage, did not have a higher yield than the treatment which had its only irrigation during the pegging stage. This could be partially due to the fact that treatment 6 had a relatively low evapotranspiration during the pegging stage.

In the case of the Florunner variety, the yield results indicated that moisture stress should occur in no more than one of the crop growth stages. All treatments with two drought periods did not have significantly higher yields than the dryland treatment. Also, an adequate supply of soil moisture during the late maturation stage is absolutely necessary in order to obtain maximum yield of Florunner peanuts. During the late maturation stage of this experiment, almost no precipitation occurred and the weather was extremely hot and dry. (This is not the usual Stephenville weather.) Treatments which had an irrigation during the late maturation stage produced near maximum yield, even though some of the treatments had a drought period, either during the pegging or the early maturation stages. Those treatments which received an irrigation during the late maturation stage had a steady evapotranspiration rate during this crop growth stage. Treatments which showed any decrease in the evapotranspiration rate during the late maturation stage had a significantly lower yield.

RECOMMENDATIONS FOR FUTURE RESEARCH

Several additional studies in peanut irrigation are needed. Since an irrigation during the late maturation stage had a positive effect on yield, especially on the Florunner variety, a treatment should be added in which the blooming and the late maturation stage are the only crop growth stages to receive an irrigation application.

A dry matter accumulation analysis is needed for the Florunner variety. A pod growth analysis would be especially useful in determining the effects of irrigating or not irrigating during certain crop growth stages. In addition to observing the pod weight accumulation, a pod count should also be included.

For a greater reliability of the evapotranspiration date, measurements of evapotranspiration should be made in all three replications rather than just one. The method of water application in the well-watered treatment could also be improved. The depth of water applied should be a function of potential evapotranspiration and soil moisture content. If the upper part of the root zone has enough water available for plant water use, the irrigation application should be delayed, until a predetermined minimum soil water content has been reached. If the Van Bavel equation is used, a correct value for the roughness factor should be determined. For treatments in which one irrigation application is applied during a critical growth stage, it would be of interest to know the minimum depth of water that can be applied, and the maximum stress that the plant can endure without a large reduction in yield. Also, soil moisture content should be included in considering the depth of irrigation water needed and the timing. The minimum soil moisture content at which an irrigation should occur, should be determined for each soil type and should be studied in conjunction with the leaf water potential to determine the stress endured by the plant.

REFERENCES

1. Bausch, W.G. 1971. Crop response at various stages of growth to sprinkler and furrow irrigation. M.S. Thesis, Texas A&M University, College Station, 62 p.

2. Bowman, D.H. and K.M. King. 1965. Determination of Evapotranspiration using the neutron scatter method. Canadian Journal of Soil Science, 45(2): 117-126.

3. Hiler, E.A. and R.N. Clark. 1971. Stress day index to characterize effects of water stress on crop yields. Transactions of the ASAE, 14(4): 757-761.

4. Klepper, B. 1973. Water relations of peanut plants p. 265-269. In: A.J. Angelo et al. (Eds.). Peanut-culture and uses. Am. Peanut Res. Ed. Assoc., Inc., Stillwater, Oklahoma.

5. Kramer, P.J. 1963. Water stress and plant growth. Agronomy Journal, 55: 31-35.

6. Kristensen, K.J. and S.E. Jensen. 1975. A model of estimating actual evapotranspiration from potential evapotranspiration. Nordic Hydrology 6(3).

7. Mantell, A. and E. Goldin. 1964. The influence of irrigation frequency and intensity of the yield and quality of peanuts. Israel Journal of Agricultural Research, 14: 203-210.

8. Matlock, R.S., J.E. Garton, and J.F. Stone. 1961. Peanut irrigation studies in Oklahoma, 1956-1959. Oklahoma State University, Agricultural Experiment Station Bulletin 3-580, Stillwater, Oklahoma.

9. Miller, D.E. and J.S. Aarstad. 1971. Available water as related to evapotranspiration rates and deep drainage. Soil Science Society of America Proceedings, 35(1): 131-134.

10. Newman, J.S. 1978. Supplemental irrigation of peanuts in north central Texas. Unpublished data, 1972-1975.

11. Newman, J.S. 1979. Sprinkler irrigation management for peanut production. Unpublished data, 1976-1978.

12. Newman, J.S. and K. Woodard. 1979. Weather summary of the 1970's in the West Cross Timbers. Unpublished data.

13. Pallas, J.E., J.R. Stansell, and T.J. Koske. 1979. Effect of drought on Florunner peanuts. Agronomy Journal 71(5): 853-858.

14. Salter, P.J. and J.E. Goode. 1967. Crop responses to water at different stages of growth. Commonwealth Agricultural Bureaux. Farnham Royal, Bucks, England.

15. Schwab, G.O., R.K. Frevert, T.W. Edminister, and K.K. Barnes. 1966. Soil and water conservation engineering. John Wiley and Sons, Inc., New York, New York.

17. Sivakuna, M.V.K. 1978. Prediction of leaf area index in soya beans. Annals of Botany, 42: 251-253.

18. Stahnke, C.R., C.L. Godfrey, J. Moore, and J.S. Newman. 1980. Soils and Climate of the Texas A&M University Research and Extension Center at Stephenville in relation to the Cross Timbers land resource area. Texas Agricultural Experiment Station publication B-1245.

19. Stansell, J.R., J.L. Shepard, J.E. Pallas, R.R. Bruce, N.A. Minton, D.K. Bell, and L.W. Morgan. 1976. Peanut responses to soil water variables in the southeast. Peanut Science, Journal of Am. Peanut Res. and Ed. Assoc. 3(1) 44:48-52.

20. Su, Kuang Chi, Tsung-Ring Chen, San-Chi Hsu and Min-Tsuang Treng. 1964. Studies on the processing water absorption and economized irrigation of peanuts (in Chinese, English summary). Journal of the Agricultural Association of China, 45:31-40.

21. Su, Kuang Chi and Ping-Change Lu. 1963. The effect of time on irrigation and amount of water irrigated on peanut yield. (In Chinese, English summary). Journal of Agricultural Association of China, 41: 43-51.

22. Van Bavel, C.H.M. 1966. Potential evaporation: the combination concept and its experimental verification. Water Resources Rsearch 2(3): 455-467.

23. Van Bavel, C.H.M. 1980. Personal communication, Texas A&M University, College Station, Texas.

24. Visvalingham, M. and J.D. Tandy. 1972. The neutron method for measuring soil moisture content - a review. Journal of Soil Science 23: 499-511.

25. Whitt, D.M. and C.H.M. Van Bavel. 1955. Irrigation of tobacco, peanuts, and soybeans. Water, The Yearbook of Irrigation. pp. 376-381.

