SIMULATION OF PEANUT GROWTH
IN OKLAHOMA

By

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PREFACE

This study is concerned with computer modeling of peanut growth in Oklahoma. Two peanut growth models from the southeast U.S. were modified and calibrated using sequential harvest data from four field sites in Caddo County, Oklahoma. After model parameters were developed for Oklahoma, the two models were used to simulate the effect of varying soil moisture availability and planting date.

The model parameters presented herein are those that produced the best simulations of the field data on all four sites. Due to scatter in the field data, the best simulations do not fit all the data points but the trend of the data. Both models did a very good job of simulating pod growth, which is economically more important than vegetative growth.

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INTRODUCTION

Crop Economics

The peanut crop is very important, both nutritionally and economically, for many areas of the world. Worldwide production of peanuts has averaged 18 million metric tonnes during the last eight years with the 1985-86 production forecast at 19.8 million metric tonnes (Carley, 1983; The Peanut Farmer, 1986). In the United States, the 1985 production was 1.89 million metric tonnes, worth an estimated 720 million dollars. The high value of the peanut crop makes it vital to many local economies throughout the United States.

In Oklahoma, peanuts are mostly produced over the southern half of the state. In 1985, 2073 farms in Oklahoma produced peanuts on 33,800 hectares (83,000 acres). The 1985 Oklahoma peanut crop amounted to 72,900 metric tonnes with an estimated value of 40 million dollars, making it third in value among Oklahoma crops. The many production inputs required for peanuts result in a large supply business connected with the crop.

The leading area of peanut production in Oklahoma is Caddo County, located approximately 50 miles west-southwest of Oklahoma City. In 1985, Caddo County produced 33,890 metric tonnes of peanuts on 10,900 hectares (26,900 acres) which was 46 percent of the production and 32 percent of the acreage in Oklahoma. The production of peanuts in Caddo

County is benefited by the presence of the Rush Springs aquifer, a shallow sandstone formation which allows nearly all of the crop to be irrigated.

Although peanuts are known to survive under poor growing conditions, the yield potential of peanuts is approached when the crop is kept well-watered and disease-free. Because of the potential high return on peanuts, producers can generally justify the expense of irrigation and pest control.

Peanuts are susceptible to many diseases which can affect yield. Among these are early leafspot, sclerotinia blight, and southern blight (Oklahoma State University, 1984). Control methods are available for some of these diseases, but the cost of the control must be considered against the potential benefit. This management decision requires certain crop and weather information.

Because peanuts have a high water demand and a long fruit set period, the yield is greatly enhanced by adequate soil moisture throughout a majority of the growing season. However, the high cost of irrigation water can greatly affect the profitability of an irrigated crop. Also, because some peanut diseases thrive under cool, damp conditions, timing of irrigations can be important. Information that helps producers manage irrigation can result in improved profitability and water-use efficiency.

Peanut Physiology

The early season growth of peanuts is characterized by relatively low dry matter accumulation which increases exponentially as the leaf area (and thus ground cover) increases. This early growth, up to 30 or

40 days after planting (DAP), is primarily reflected in stem elongation and leaf number increase. Boote (1983) summarized many works on drought sensitivity that showed that this vegetative growth stage is the least sensitive to water deficits.

At about 28-35 DAP, reproductive growth is initiated by the appearance of the first flowers. Thus begins the unusual fruit set of the peanut plant. The fertilized ovary begins to elongate and grow downward toward the soil. This elongated ovary is referred to as a "peg". The peg grows downward and penetrates the soil to a depth of approximately 5 cm at 8 to 12 days after fertilization (Boote, 1983). The tip of the peg then begins to swell and takes on the characteristic shape of the peanut pod. Upon reaching normal pod size for the cultivar, seeds begin to form and grow in size until mature.

The number of mature pods that could potentially be harvested is controlled by the following three phases: (1) flower initiation, (2) peg growth and soil penetration, and (3) pod formation and growth. To obtain optimum yields, growing conditions must be favorable during all three phases. Flowering and peg formation can occur from 35 until 91 DAP with the peak time being between 50 and 80 DAP. Because of the long fruit set time, a drought during part of the fruit set period often can be compensated for when the drought is relieved. However, prolonged drought can reduce the number of pods by reducing flowering, preventing peg penetration into the soil, and slowing the rate of pod addition.

Because peanut pods are set over an extended time period, they also mature over a time period. This is in contrast to most crops in which the fruit ripens nearly simultaneously. In addition, peanuts mature underground, making it difficult to judge maturity and increasing susceptibility to overmature losses due to pod rot and detachment from pegs. Thus, while some pods are mature and harvestable, others are still immature. In judging when to harvest a peanut crop, the producer must decide when most of the pods are mature and when further maturity time will result in loss due to rot and detachment.

Uses of Growth Models

Growth models are mathematical simulations of crop growth. Crop growth models use weather, soil, and varietal inputs to predict the amount of dry matter accumulated in vegetative and reproductive tissue. Thus, a good crop model can be used to simulate many different growing conditions that would take too much time and money to accomplish with test plots.

Growth models can provide a multitude of information for crop management. Although producers can usually judge qualitatively the condition of their crops, a growth model could provide quantitative information on such things as soil moisture, root depth, plant mass, and harvestable mass. Another use of growth models would be to predict the effect of extreme growing conditions such as drought, extended high temperature, and low radiation. A simulation model could be used to investigate the best management to reduce the impact of these conditions. Potentially, the most practical use of growth models would be for yield estimates. This would allow economic analysis of different management schemes.

A good crop model can provide information as to the harvestability of the crop, particularly for peanuts. Because the peanut plant is continually setting, filling, and maturing fruit, there is no one certain time when harvest is to start. Instead, the producer must decide if further maturation time will allow more pods to mature without the loss of pods that are already mature. A growth model could predict the percentage of mature pods and the losses that would likely be incurred in delaying harvest.

Demonstration by Cooperative Extension and teaching personnel is another potential application of crop growth models. A crop simulation demonstration could be used to help producers and students realize the effects of certain growing conditions on the development and yield of the crop.

Objectives of Study

The purpose of this study is to adapt available peanut growth models to Oklahoma conditions, in order to provide information for improved management of peanuts, especially with regard to irrigation. In order to achieve this goal, the following procedural objectives will be followed:

1. Investigate existing peanut growth models and choose those to be used in this study,
2. Collect necessary field data for use in the models,
3. Calibrate the models using the field data,
4. Compare the models' ability to simulate crop growth, and
5. Compare the usefulness of the models and make recommendations.

CHAPTER II

REVIEW OF LITERATURE

Crop Models

Researchers have suggested and developed growth models for many crops. Among these numerous modeling efforts are a soybean growth model by Curry et al. (1975), an alfalfa model by Miles et al. (1973), a cotton model by Baker et al. (1972), and a corn model by Baker et al. (1975). Holt et al. (1976) and Singer (1975) have reported crop simulation models primarily for educational uses.

A general model for all crops is part of an overall farming impact model called EPIC by Williams et al. (1984). This model simulates plant growth and its effect on soil productivity and soil erosion. The growth model subroutine is general and used to simulate many corps.

Researchers in the Netherlands have done work on simulating crop growth. van Kuelen (1975) published work on simulation of grass growth in arid regions. de Wit et al. (1978) has reported work on models to simulate assimilation, respiration, and transpiration by crops.

Peanut Growth Models

Work on developing peanut growth models has taken place primarily in the last ten years. Although several researchers are known to be working on models, to date few have published results of their work.

Duncan (1974) described an early attempt at peanut growth modeling. However, apparently no details of this early model were published.

A very simple model, designed to be used for demonstration purposes, was developed by Ingram et al. (1981) at the University of Florida. Their model, PNUTMOD, looks only at the effect of temperature and radiation on the crop and assumes all other production factors to be adequate for good growth. This is an educational model capable of being run on a programmable calculator.

A more complex model has been developed by Young et al. (1979) at North Carolina State University. Their model is comprehensive and attempts to model all vegetative and reproductive processes of the peanut plant. Since the 1979 article, further work has been done to simulate root growth and soil moisture and produce a more complete model (Young and Singh, 1985).

Boote, at the University of Florida, is in the process of converting a soybean growth model (SOYGRO) to a peanut model. However, to date no information has been published.

Water Management of Peanuts

The yield of peanuts increases as seasonal water use increases, and appears to peak at a seasonal water use of 60 cm (Boote, 1983) although distribution of water application is also important. Therefore, for peanut production areas where rainfall is sometimes deficient, irrigation can markedly increase yields.

Matlock et al. (1961) reported results of irrigation studies on peanuts in Oklahoma that showed irrigation significantly increased yields for four straight years. There was also a significant increase in quality for two of four years.

Vivekanandan and Gunasena (1976) observed that maintaining high soil water potentials did not increase pod yield but did increase vegetative growth. Many researchers have concluded that the period of pod formation and addition is the most critical with regard to soil moisture (Boote, 1983).

The major concern in irrigation water management is deciding when and how much to irrigate. Boote (1983) reviews much of the work done on different management schemes for peanuts and presents the recommendation that irrigation commence when the root zone reaches the 50 percent available water level or when the top 30 cm reaches -0.6 bar soil water potential.

Stansell et al. (1976) reported that peanuts can extract almost all of the available water in the soil profile but that yield and quality improve markedly when soil water potential is maintained above -0.6 bar during pod formation and -2.0 bar during pod maturation. Under conditions in India, Pahalman and Tripathi (1984) found that watering at a ratio of applied water to cumulative pan evaporation of 0.5 during early growth, 0.9 during flowering and pegging, and 0.7 during maturation gave the best combination of yield and water use efficiency.

Wilson and Stansell (1983) reported results of a study on irrigation's influence on aflatoxin contamination of peanut pods. They found that when water was applied to the crop during the last forty days, aflatoxin production seemed to be inhibited. However, they could not conclusively state that water deficits promoted aflatoxin production.

A very thorough review of research concerning soil water and irrigation as related to peanuts can be found in Boote (1982) and Boote (1983).

CHAPTER III

MODEL DESCRIPTIONS

The models presented by Ingram et al. (1981) and Young et al. (1979), referred to henceforth as PNUTMOD and Young's model, respectively, are the two considered in this study of peanut growth simulation in Oklahoma. Since PNUTMOD is relatively simple and Young's model is much more involved, these two provide a contrast in model complexity.

PNUTMOD

The model developed by Ingram et al. (1981) is a simple simulation developed for a hand calculator. Growth phenology is a function of temperature while dry matter accumulation is a function of solar radiation. PNUTMOD divides the growing season into three phases: expansion, pod set, and pod fill.

Expansion

The expansion phase of growth in PNUTMOD is the time from emergence until pod set begins. During expansion, growth is controlled by developmental units (DU), defined as the summation from emergence of the daily temperatures exceeding 10 °C:

$$DU_i=\sum_{j=1}^{i}(ADB_j-10) \qquad (1)$$

where DU_i is the developmental units accumulated from emergence until day i (°C) and ADB_j is the average dry bulb temperature on day j (°C). Daily assimilation then depends on the daily solar radiation corrected for ground cover fraction and photosynthetic efficiency:

$$DAS_i=(RAD_i)(GC_i)(PNE) \tag{2}$$

where DAS_i is the assimilate available for growth on day i (g/m^2), RAD_i is the solar radiation for day i (MJ/m^2), PNE is the photosynthetic efficiency (g/MJ), and GC_i is the ground cover fraction (dimensionless). The increase in vegetative mass for day i is then equal to DAS_i. Ground cover fraction is an exponential function:

$$GC_i=(DU_i/DUE)^P \tag{3}$$

where DUE is the total DU during the expansion phase (^oC) and P is the growth exponent (dimensionless). DUE and P are varietal constants.

Pod Set

The pod set phase begins when ground cover fraction (GC) equals one. During pod set, daily pod matter accumulation is a function of DU accumulated after expansion:

$$DPDM_i=(PSF)(DU_i-DUE) \tag{4}$$

where $DPDM_i$ is the increase in pod mass on day i (g/m^2) and PSF is a pod set factor ($g/m^2/^oC$). Daily vegetative matter accumulation is then the difference between DAS_i and a scaled $DPDM_i$:

$$DVDM_i=DAS_i-(DPDM_i/PCF) \tag{5}$$

where $DVDM_i$ is the increase in vegetative mass for day i (g/m^2) and PCF is a pod composition factor (dimensionless). Pod set continues until the fraction of DAS_i allocated to pods reaches the maximum partitioning (PART). Thus when PL reaches one, where:

$$PL_i = \frac{DPDMi}{(PCF)(DAS_i)(PART)} \tag{6}$$

pod set is finished and pod fill begins.

Pod Fill

Pod fill continues until all pods set are filled or until the season is ended. The amount of DU needed to fill all pods is estimated as:

$$DUF=0.633(PWF)(DUP)/PART-125 \tag{7}$$

where DUP and DUF are the amounts of DU during pod set and pod fill, respectively, (°C) and PWF is a pod weight factor (dimensionless). During pod fill, daily pod matter accumulation becomes:

$$DPDM_i=(DAS_i)(PCF)(PART) \tag{8}$$

Pod fill is finished when the DU during pod fill equals or exceeds DUF.

In addition to the two weather inputs, temperature and radiation, PNUTMOD requires 7 varietal inputs (PNE, P, DUE, PSF, PCF, PART, and PWF).

PNUTMOD was first developed using growth data from Florida and Malawi. Simulation results were satisfactory except for the lack of senescence of older leaves during the pod fill phase.

Young's Model

Young and associates at North Carolina State University have attempted the most complete and detailed model for peanut growth simulation. All facets of peanut growth and reproduction are modeled mathematically, based on research and hypothesis. Among the processes modeled are emergence; photosynthate production; respiration; initiation and number of flowers, pegs, and pods; soil moisture; root growth; peg strength; and leaf drop.

Emergence

Time to emergence is a function of average daily temperature. Emergence is set to occur when:

$$f(T_{AV}) >= P(1) \tag{9}$$

where P(1) is a varietal constant, T_{AV} is the average daily temperature, and f is the emergence function.

Photosynthate Production

After emergence, growth is a function of the photosynthate accumulated daily. Photosynthate production is:

$$CFIX=(ALFWT)(FK) \tag{10}$$

where CFIX is the gross photosynthesis (g/m^2), ALFWT is the active leaf mass (g/m^2), and FK is a dimensionless growth parameter. FK is calculated as:

$$FK=P(10)(RFAC)(SF)(TF)(XMF) \tag{11}$$

where P(10) is a varietal constant, RFAC is a function of daily solar radiation, SF is a function of leaf density, TF is a function of average daily temperature, and XMF is a function of soil moisture. All the factors in equation 11 are dimensionless and all except P(10) have an optimum value of 1.0 and decrease as the functional parameter becomes limiting.

Respiration

Some of the total photosynthate produced is spent on maintenance of the existing tissue. The amount of respiration is calculated as:

$$\mathrm{TRESPM}=(\mathrm{APWT})\,g(T_{AV}) \qquad (12)$$

where TRESPM is the respiration requirement (g/m^2), APWT is the active plant mass (g/m^2), and g is the respiration function.

Photosynthate Storage

A portion of the vegetative mass is assumed to be available as part of a photosynthate pool for use when photosynthate production is less than demand.

Pods

Once photosynthate is adjusted for respiration and pooling (if needed), pod filling is given priority. If photosynthate is sufficient all pods are increased in weight by an amount P16 which is a function of T_{AV}. Thus, the total pod mass increase is P16 times the number of growing pods. If photosynthate is limiting, it is all used on pod growth and the average pod increase is CAVAIL/P(18) where P(18) is a pod respiration factor and CAVAIL is the photosynthate available for pod growth.

The maximum pod mass for a pod initiated on day i is P(19) times its mass on day i-28. Thus, pods are considered mature when their mass equals or exceeds their maximum mass. The number of mature pods is subtracted from the total to obtain the number of growing pods.

If there is photosynthate available after pod growth, new pods can be initiated if pegs are available. The number of new pods is the lesser of the number of available pegs or the available photosynthate divided by P(17), the amount of photosynthate required to trigger a pod (g/m^2 per pod).

Pegs

Photosynthate is next available to pegs. Peg mass is increased in a manner similar to pod mass and if photosynthate and flowers are both available, new pegs are added. In addition, there are provisions for maturing pegs that have reached a mass of P(23) grams and "killing" pegs over seven days old if the soil is too dry.

Flowers

If the vegetative growth rate on day i-3 is greater than P(28) g/plant per day, then flowers are added on day i according to:

$$FC_i = (TOPINC_{i-3} - P(28))(PLPFT)(P(29))(TFFLR)(XMF)/ROWSP \qquad (13)$$

where FC_i is the number of flowers added on day i ($flowers/m^2$), $TOPINC_{i-3}$ is the vegetative growth rate on day i-3 (g/plant/day), PLPFT is the number of plants per meter of row (plant/m), P(29) is a varietal constant (flowers/g), TFFLR is the temperature factor for flowering (a function of T_{AV}), and ROWSP is the row spacing (m).

Soil Moisture

Soil water interactions are also modeled, including the moisture content-tension relationship, redistribution, surface evaporation, and root uptake of water.

In the soils portion of the model, the root zone is divided into layers with each layer having its own moisture content-tension curve. The functional relationship assumed for the curve is a decaying exponential of the form:

$$\theta = B \cdot T^{-A} \tag{14}$$

where θ is volumetric moisture content, T is soil water tension (bars), B is the volumetric moisture content at 1 bar of tension, and A is an exponent dictating the shape of the curve.

Overnight redistribution of soil moisture, due to extraction or addition, is modeled based on dynamic potentials. Surface evaporation is calculated based upon the availability of water for evaporation, average daily temperature and net radiation. This amount of evaporation is then distributed among the soil layers. Root uptake of water is a function of the soil water tension and root mass at a particular soil layer. A layer with high root mass and low tension has more water extracted than a layer with low root mass and high tension.

Root Growth

Vertical root growth is assumed to be 2.5 cm/day starting at an initial root depth at emergence and ending when the maximum rooting depth is reached. Root mass increase for each soil layer is influenced by the existing root mass and soil water tension in the layer. Total photosynthate available for root mass increase is a function of soil moisture. As the moisture deficit increases, photosynthate allocated to root growth is increased.

Peg Strength

The amount of force required to sever a peg provides a means of estimating probable losses due to detachment of pegs from harvestable pods. Pegs are assumed to have an initial attachment force of 870 grams. This initial force is reduced by high temperature and low moisture. The reduction in attachment force is used to estimate the below ground losses for pods initiated on day i. The total loss is then the summation of losses of pods initiated throughout the season.

Leaf Drop

In response to a photosynthate deficiency, a portion of the oldest leaves is dropped and used to supply photosynthate from the pool. The amount of leaf drop is limited to a certain percentage of the total leaf mass, P(41).

Just as there are seven varietal parameters in PNUTMOD, the current version of Young's model requires 65 parameters. However, the model contains six parameters that are not used in the study reported herein. Four of these had no use when the model was acquired and two are for provisions not used in this study. In addition, two are printer control parameters, six are used in estimating peg attachment force decay and related losses, six deal with soil water equations, two define the number and size of soil layers, and one is a constant used in calculating leaf area index. The remaining 42 parameters control the growth of the vegetation and pods.