APPENDIX A

EXPERIMENTAL DATA

TABLE A1

Rainfall Totals and Dates of Rainfall

Dates	Rainfall Amounts	
	mm	inches
6-24	38.86	1.53
6-25	0.25	0.01
7-6	5.08	0.20
7-7	4.83	0.19
7-16	29.97	1.18
7-17	2.67	1.00
7-31	11.68	0.46
8-9	33.02	1.30
8-19	11.43	0.45
8-21	8.13	0.32
8-22	1.27	0.05
8-24	1.78	0.07
8-29	0.51	0.02
9-3	7.11	0.28
9-18	9.40	0.37
9-19	2.29	0.09
10-14	15.24	0.60

TABLE A2

Yield of Florunner Peanuts in Each Replication

Treatment	Replication					
	R1		R2		R3	
	kg/ha	lbs/ac	kg/ha	lbs/ac	kg/ha	lbs/ac
1	2555.9	2280.0	1821.1	1624.5	2012.8	1795.5
2	2523.9	2251.5	2268.3	2023.5	1757.2	1567.5
3	2236.4	1995.0	2540.0	2265.8	2124.6	1895.3
4	3610.2	3220.5	2955.3	2636.3	2236.4	1995.0
5	3083.1	2750.3	2523.9	2251.5	2891.4	2579.3
6	2204.4	1966.5	2460.0	2194.5	2076.7	1852.5
7	2875.4	2565.0	3354.6	2922.5	2236.4	1995.0
8	3482.4	3106.5	2939.3	2622.0	2747.6	2451.0

TABLE A3

Yield of Spanish Peanuts in Each Replication

	Replication					
	R1		R2		R3	
Treatment	kg/ha	lbs/ac	kg/ha	lbs/ac	kg/ha	lbs/ac
1	1437.7	1282.5	2252.4	2009.3	1932.9	1724.3
2	2859.4	2550.8	2859.4	2550.8	1597.4	1425.0
3	2156.6	1923.8	2348.3	2094.8	1629.4	1453.5
4	3051.1	2721.8	2587.8	2308.5	2236.4	1995.0
5	1948.9	1738.5	2603.9	2322.8	2476.1	2208.8
6	2364.2	2109.0	2428.1	2166.0	2044.7	1824.0
7	2683.7	2394.0	2843.4	2536.5	2316.3	2066.3
8	3083.1	2750.3	3035.1	2707.5	3386.5	3021.0

TABLE A4

Runoff Estimates for a Windthorst Fine Sandy Loam

Soil Group B - Good hydrologic conditions, terraced.

For Antecedent Moisture Condition (AMC) II; curve number N = 71.

Date	Rainfall Amount inches	AMC	Runoff	
			inches	mm
6-24	1.53	II	0.11	2.70
7-16	1.18	II	0.03	0.76
7-12	1.05	III	0.20	5.14
8-9	1.30	II	0.05	1.30

For Treatment 8, the well-watered treatment used AMC II for the last 4 irrigation applications. The estimated runoff from the well-watered treatment was 8.6 mm or 0.34 inches.

TABLE A5

Crop Yield of Replication No. 1 Versus Evapotranspiration

Treatment	Spanish		Florunner	
	Yield (kg/ha)	ET (mm)	Yield (kg/ha)	ET (mm)
1 (000)	1437.7	270.6	2555.9	280.6
2 (100)	2859.4	361.5	2523.9	392.2
3 (010)	2156.6	346.9	2236.4	390.2
4 (101)	3051.1	396.8	3610.2	407.4
5 (011)	1948.9	315.6	3083.1	316.1
6 (110)	2364.2	360.9	2204.4	376.0
7 (111)	2683.7	446.9	2875.4	446.7
8 (check)	3083.1	486.2	3482.4	562.9

TABLE A6

Average Number of Plants per Plot and Average Plant Density

Treatment	Average No. of Plants / Plot	Average No. of Plants / Ft.
TM 1	1680	8.4
TM 2	1880	9.4
TM 3	1960	10.4
TM 4	2120	9.8
TM 5	1760	10.6
TM 6	2240	8.8
TM 7	1800	11.2
TM 8	1920	9.0

TABLE A7

Climatic Data and Daily Evapotranspiration

Date	Max Temp C°	Min Temp C°	Wind Speed At 2m High km/dy	Net Radia-tion mm/dy	ET Van Bavel mm/dy	ET Penman mm/dy	Pan Evaporation mm/dy
6-21	33.3	21.1	570.4	1.95	4.45	2.63	9.4
6-22	34.4	22.8	571.1	7.73	8.68	7.03	9.4
6-23	34.4	22.8	570.4	7.73	8.68	7.03	9.1
6-24	32.8	18.9	529.3	7.41	8.65	6.85	0.0
6-25	27.8	18.9	185.9	4.75	4.26	3.90	5.6
6-26	30.6	20.0	291.2	3.45	3.97	3.23	6.1
6-27	33.3	21.7	473.3	6.19	7.07	5.68	8.1
6-28	33.3	20.0	649.5	7.19	9.21	6.86	4.1
6-29	32.8	21.7	649.5	7.73	8.97	7.05	4.1
6-30	35.6	21.1	649.5	7.86	9.89	7.51	4.1
7-1	34.4	21.1	692.1	7.79	9.82	7.41	9.9
7-2	34.4	22.2	913.0	8.13	10.83	7.90	10.9
7-3	34.4	22.2	657.0	8.32	9.71	7.66	9.4
7-4	32.8	21.7	613.7	6.45	7.82	6.03	8.1
7-5	32.2	22.8	350.9	5.90	5.92	5.13	3.0
7-6	32.2	20.0	350.9	8.21	8.08	7.02	3.0
7-7	33.9	20.6	350.9	8.33	8.35	7.24	3.0
7-8	35.0	20.0	483.0	8.36	9.45	7.63	10.9
7-9	35.0	21.7	284.4	7.93	7.68	6.87	8.9
7-10	33.9	19.4	231.4	6.80	6.61	5.90	9.1
7-11	34.4	20.6	562.9	7.42	8.97	6.96	9.9
7-12	35.0	21.7	563.6	7.31	8.71	6.84	9.9
7-13	35.0	22.8	562.9	7.37	8.48	6.80	9.9
7-14	34.4	21.7	562.9	7.27	8.57	6.76	9.9
7-15	36.1	22.2	397.9	7.41	7.96	6.71	9.7

Date	Max Temp C°	Min Temp C°	Wind Speed At 2m High km/dy	Net Radiation mm/dy	ET Van Bavel mm/dy	ET Penman mm/dy	Pan Evaporation mm/dy
7-16	29.4	20.0	403.1	6.68	6.72	5.69	0.0
7-17	26.1	18.9	541.2	1.38	2.97	1.76	0.0
7-18	27.2	18.9	545.0	3.02	4.44	3.06	0.0
7-19	26.1	19.4	227.7	3.69	3.42	3.05	4.8
7-20	30.6	21.1	227.7	4.42	4.28	3.81	5.3
7-21	32.2	21.7	227.7	4.54	4.49	3.99	5.3
7-22	33.3	20.6	269.5	4.54	4.94	4.17	7.6
7-23	32.8	21.1	317.3	6.64	6.64	5.77	8.1
7-24	31.7	20.6	813.0	6.37	8.80	6.24	8.6
7-25	31.7	20.6	872.7	5.47	8.42	5.65	9.4
7-26	32.2	21.1	673.4	4.83	6.91	4.88	9.7
7-27	35.6	22.2	674.1	7.12	9.13	6.88	9.7
7-28	35.0	21.1	673.4	7.02	9.26	6.85	9.7
7-29	35.0	22.2	853.3	7.09	9.89	7.07	10.7
7-30	35.0	20.6	518.9	7.65	8.99	7.11	3.6
7-31	23.9	18.9	315.8	4.09	3.72	3.26	0.0
8-1	30.6	19.4	636.1	-0.04	3.23	1.20	3.3
8-2	30.0	20.6	383.0	4.27	4.84	3.89	6.9
8-3	32.2	20.6	378.5	5.93	6.42	5.31	7.4
8-4	32.8	20.6	386.7	5.96	6.57	5.39	7.1
8-5	34.4	20.0	286.7	6.02	6.35	5.42	8.1
8-6	34.4	19.4	295.6	6.92	7.16	6.15	9.1
8-7	32.8	20.0	383.0	6.61	7.14	5.92	8.4
8-8	32.8	20.0	565.2	5.92	7.64	5.70	7.9
8-9	35.6	20.0	405.4	6.31	7.47	5.96	0.0
8-10	23.9	16.1	405.4	3.95	4.48	3.46	5.1
8-11	27.8	17.8	405.4	4.18	5.04	3.86	5.3
8-12	32.2	20.0	420.3	4.50	5.66	4.34	7.4
8-13	32.2	19.4	561.4	6.38	7.99	6.03	9.1