CHAPTER IV

FIELD PROCEDURES AND DATA

A review of the available peanut growth models gave an indication as to the weather, soil, and varietal inputs necessary for execution of the models. Obvious needs were weather data (temperature, rainfall, radiation, etc.), soil data (moisture storage, availability, etc), planting information (date, variety, spacing, etc.), and growth data for comparison against model predictions.

Since research was being done in Caddo County on irrigation scheduling, it was decided to obtain field data from sites in that area. Four cooperators' fields were chosen as representatives of peanut fields in Caddo County. These sites allowed collection of soil moisture data and sequential harvest data needed to test the growth models.

Site Descriptions

To be consistent with the irrigation scheduling project, the sites for this modeling study were designated as 4A, 6B, 9A, and 10A.

Site 4A - Location: NW1/4 Section 2 R13W T8N. According to the USDA-SCS Soil Survey (1973), the soil type is Hollister silt loam with 0-1 percent slope. The site was very level with a good uniform stand of Spanco spanish type peanuts. The site was irrigated by a center pivot with low angle impact sprinklers. The site was kept fairly well watered and disease free. Planting date was May 25, 1985, or calendar day (CD)

145, with emergence on May 31. Row spacing was 91 cm (36 in) and average plant density was 16.8 plants/m. Monitoring equipment was installed on June 14. Equipment was removed and final yield samples taken on September 28 (CD 271).

Site 6B - Location: NE1/4 Section 34 R13W T9N. The soil survey classification is Cobb fine sandy loam, 3-8 percent slope. The site was slightly sloping with a good stand of Spanco peanuts. Irrigation was by center pivot with low angle impact nozzles. The site was kept fairly well watered but suffered a slight amount of disease damage, primarily from leafspot. Planting date was May 23, 1985 (CD 143) with emergence on May 29. Installation of monitoring equipment was on July 2 with removal and final yield sampling on September 28 (CD 271). Row spacing was 91 cm and plant density averaged 10.7 plants/m.

Site 9A - Location: SW1/4 Section 21 R12W T9N. The soil survey indicated the soil is a Dougherty loamy fine sand with 1-3 percent slope. This site was slightly sloping and planted to Spanco peanuts. The site was only marginally irrigated with a center pivot. The planting date of June 13, 1985 (CD 164) was later than the average with emergence occurring on June 18. Monitoring equipment was installed on June 26 and removed on October 1 (CD 274) when final yield samples were taken. Row spacing was 91 cm and plant density averaged 9.8 plants/m.

Site 10A - Location: SE1/4 Section 7 R12W T9N. According to the soil survey, the soil type is Dougherty loamy fine sand. The site was nearly level with a good stand of Spanco peanuts. The crop was marginally watered with a sideroll irrigation system. The site was adversely affected by leafspot which resulted in an abnormal leafdrop. This is believed to have occurred because of high humidities due to reduced air movement behind a tree windbreak located about 80 m south of the site. The presence of the disease damage prompted an early termination of the growing season. The crop was planted on May 28, 1985 (CD 148) and emerged June 3. Equipment was installed on June 10 and removed on September 21 (CD 264) at the time of final yield sampling. Row spacing was 91 cm with an average plant density of 16.0 plants/m.

Table I gives the results of soil textural analysis made on samples from the four study sites. The textural analysis results agreed with the soil survey classifications except for site 4A which tested to be sandy loam and not silt loam.

Weather Data

A portable weather station was set up at the Caddo Research Station near Ft. Cobb, Oklahoma, on May 16, 1985. The weather station was situated within 12 km (8 miles) of all four study sites. The station consisted of environmental sensors connected to a Campbell Scientific CR-21 Micrologger. The following sensors were used: a Campbell Scientific model 101 temperature probe for air temperature, a Delta-T WVU-21 ventilated psychrometer for wet bulb temperature, a Met One 024A windvane for wind direction measurement, a Met One 014A anemometer for windspeed, a Licor LI200S silicon pyranometer for solar radiation, and a Sierra-Misco RD2501 tipping bucket raingage for rainfall. The CR-21 Micrologger was programmed to read the sensors every minute (every hour for wet bulb temperature) and compute hourly and daily summaries. The micrologger was capable of storing 48 hours of weather data in memory as well as having cassette tape data storage for backup.

TABLE I

SOIL TEXTURAL ANALYSIS FOR THE FOUR STUDY SITES

Site	Depth	% Sand	% Silt	% Clay
4A	30 cm	73	11	17
	60 cm	53	25	23
6B	30 cm	77	9	15
	60 cm	53	17	31
9A	30 cm	69	23	9
	60 cm	63	17	21
10A	15 cm	91	0	13
	30 cm	83	3	15
	60 cm	79	7	15

Note: Percentages may not total to 100.

The weather station was connected via phone line to an IBM PC XT microcomputer located at the Caddo Electric Cooperative at Binger, Oklahoma. The computer was set up on a timer to call the weather station at 12:05 AM and read the preceding day's weather data, calculate and print a summary, and store the data in a data file. Data collection began on May 27. Temperature data from May 20 to May 26 were acquired from the Oklahoma Climatological Survey for Carnegie, Oklahoma. Daily solar radiation was assumed to be 500 Langleys and windspeed was assumed to be 2.68 m/s for the days between May 20 and May 26. From this main weather file, others were constructed as required for each growth model. See Appendix A for the summary of daily weather data for the 1985 growing season. The same weather station was used to collect weather data during 1984 for the irrigation scheduling research and thus 1984 weather data were available for use in simulations.

Rainfall and irrigation data were collected at each site using two rain gauges mounted just above the crop canopy. Two TruCheck rain gauges were installed on wooden stakes driven into the soil and were placed approximately 60 cm (2 ft) above the ground. The rain gauges were read when soil moisture readings were taken at the test sites. The amount of rain/irrigation and an estimate of the date of application were recorded on data sheets. Because of the time delay in reading the rain gauges, a small amount of cooking oil was added to the rain gauges to suppress evaporation. See Appendix B for the rainfall/irrigation data for the four sites.

Soil Moisture Data

Soil moisture is an important factor in plant growth and a necessary input for most crop models. Therefore, it was necessary to collect some kind of data relating to soil moisture.

Because of the irrigation scheduling research project, a neutron scattering moisture gauge (neutron probe) was available for soil moisture measurements. The neutron gauge used was a Troxler Model 3333 moisture gauge featuring internal memory and a serial port for transferring data to a computer.

A review of research related to peanut root growth and water uptake by Boote (1983) revealed that peanuts have the ability to send roots down to 200 cm or greater. However, most water uptake is from less than 150 cm deep. It also has been found that under irrigation root growth and water uptake occur at more shallow depths than under dry land conditions. For these reasons, a root zone of 122 cm (48 in) was assumed for the conditions of the study sites.

Each site was equipped with two neutron probe access tubes. The access tubes consisted of 1.52 m (5 ft) lengths of 5 cm diameter electro-mechanical tubing. The tubes were installed in the soil to a depth of 1.37 m (54 in). The two tubes were located about 3 m apart in a peanut row in a uniform area representative of the surrounding field.

Using the neutron probe, the soil moisture was measured every 15 cm (6 in) to a depth of 1.22 m (48 in). Moisture data were collected every two to three days throughout the growing season.

The data from the neutron probe was in the form of a count ratio relating a measured count to a reference count. These data were transformed into volumetric soil moisture content data using equations calibrated by the OSU Agronomy Department:

$$\theta = .0097 + .5851\ (CR) \qquad \text{(for depth = 15cm)}$$

$$\theta = -.0162 + .5674\ (CR) \qquad \text{(for depth > 15cm)}$$

where θ is volumetric moisture content (cm^3/cm^3) and CR is the count ratio. Appendix C contains the total water data for the four sites.

A good estimate of the field capacity was obtained from neutron probe readings taken after a high rainfall event early in the growing season. Later, the wilting point (15 bars tension) was estimated from field data, hypothesis, and the work of Rawls et al. (1982). Table II is a summary of these values.

TABLE II

ESTIMATED SOIL WATER CONTENTS FOR A 1.22 m (4 ft) ROOT ZONE AT FIELD CAPACITY AND WILTING POINT

Site	Field Capacity (cm)	Wilting Point (cm)
4A	29.1 (11.4 in)	16.8 (6.6 in)
6B	34.3 (13.5 in)	19.6 (7.7 in)
9A	24.9 (9.8 in)	10.4 (4.1 in)
10A	25.7 (10.1 in)	9.9 (3.9 in)

Growth Data

In order to test the model simulations, whole plant samples were taken throughout the growing season at the four study sites. At intervals of about five days, a 60 cm (2 ft) section of row was taken from an area within approximately a 10 m radius from the access tubes. Samples were taken no closer than 2 m from a previous sample and were visually chosen based on being uniform and representative of the surrounding field. Larger samples would have been more desirable statistically but would have resulted in excessive field damage. For the final yield determination, four of the 60 cm samples were taken for replication.

The plant samples were allowed to air dry and were then stored in plastic bags along with identification as to date and site. At the end of the season, the plant samples were processed by separating the vegetation and pods and removing surface dirt. The pod samples were washed to further remove dirt, dried in an oven at 130 °C for six hours, and the dry mass determined. This procedure follows the suggestions of Young et al. (1982). The air dried vegetation samples were crushed and oven dried at 70 °C for six hours and the mass determined. These data were then converted to a mass per unit area basis (Tables III through VI).