Date	Max Temp C°	Min Temp C°	Wind Speed At 2m High km/dy	Net Radia-tion mm/dy	ET Van Bavel mm/dy	ET Penman mm/dy	Pan Evaporation mm/dy
8-14	32.8	19.4	371.0	7.01	7.47	6.23	8.1
8-15	32.8	20.0	348.6	6.88	7.15	6.06	7.9
8-16	32.2	20.0	526.3	6.74	7.92	6.19	8.4
8-17	33.3	21.1	526.3	6.32	7.56	5.90	8.4
8-18	34.4	21.1	525.6	6.39	7.82	6.06	8.4
8-19	32.2	17.8	642.8	6.08	8.79	6.13	0.0
8-20	33.9	18.9	730.1	5.48	8.93	5.90	8.1
8-21	35.6	17.2	793.6	5.52	10.51	6.47	4.1
8-22	30.6	18.3	338.2	6.57	6.79	5.70	5.6
8-23	32.2	18.9	297.9	5.18	5.67	4.71	5.6
8-24	26.7	18.3	298.6	5.12	4.93	4.25	5.6
8-25	31.7	20.0	297.9	5.44	5.64	4.80	5.6
8-26	32.8	19.4	477.8	5.47	6.94	5.25	8.6
8-27	33.3	18.9	422.5	6.43	7.54	5.97	9.4
8-28	33.3	18.9	433.8	6.53	7.69	6.06	8.9
8-29	33.3	20.0	303.1	6.61	6.77	5.83	7.9
8-30	33.3	20.6	321.0	5.26	5.76	4.80	7.9
8-31	34.4	19.4	321.0	5.49	6.24	5.11	7.9
9-1	33.3	19.4	321.0	5.43	6.05	4.99	7.9
9-2	32.8	18.9	317.3	5.37	6.00	4.92	7.9
9-3	32.2	18.9	255.3	5.09	5.34	4.56	1.3
9-4	33.3	18.9	136.3	4.57	5.01	4.23	7.9
9-5	33.9	19.4	335.2	6.08	6.71	5.55	8.1
9-6	32.2	18.3	382.0	5.37	6.43	5.04	8.4
9-7	32.8	16.1	383.0	5.00	6.68	4.97	8.4
9-8	29.4	10.6	383.0	4.62	7.17	4.89	8.4
9-9	30.6	12.8	311.3	4.75	6.24	4.68	9.1
9-10	30.6	15.0	334.4	5.94	6.88	5.44	9.1
9-11	30.6	14.4	511.4	4.37	7.29	4.78	8.1
9-12	30.0	13.3	931.0	4.79	11.46	6.24	9.4

Date	Max Temp C°	Min Temp C°	Wind Speed At 2m High km/dy	Net Radia-tion mm/dy	ET Van Bavel mm/dy	ET Penman mm/dy	Pan Evaporation mm/dy
9-13	24.4	12.8	569.6	4.66	7.00	4.63	8.4
9-14	23.9	11.1	568.9	4.75	7.53	4.83	8.4
9-15	24.4	8.9	569.6	4.70	8.56	5.17	8.4
9-16	27.8	10.0	369.5	4.84	7.04	4.90	7.9
9-17	25.0	15.6	454.7	5.43	6.12	4.72	3.6
9-18	21.1	16.1	469.6	0.74	1.87	1.05	1.0
9-19	22.8	13.9	671.9	0.58	3.14	0.93	0.5
9-20	26.7	14.4	311.3	1.31	2.98	1.86	6.3
9-21	27.8	15.6	312.1	4.67	5.29	4.21	6.3
9-22	31.7	16.7	311.3	4.89	5.81	4.60	6.3
9-23	32.8	12.8	312.8	4.76	6.54	4.85	7.1
9-24	30.6	10.6	206.0	4.76	5.54	4.51	7.4
9-25	31.1	11.7	231.4	5.01	5.89	4.73	6.6
9-26	33.3	13.9	512.9	5.12	8.55	5.64	8.1
9-27	37.8	15.0	488.2	5.24	8.79	5.90	17.8
9-28	35.0	13.3	489.0	4.83	8.55	5.55	17.8
9-29	33.3	15.0	488.2	4.83	7.79	5.25	17.8
9-30	36.7	12.2	645.8	4.86	10.94	6.35	10.9
10-1	31.1	13.3	378.5	4.42	6.58	4.63	7.6
10-2	33.3	7.8	1025.0	4.84	17.42	8.27	11.7
10-3	26.1	7.8	383.7	3.93	6.88	4.41	7.4
10-4	32.2	10.0	792.1	4.74	12.61	6.69	9.7
10-5	31.7	13.9	792.1	4.57	10.31	5.84	9.7
10-6	36.7	14.4	792.1	4.84	11.50	6.48	9.7
10-7	35.6	16.7	1258.7	4.90	14.15	7.24	10.7
10-8	20.0	3.9	1262.4	3.82	17.05	7.27	9.4
10-9	21.7	5.0	348.6	1.66	5.05	2.78	5.1
10-10	35.0	10.0	339.7	4.18	7.25	4.88	7.1
10-11	35.0	15.0	779.4	4.69	10.62	6.08	5.6
10-12	21.7	13.3	780.1	1.42	4.89	2.37	5.6

Date	Max Temp C°	Min Temp C°	Wind Speed At 2m High km/dy	Net Radiation mm/dy	ET Van Bavel mm/dy	ET Penman mm/dy	Pan Evaporation mm/dy
10-13	23.9	14.4	779.4	1.53	5.26	2.57	5.6
10-14	24.4	15.6	836.9	1.59	5.23	2.58	7.6
10-15	32.2	16.1	734.6	0.15	5.50	1.95	6.3
10-16	30.6	15.6	480.8	3.93	6.41	4.28	4.1
10-17	29.4	16.1	855.5	2.54	7.54	3.87	6.6
10-18	30.0	18.3	1312.4	3.60	9.94	5.11	7.6
10-19	31.1	18.3	1312.4	3.37	10.31	5.14	7.6

TABLE A8

Analysis of Variance for Testing Differences Between Spanish and Florunner Peanuts for the Same Treatment

Treatment	Sum of Square Model	Sum of Square Error	Sum of Square Model	Sum of Square Error	F Test
1	77953.2	499437.3	77953.2	124859.3	0.62
2	77998.8	1087542.4	77998.8	271885.6	0.29
3	77976.0	294077.3	77976.0	73519.3	1.06
4	113850.4	1017247.7	113850.4	254311.9	0.45
5	286453.5	320360.0	286453.5	80090.0	3.58
6	1218.4	127794.0	1218.4	31948.5	0.04
7	51467.1	617148.0	51467.1	154287.0	0.33
8	14930.1	289018.0	14930.1	72254.0	0.21

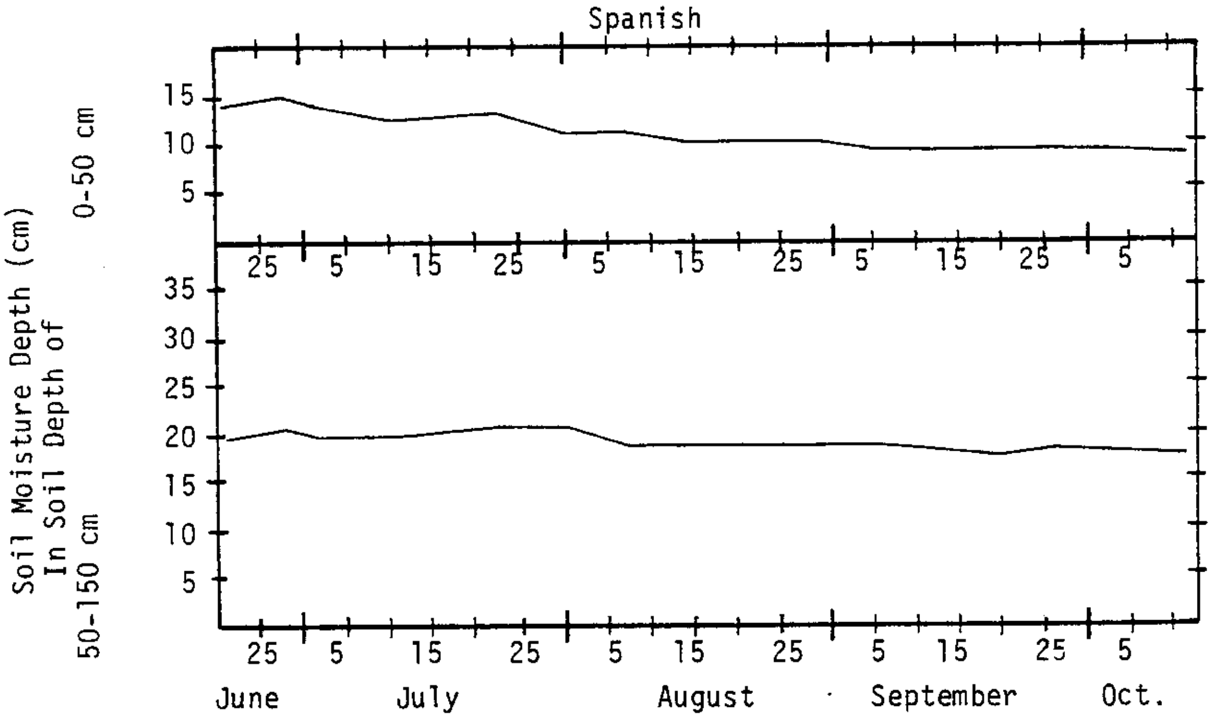
Degree of freedom of error = 4

Degree of freedom of model = 1

F value for 10% significance level = 4.54.