The pod samples from the four replications of final yield for each site were counted and averaged for total pod count. In addition, a sample of the largest pods was selected, dried, and weighed, and an average pod mass was determined. This was done to estimate the maximum pod mass. Also, a sample of the smallest acceptable pods was selected, dried, weighed, and an average taken to estimate the minimum acceptable

TABLE III

PLANT SAMPLE DATA FOR SITE 4A

Calendar Day	Pod Mass (g/m^2)	Vegetative Mass (g/m^2)
186	--	87.8
197	6.6	221.5
203	15.4	274.2
207	18.1	348.2
212	54.0	--
218	127.5	491.6
224	184.2	432.2
231	274.2	--
235	283.9	493.2
239	397.9	538.5
243	359.3	612.8
246	441.7	531.6
250	607.1	666.6
253	511.9	624.7
257	539.7	499.9
260	580.4	582.8
267	518.2	486.7
271	592.9	554.5

TABLE IV

PLANT SAMPLE DATA FOR SITE 6B

Calendar Day	Pod Mass (g/m^2)	Vegetative Mass (g/m^2)
186	--	108.5
200	20.0	276.4
205	27.0	263.1
210	78.0	409.6
218	117.6	529.6
224	278.2	--
231	254.5	488.3
235	444.4	447.4
239	324.9	457.6
243	370.9	557.3
246	357.4	427.0
250	445.0	478.3
253	465.9	483.8
257	285.5	357.0
260	456.4	405.2
267	721.7	589.6
271	527.3	426.1

TABLE V

PLANT SAMPLE DATA FOR SITE 9A

Calendar Day	Pod Mass (g/m^2)	Vegetative Mass (g/m^2)
186	--	27.4
197	--	94.8
203	--	140.7
207	--	130.6
212	6.1	205.4
218	21.9	278.2
224	42.9	359.6
231	79.8	371.0
235	119.6	538.2
239	108.4	566.2
243	144.3	553.4
246	269.1	560.8
250	219.6	528.2
253	188.2	463.3
257	267.9	455.1
260	245.0	486.0
267	342.6	450.7
274	295.1	443.1

TABLE VI

PLANT SAMPLE DATA FOR SITE 10A

Calendar Day	Pod Mass (g/m^2)	Vegetative Mass (g/m^2)
186	--	82.1
197	13.6	213.1
203	22.4	221.9
207	53.7	268.9
212	69.3	351.0
218	111.1	--
224	184.3	348.0
231	237.7	414.7
235	212.7	281.7
239	250.0	378.5
243	334.4	461.6
246	475.4	468.2
253	495.8	362.5
260	460.5	392.4
264	437.9	362.4

pod size. These three values were needed in the calibration of Young's model. Table VII presents the results of the pod analysis.

TABLE VII

SUMMARY OF POD ANALYSIS

Site	Pod Count	Max. Pod Mass	Min. Pod Mass
4A	$760/m^2$	1.30 g	0.50 g
6B	680	1.32	0.48
9A	600	1.17	0.36
10A	490	1.42	0.61

CHAPTER V

RESULTS AND DISCUSSION

Adaptation and Calibration of the Models

The two models required some software as well as varietal adaptation. In addition, some parts of the models were modified or expanded and these changes are discussed as follows.

PNUTMOD

The 1981 article by Ingram et al. presented all the theory and equations that comprise PNUTMOD. Using the article as a guide, a BASIC program was written to incorporate the workings of PNUTMOD (Appendix D). Input data consisting of calendar day, average dry bulb temperature, and solar radiation were stored in a weather file constructed from the weather station data. The seven varietal constants were input from the keyboard during the calibration phase and made constants during simulation. Output from the program was directed to the computer screen and to output files containing vegetative and pod masses versus calendar day. The output files could then be plotted against the field data to determine the accuracy of the simulation.

The four study sites from which data were collected were planted with the same peanut cultivar (Spanco) and made use of common temperature and radiation data. Management of the four sites was assumed to be adequate with fertility and weeds not limiting growth. Although disease may have had some effect on the growth of the peanuts, it is difficult to quantify disease damage. Thus the differences in growth at the four sites were assumed to be primarily due to soil moisture and planting date.

To improve PNUTMOD and develop a more general model, it was decided to incorporate a soil moisture function. This would hopefully allow PNUTMOD to better simulate the differences in growth at the four test sites. The assumption was made that a soil moisture deficit would limit the amount of daily assimilate. Thus, as moisture stress increased, the ability to form assimilate would decrease. A soil moisture factor (KA) was added to equation 2 in PNUTMOD:

$$DAS = (RAD_i)(PNE)(GC_i)(KA_i) \tag{15}$$

The factor KA was selected from Jensen (1971) as:

$$KA_i = \ln(AW_i + 1)/\ln(101)$$

where AW_i is the percent available water ($0 \le AW \le 100$) on day i. This factor has been used to adjust estimates of evapotranspiration when soil moisture is limiting. The reduction of DAS due to soil moisture stress has the effect of reducing vegetative mass throughout the season and reducing pod mass during fill.

The available water for each site was calculated using the neutron probe data and the estimates of field capacity and wilting point described in Chapter IV. The total water in the soil was assumed to change linearly between measurement days.

One safeguard incorporated into the model concerns the termination of pod set. In equation 6, the terms PCF and PART are constants and

$DPDM_i$ is a steadily increasing term during pod set. The term DAS_i is a function of RAD_i. An abnormally low radiation day (e.g., 50% of the average) can produce a PL value greater than 1.0 early in the pod set phase, which results in an abnormally short season. In simulations done with actual radiation data, values of RAD below 12 MJ/m^2 were seen to terminate pod set prematurely. To counteract this, the PL computation is skipped when RAD falls below 12 MJ/m^2. In addition, instead of using the DAS as calculated from equation 15, it was decided to use the maximum amount of DAS potentially available. Thus, in equation 6, DAS_i is replaced by $DASMAX_i$ which is RAD_i times PNE. This eliminates a termination of pod set due to a low KA factor.

A program called PNTAUTO was written to iteratively test combinations of model parameters. PNTAUTO was run with input data for sites 4A and 9A. These sites were used because they received the most and least irrigation water of the study sites and were nearly disease free. The optimum parameters for these two sites were found using a least squares criterion for both vegetation and pods. The optimum parameters for the two sites were compared and found to be similar. The range on each parameter was used to select values for further testing. The parameters were adjusted until a compromise "best fit" was obtained for both sites. The following parameters were found to best simulate the field data:

DUE = 640 °C

PNE = 0.92 g/MJ

P = 3.5

PCF = 0.62

PSF = 0.0196 g/m^2 °C

PART = 0.96

PWF = 1.85

These parameter values were then used in a simulation run of site 6B. The result was a very good fit of the field data, especially for the pod mass. The simulation of site 10A also resulted in a very good fit of the data. Figures 1 through 4 are the growth curves obtained for the four sites along with the field data. The pod growth curves fit the field data very well on all four sites. Because the pods provide the economic return, it is more important for a model to simulate pod growth well. The vegetative growth curves however were only crude approximations of the field data. From these plots and analysis of the governing equations, it can be seen that vegetative mass can decrease during pod set only and that during pod fill the vegetative mass slowly but steadily increases.

Young's Model

The model of Young and associates is a FORTRAN program composed of 11 subroutines. The model was acquired from Dr. Young in November of 1985 at which time two days were spent reviewing the model's main functions and input parameters. The program is quite complex and required modification to be run on the IBM PC. A FORTRAN compiler was used to compile and link the subroutine text files so that the program could be run on a microcomputer.