APPENDIX B

SOIL MOISTURE DEPTH OVER TIME



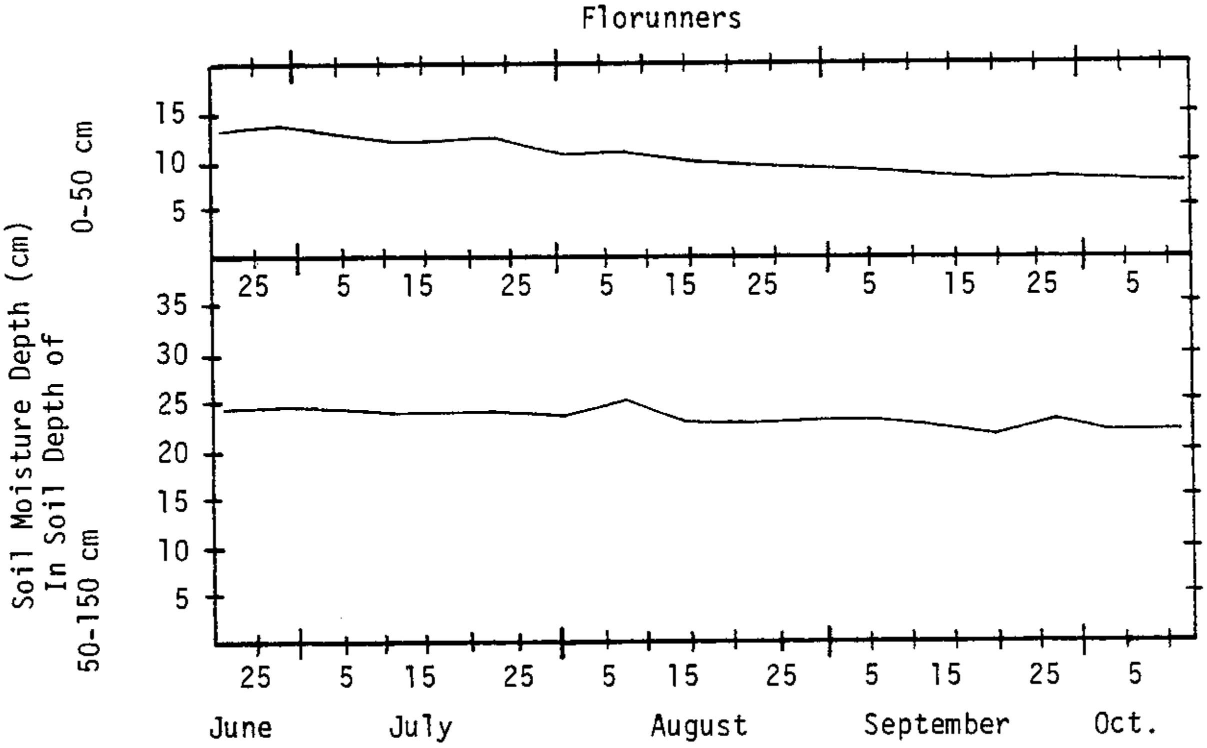


FIG. B1 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 1

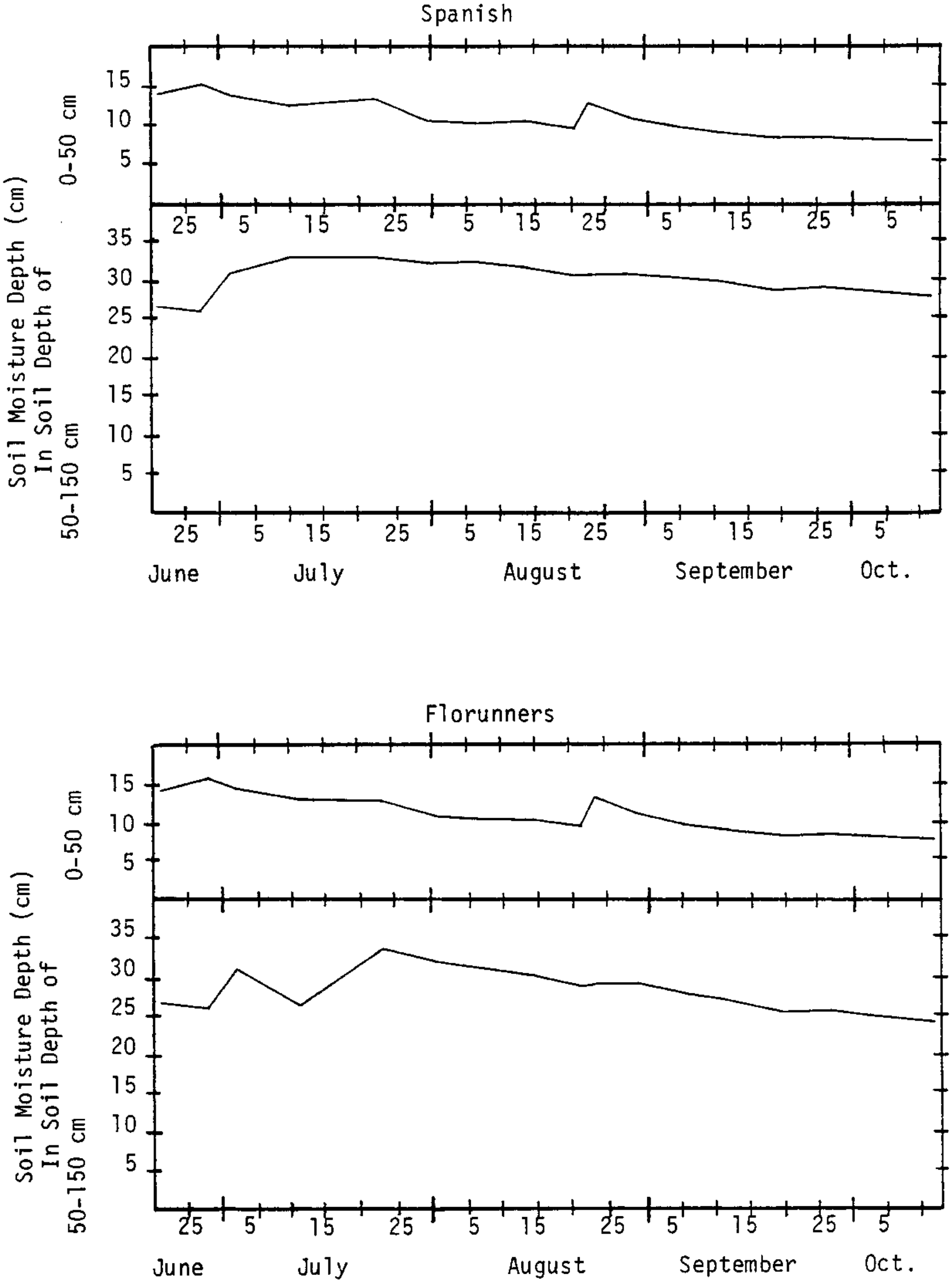


FIG. B2 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 2

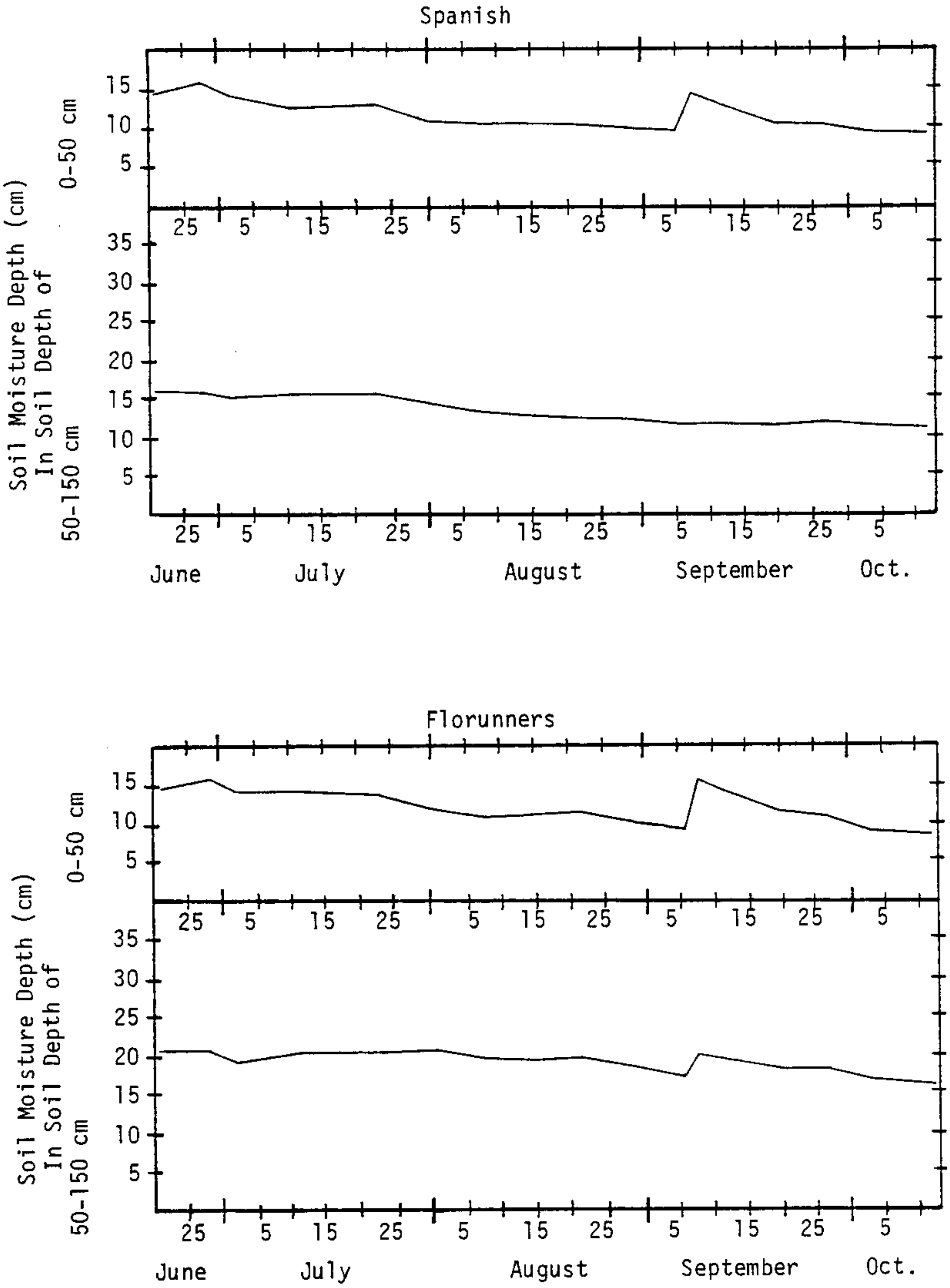
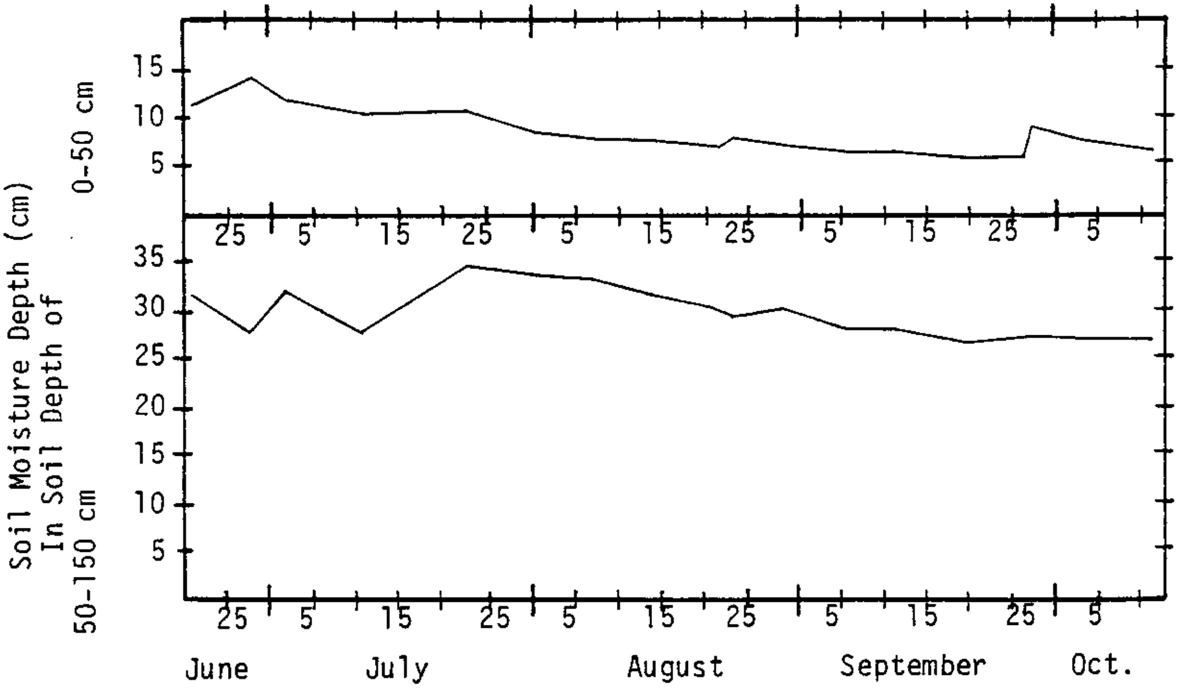


FIG. B3 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 3

Spanish



Florunners

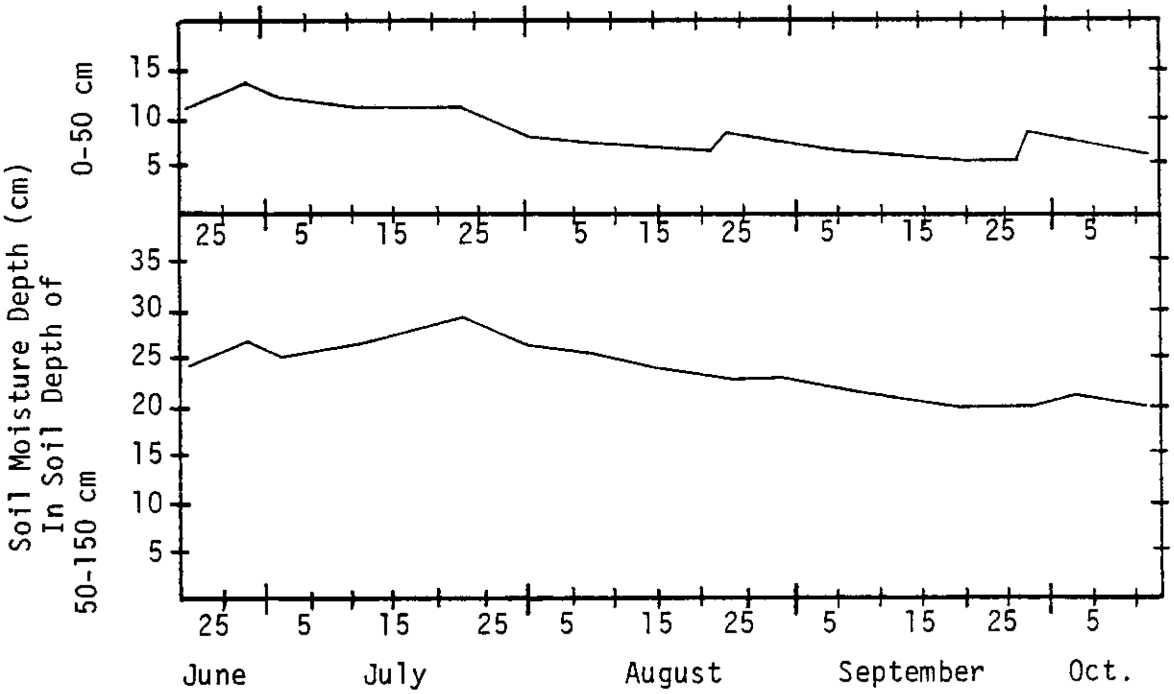
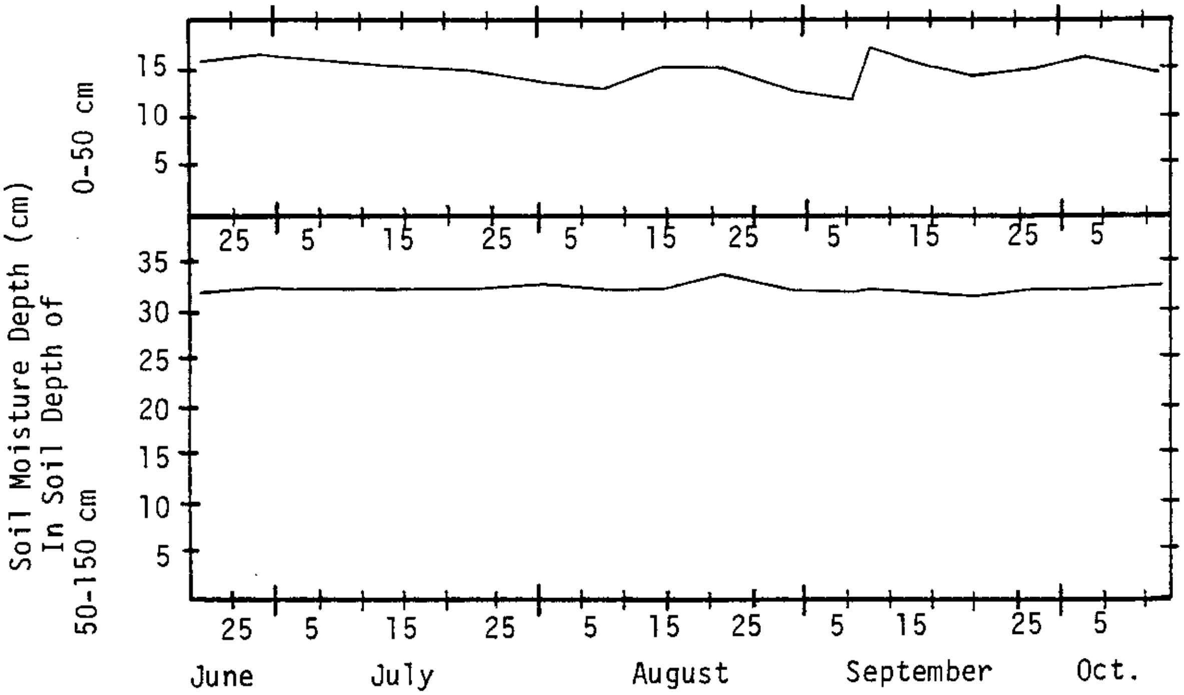