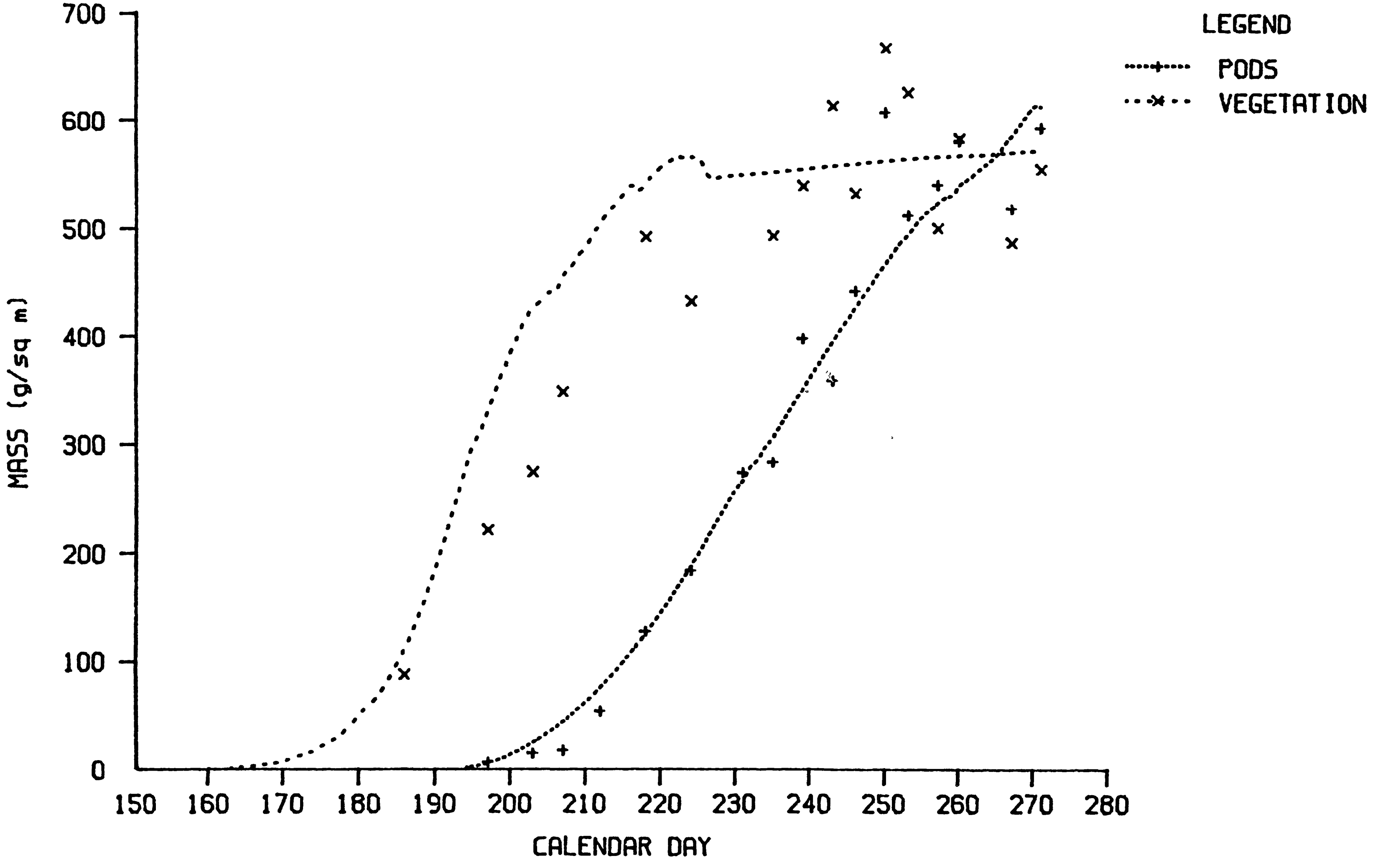

Figure 1. PNUTMOD Simulation of Site 4A

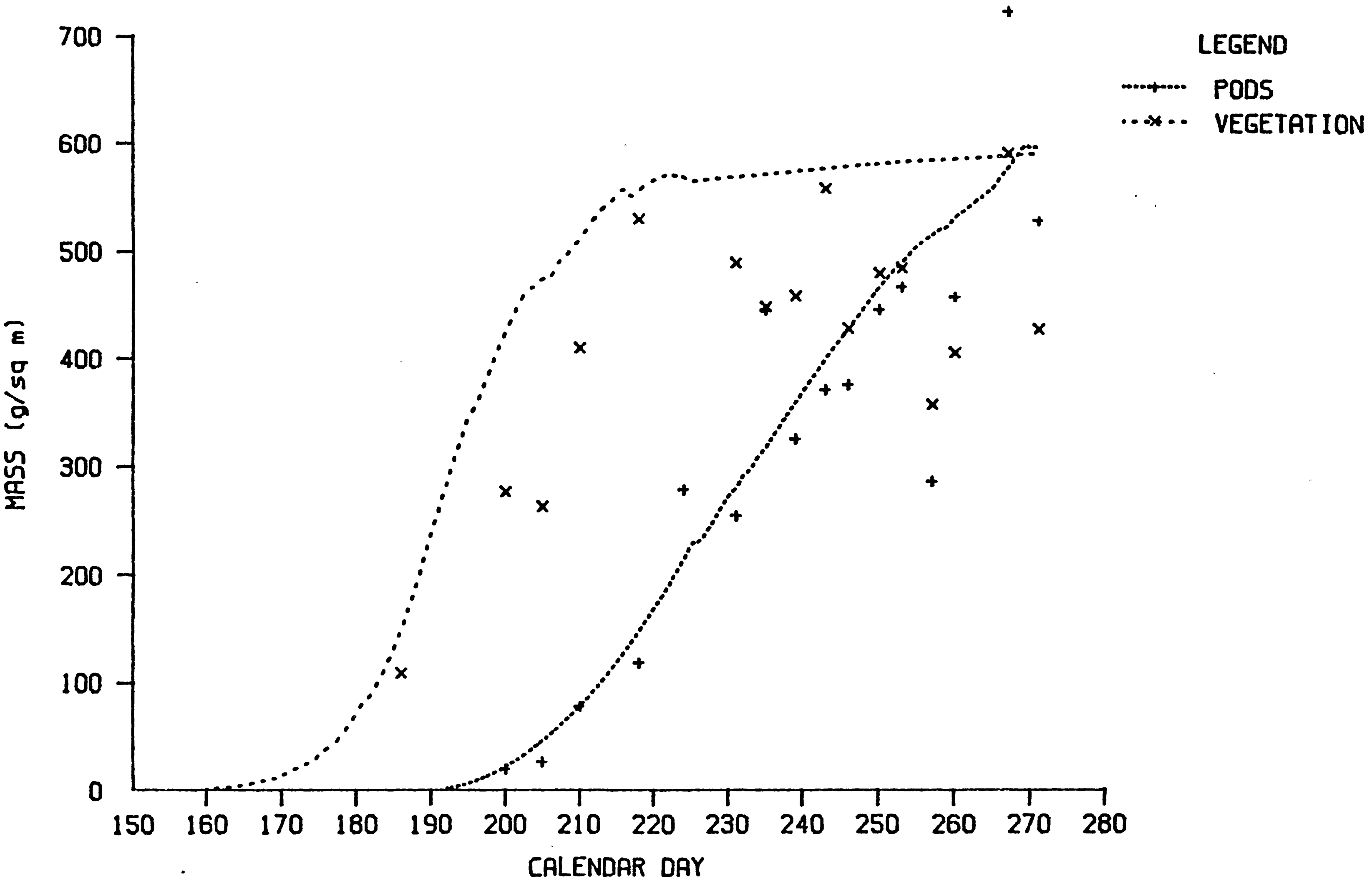

Figure 2. PNUTMOD Simulation of Site 6B

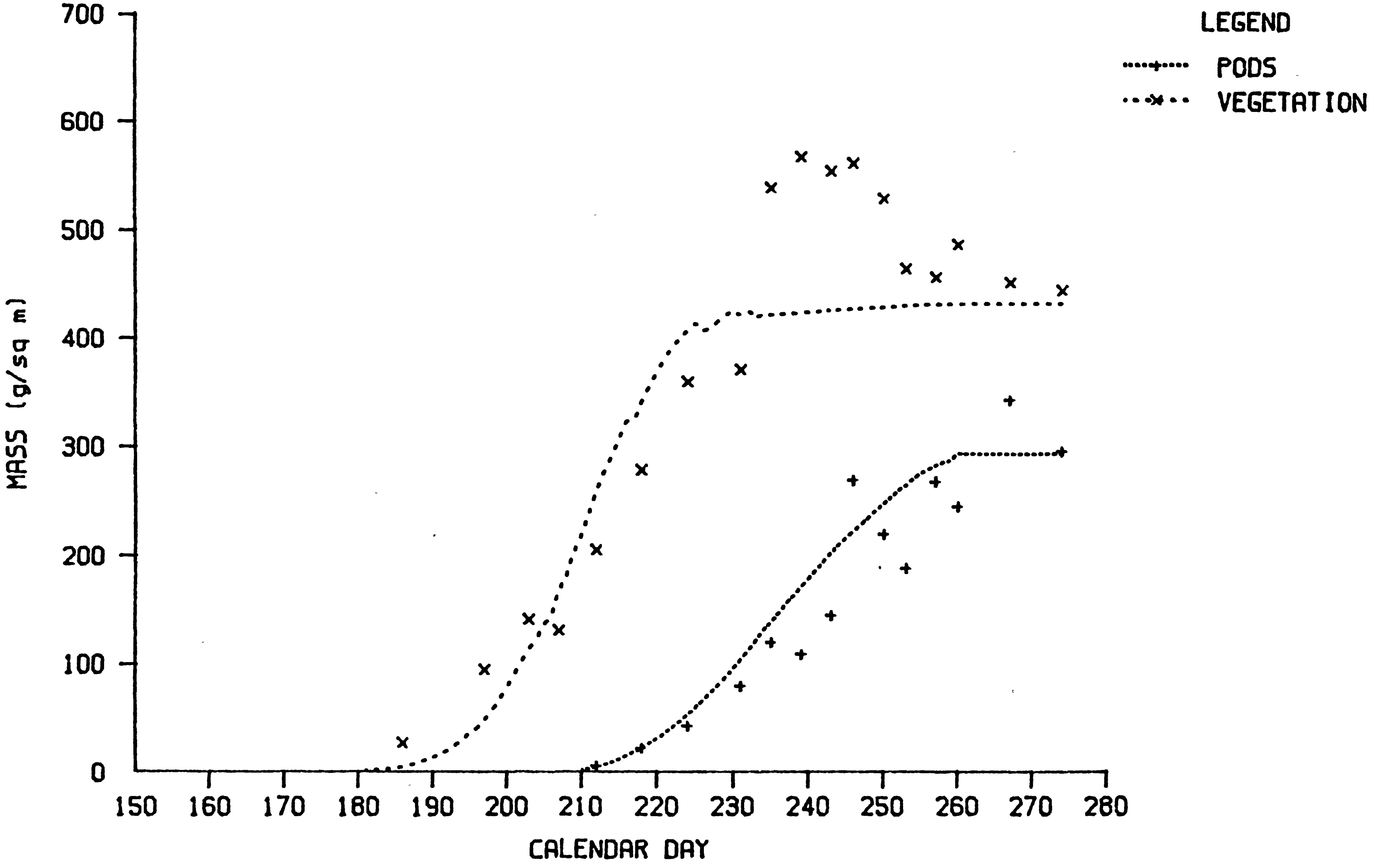

Figure 3. PNUTMOD Simulation of Site 9A

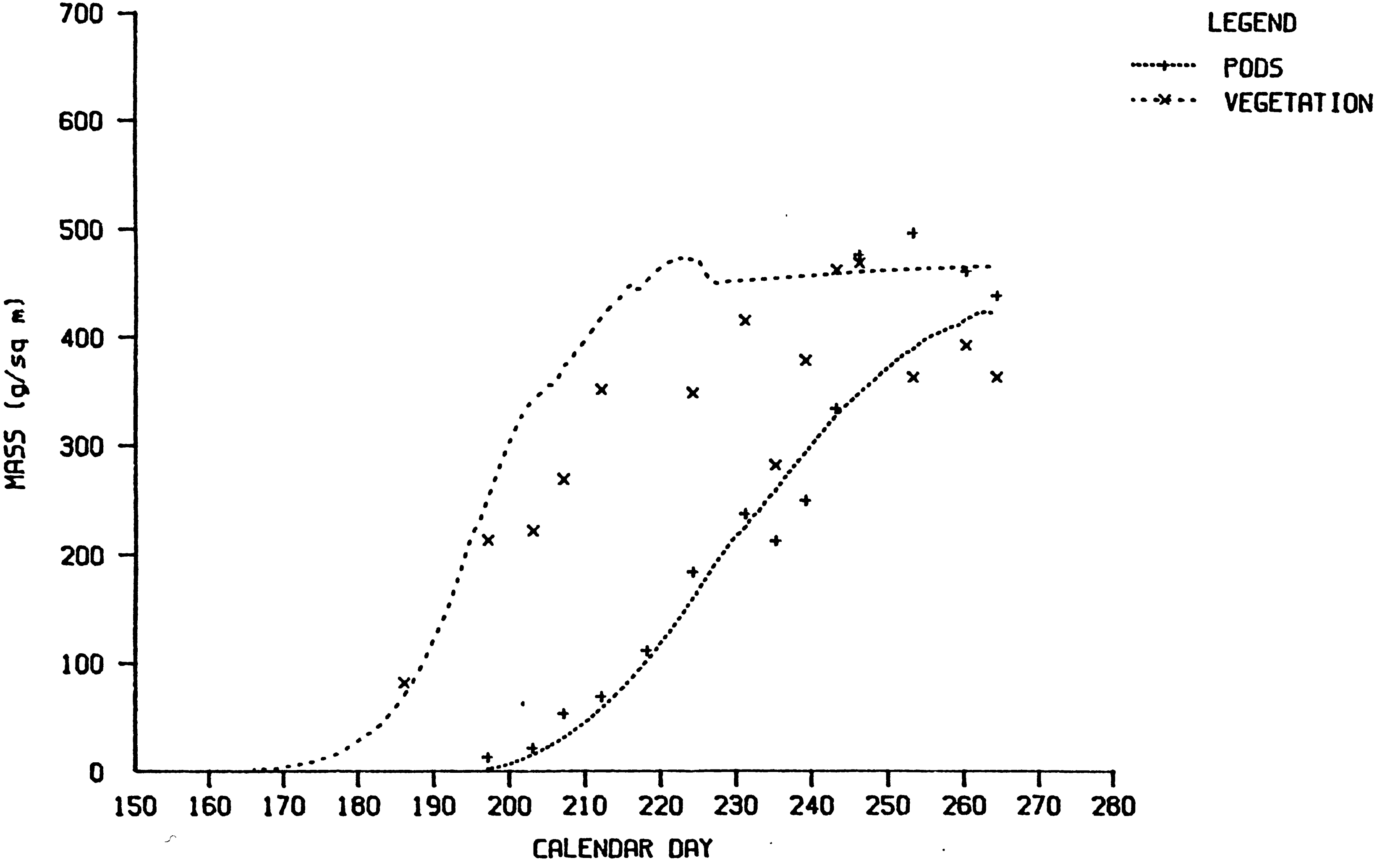

Figure 4. PNUTMOD Simulation of Site 10A

The subroutines in Young's model are listed below with a description of their functions:

MAIN - opens input and output files, reads input files, and puts input data into arrays.

PENUT - controls the majority of plant growth including emergence and photosynthate production, and calls the supporting subroutines.

WUPTAK - calculates root growth factors and redistributes soil moisture.

PET - calculates surface evaporation and potential plant transpiration.

SOILS - reads soil input data and calculates field capacity and wilting point for each soil layer.

STORAG - regulates removal of photosynthate from pool.

ROOTGR - allocates photosynthate available for root growth.

EVAPDIST - allocates bare soil evaporation to different soil layers.

PODMAS - computes daily increase in pod mass, matures pods, and determines harvestable mass.

PEGMAS - computes daily peg growth, matures pegs, and "kills" old pegs.

PEGSTR - determines strength of pegs and probable losses due to weakening.

Changes were made to some of the subroutines for various reasons. Some changes were made to streamline model output to that usable for this study while others were to correct inherent assumptions that differed from conditions used in this study.

In subroutine MAIN, the output files were deleted and replaced with the following: TOPMASS, a file of vegetative mass and calendar day; PODMASS, a file of pod mass and calendar day; and CON, screen output. An option that attempted to model disease loss was eliminated because of a lack of data necessary for its execution. The original program called for two weather files, one containing calendar day, maximum temperature, minimum temperature, and daily solar radiation and the other calendar day, average daily relative humidity, average wind speed, rainfall and irrigation. The weather data were consolidated into one file containing all of the above except rainfall and irrigation, which were not differentiated but rather combined into one value.

In subroutine WUPTAK, the equation for predicting which soil layer the roots had reached was originally written with the inherent assumption that soil layers were 2.5 cm thick. Because this study used soil layers of 15 cm, the equation was changed and made general so that any size soil layer could be used.

Subroutine SOILS was extensively altered. The original version contained equations for predicting the coefficients A and B of the water retention curve for each soil layer. These equations were calibrated for a certain North Carolina location and were judged unsatisfactory for describing the soils at the test sites. Also included was a provision for the influence of a water table. Caddo County is normally dry during the summer and has few locations with a water table near the surface. Therefore, this provision was elimination. To provide the soils information to the model, the coefficients A and B were made inputs and read by subroutine SOILS for use in the program. The coefficients A and B were estimated using the values of field capacity and wilting point presented in Chapter IV and are tabulated in Appendix F.

Subroutine ROOTGR also contained the inherent assumption that soil layers were 2.5 cm thick. The subroutine was slightly altered and made general so that vertical root growth ends when the bottom of the deepest soil layer is reached.