FIG. B4 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 4

Spanish



Florunners

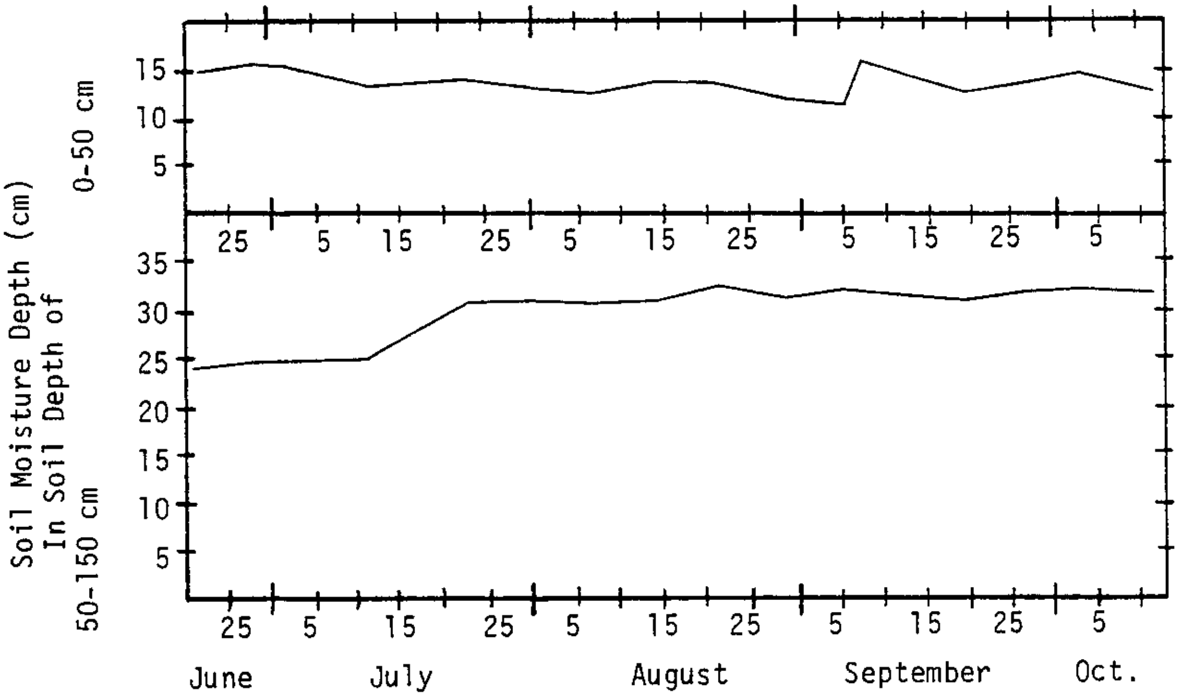
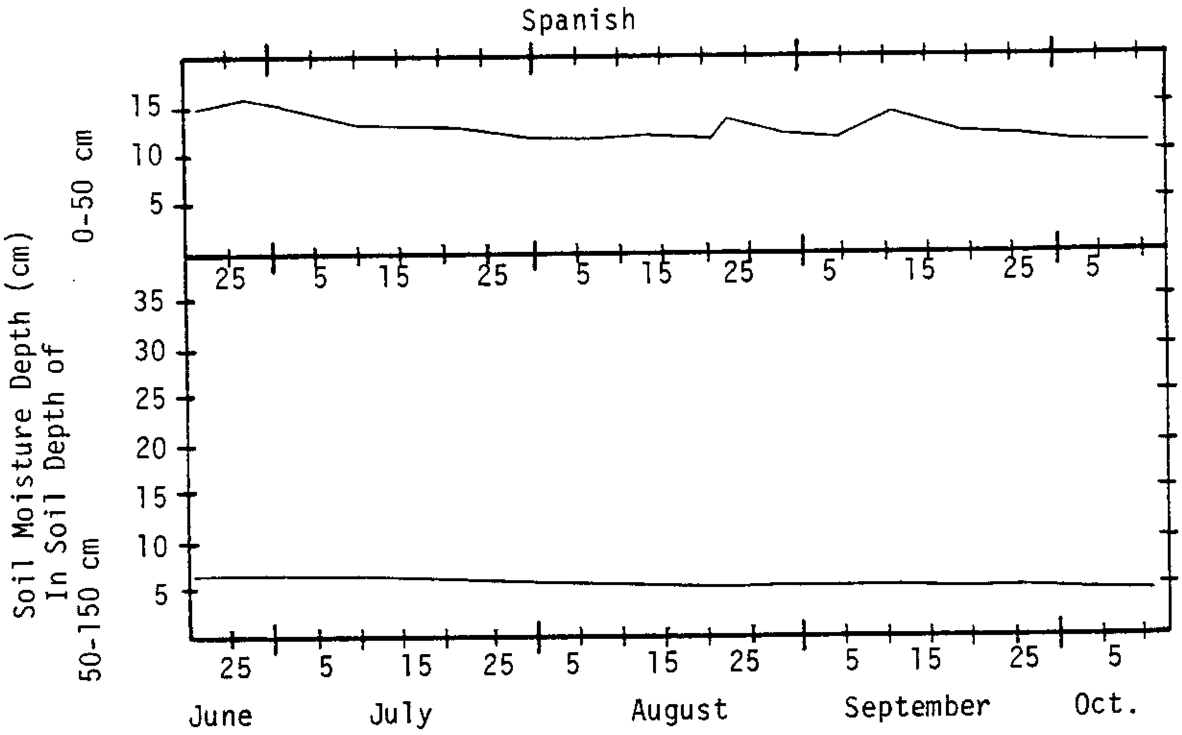