A listing of the subroutines as used in this study is provided in Appendix E.

While examining the parameter values developed in North Carolina, some observations were made. The first concerned the parameters P(40) and P(42) in the following equation:

$$P16=P(16)+P(40)(T_{AV})+P(42)(T_{AV}^{2}) \qquad (17)$$

where P(16) is the potential pod fill rate (g/pod) and P(16), P(40), and P(42) are coefficients of the quadratic equation of T_{AV} that dictate the shape of the fill rate versus T_{AV} curve. Because P(40) and P(42) are coefficients of T_{AV} and T_{AV} squared, the magnitude of the numbers was very small. In order to increase their magnitude, T_{AV} was scaled by 301.5 K, the temperature that maximizes the pod fill rate equation. This resulted in P(16), P(40), and P(42) being of the same magnitude. The second observation was that many of the parameter values had greater than four significant digits. Due to the empirical nature of the model, it was decided to reduce all parameters to three significant digits where this did not greatly alter any function of the parameters. These changes had a negligible effect on the model output.

To begin the calibration process, the P parameters were examined to identify those that would possibly need to be altered for the

Oklahoma crop and for which information was available for making changes. In Oklahoma, the spanish type peanut is primarily grown. In North Carolina, where Young's model was formulated, the virginia type peanut is primarily grown. One major difference between the two types is that spanish peanuts have more pods of smaller size. Noting this difference the model was examined for those parameters that would make significant differences if changed. Six growth parameters were so identified: P(10), the parameter that adjusts CFIX, the daily photosynthate available from photosynthesis; P(16), P(40), P(42), coefficients of the quadratic equation for determining the pod fill rate; P(19), the ratio of pod mature weight to pod weight 28 days after initiation; and P(39), the minimum pod mass considered harvestable. In addition to these, five other growth parameters were found to be potentially different for the spanish type peanut. These included P(1), the emergence constant; P(13), the maximum fraction of photosynthate deficiency that can be supplied from storage; P(17), the photosynthate needed to trigger a pod; P(28), the threshold growth rate for flowering; and P(29), a constant in the equation to determine the number of flowers set.

From the results of the analysis of final harvest samples, it was decided to use a value for P(39) of 0.50 grams. Also from that analysis, it was observed that the spanish peanut pod at maturity had a mass approximately half that of a virginia type peanut pod. Because the length of the pod maturation phase of peanut growth is about the same for both types, it was decided to try maximum pod fill rates near half of that used in the original model.

The model was run with the described modifications and all other growth and soil water parameters the same as those used in North

Carolina. Model output was observed and the identified parameters adjusted so that the simulations better modeled the field data. Factors used to determine how well the simulation was performing were emergence date, least squares differences for both vegetation and pod mass, general shape of vegetation and pod growth curves, final pod and vegetative masses, beginning of pod set, total pod number, and maximum pod mass.

Parameter P(1) was adjusted until the model predicted the actual emergence dates for the four study sites. The parameter P(10) was adjusted for each run so that the total biomass production was similar to the field data. P(28) was decreased until the early pod mass predictions were similar to the field data. The maximum pod fill rate was found to lie between 0.02 and 0.03 g/pod per day. P(17) was found to lie between approximately 0.5 and 1.0 g/m^2 per pod. Combinations of maximum pod fill rate and P(17) were tested and the output compared. It was found that lower fill rates and higher P(17) values produced good approximations to the pod and vegetative growth data obtained from the plant samples. From the results of this analysis on sites 4A, 6B, and 9A it was concluded that the maximum pod fill rate should be 0.023 g/pod per day (because fill rate is assumed to be zero at 283 K, P(16)= -6.0859, P(40)=12.2178, P(42)=-6.1089), and that P(17) should be 0.9 g/m^2 per pod. Once these values were set, P(10) and P(19) were found to have values of 0.40 and 2.1, respectively. These values produced simulations that had total biomass and maximum pod mass near that of the field data. Parameters P(13) and P(29) were not changed because of a lack of information for making any change in their values. Due to a lack of information for making appropriate changes, most of the P parameters were assumed to be the same as those used in North Carolina (except for the reduction in significant digits). However this assumption is not unrealistic because functions such as temperature factor, shade factor, peg growth rate, peg decay, etc., do not differ greatly among peanut cultivars.

Table VIII is a listing of the 65 parameters for Oklahoma. Figures 5 through 8 are the growth curves obtained from the model using these parameter values. The pod growth curves fit the pod data fairly well. Pod mass increase during the last days of the season was in general underpredicted by the model. The vegetative growth simulation was very good for sites 6B and 9A but less so for sites 4A and 10A.

Simulation of Different Irrigation Schemes and Planting Dates

PNUTMOD

The model was run with different assumed available water contents throughout the season to explore the model's response to water deficit. Five different available water conditions were used on two different emergence dates. The moisture conditions used were:

1. 100% available water (% AW) throughout the season.
2. Weekly cycle of 100% AW declining to 50% AW.
3. 50% AW throughout the season.
4. 25% AW throughout the season.
5. 10% AW throughout the season.

Figures 9 and 10 show the effects of the different moisture levels on pod and vegetative growth for an emergence date of May 31 (CD 151). Figures 11 and 12 show the effects for an emergence date of June 18, (CD 169). The weather data from 1985 were used in the simulations. For

TABLE VIII

PARAMETERS OF YOUNG'S MODEL CALIBRATED FOR OKLAHOMA

P(1) = 4.5   P(2) = 0.4   P(3) = 301.5   P(4) = 11.4
P(5) = 0.0112   P(6) = 2.0   P(7) = 0.1   P(8) = 206.0
P(9) = 812.0   P(10) = 0.40   P(11) = 12.0   P(12) = 0.0217
P(13) = 0.22   P(14) = 0.00753   P(15) = 11.1   P(16) = -6.0859
P(17) = 0.90   P(18) = 2.3   P(19) = 2.1   P(20) = 0.0
P(21) = 0.00553   P(22) = 1.44   P(23) = 0.0363   P(24) = 18.0
P(25) = 0.300   P(26) = 15.0   P(27) = 1.7   P(28) = 0.10
P(29) = 6.0   P(30) = 11.67   P(31) = 0.197   P(32) = 0.555
P(33) = -0.00438   P(34) = 0.00263   P(35) = 293.5   P(36) = 42.49
P(37) = 0.0   P(38) = 0.0   P(39) = 0.5   P(40) = 12.2178
P(41) = 0.0286   P(42) = -6.1089   P(43) = 870.0   P(44) = 0.00006
P(45) = 1.86   P(46) = 0.027   P(47) = 0.082   P(48) = 0.0
P(49) = 3.63   P(50) = 0.0   P(51) = 38.6   P(52) = 0.0
P(53) = 15.0   P(54) = 8.0   P(55) = 6.50   P(56) = 25.0
P(57) = 0.431   P(58) = -0.0321   P(59) = 1.0   P(60) = -1.10
P(61) = 10.00   P(62) = 0.80   P(63) = 1.0   P(64) = 0.0
P(65) = 0.0