FIG. B5 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 5



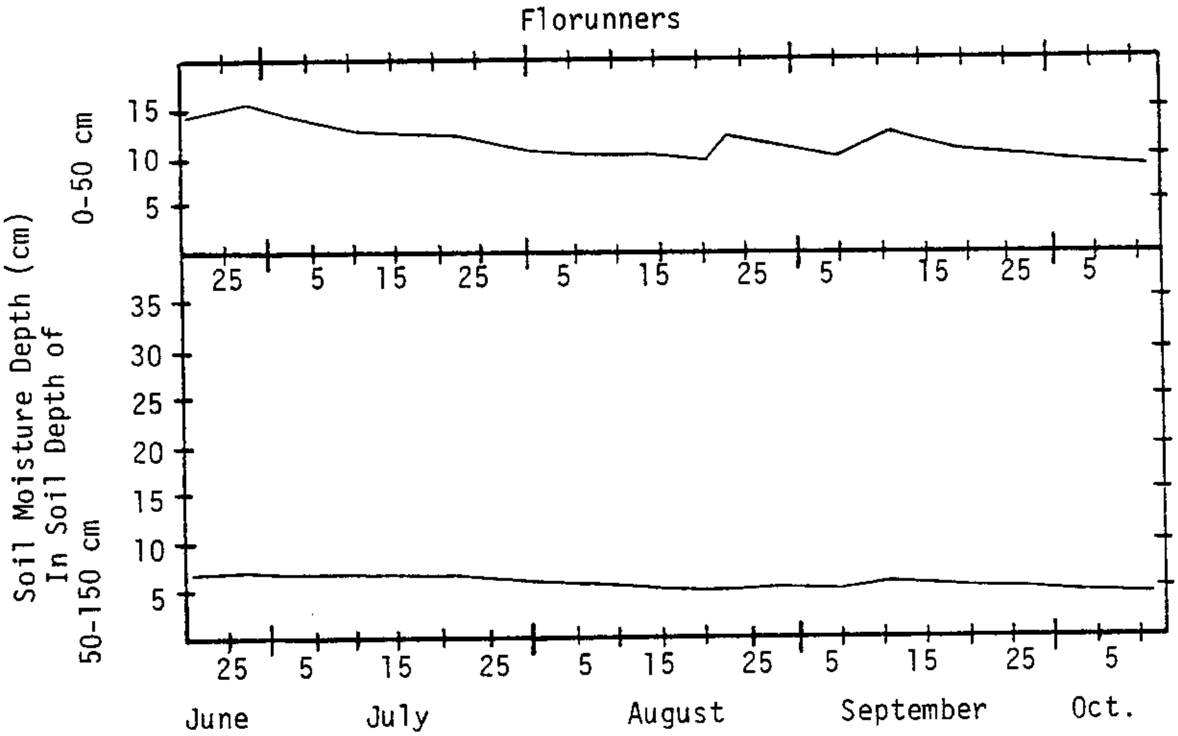
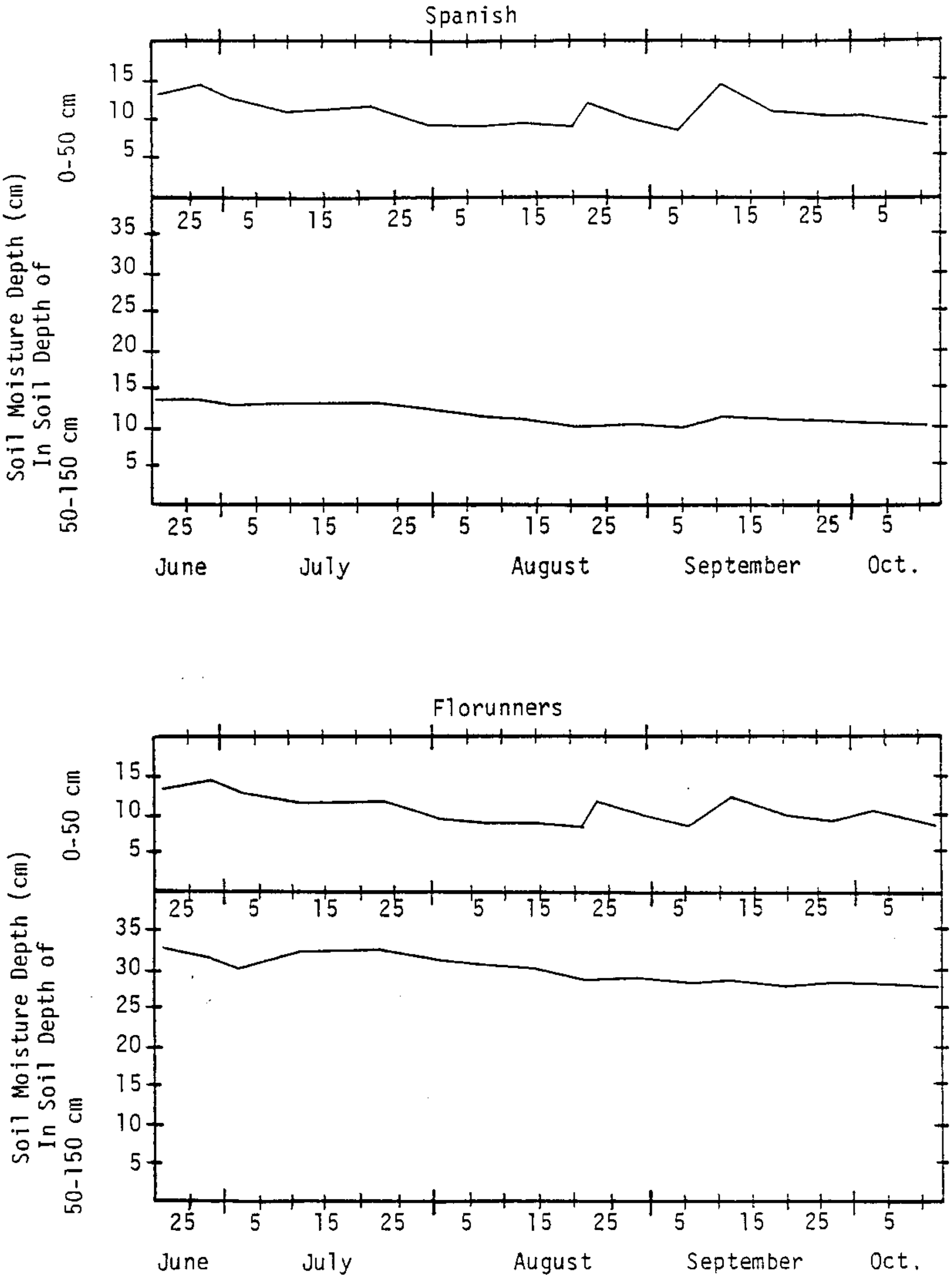


FIG. B6 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 6


Spanish

Florunners

FIG. B7 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 7

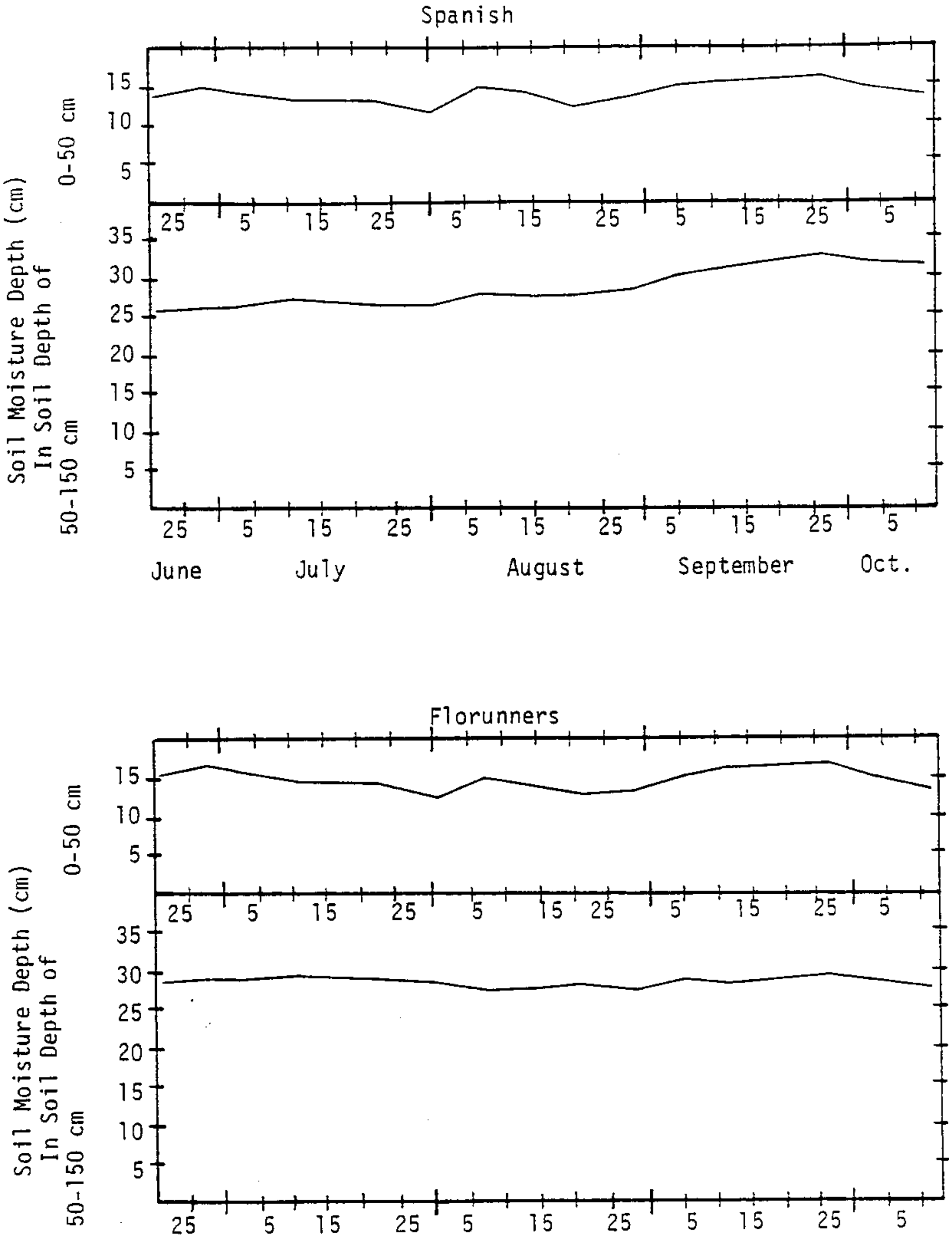


FIG. B8 SOIL MOISTURE DEPTH OVER TIME FOR TREATMENT 8