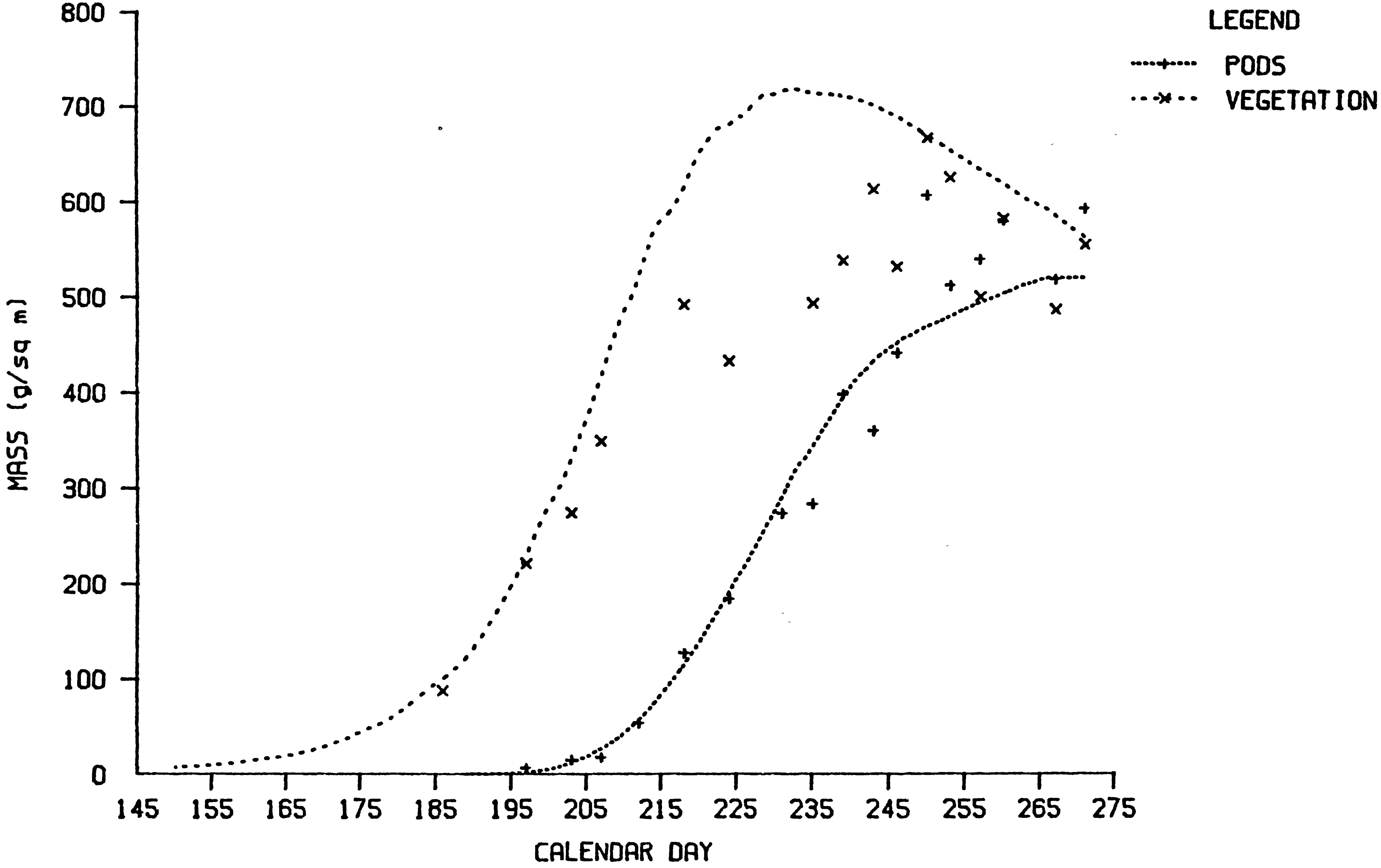

Figure 5. Young's Model Simulation of Site 4A

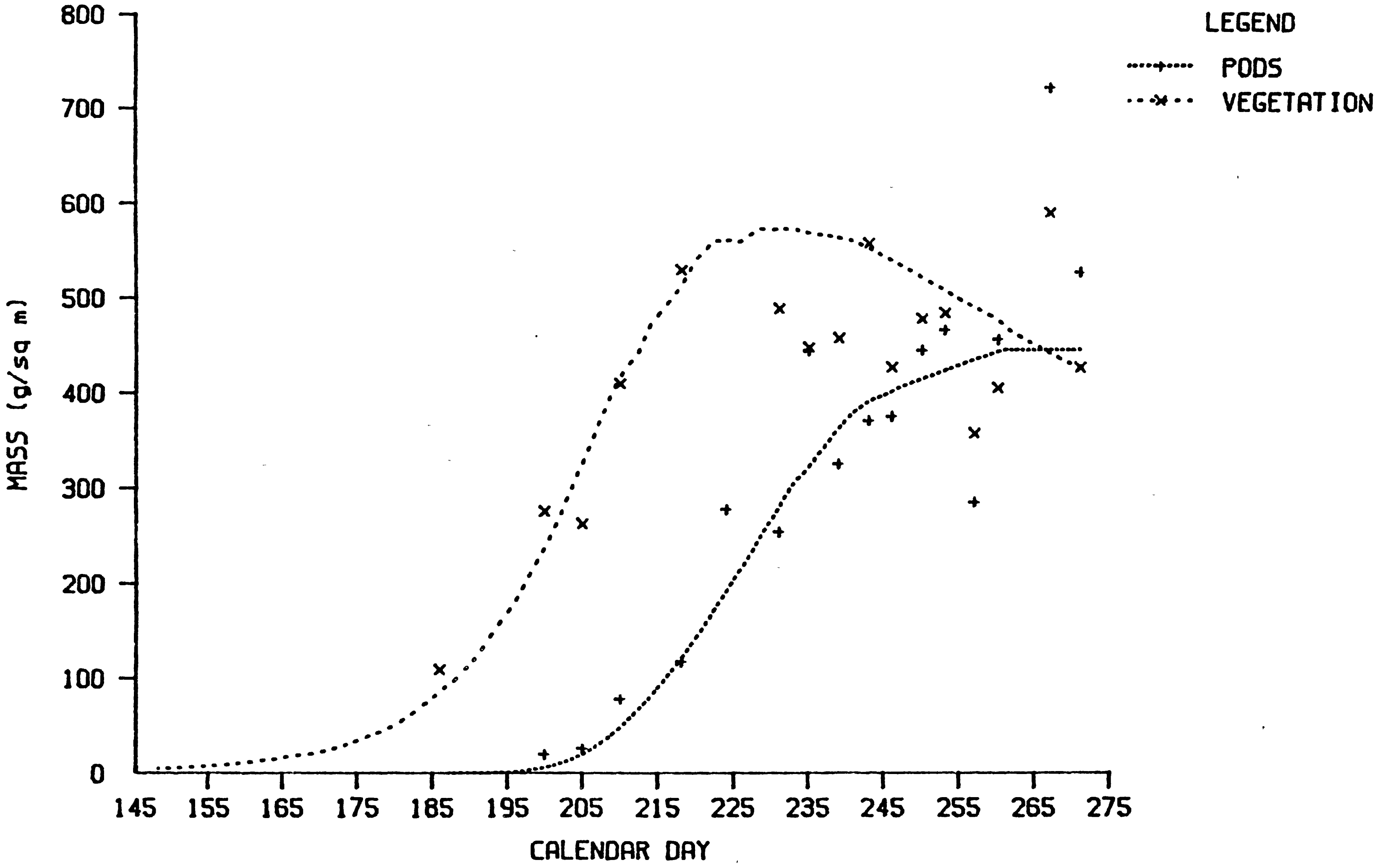

Figure 6. Young's Model Simulation of Site 6B

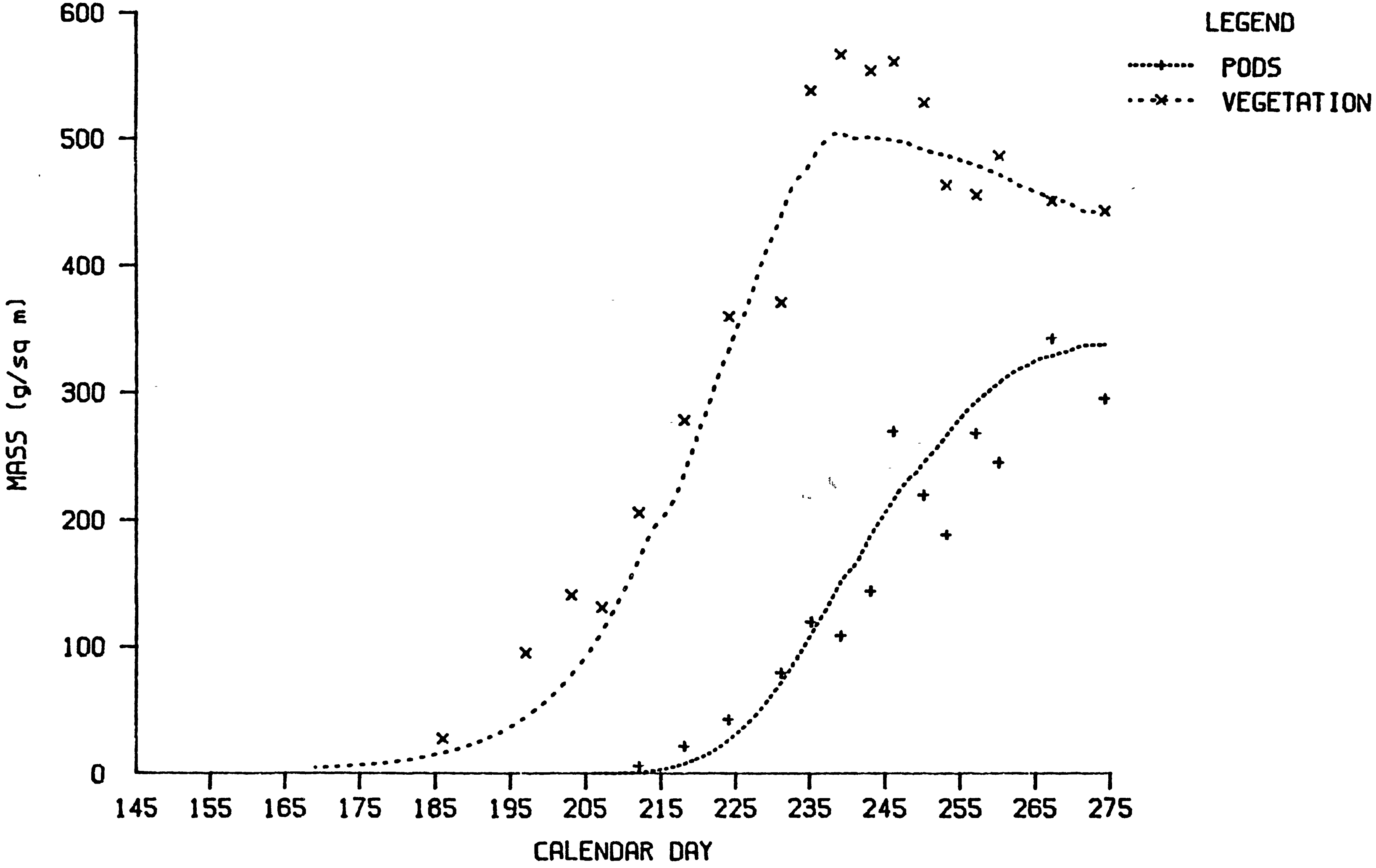

Figure 7. Young's Model Simulation of Site 9A

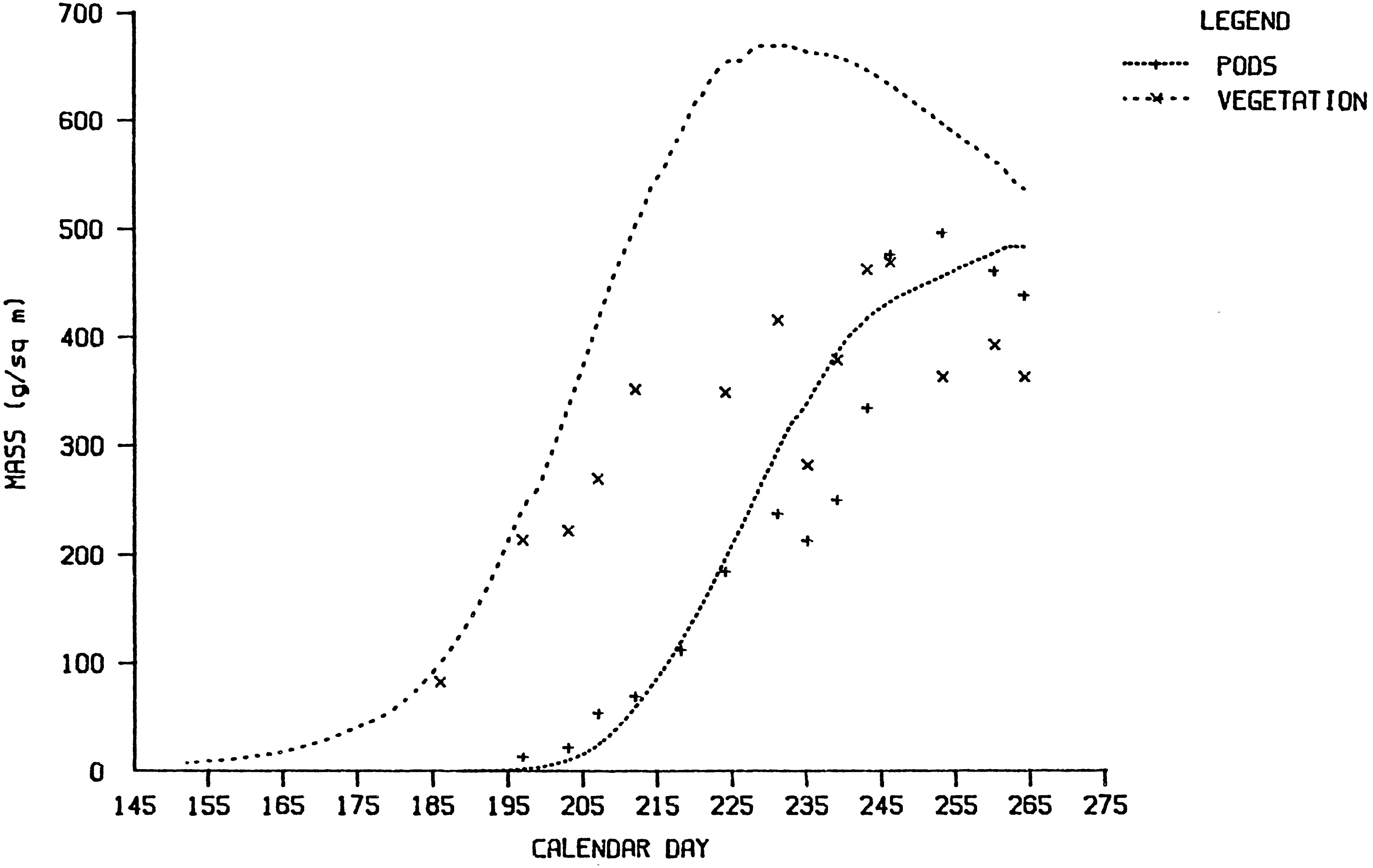

Figure 8. Young's Model Simulation of Site 10A

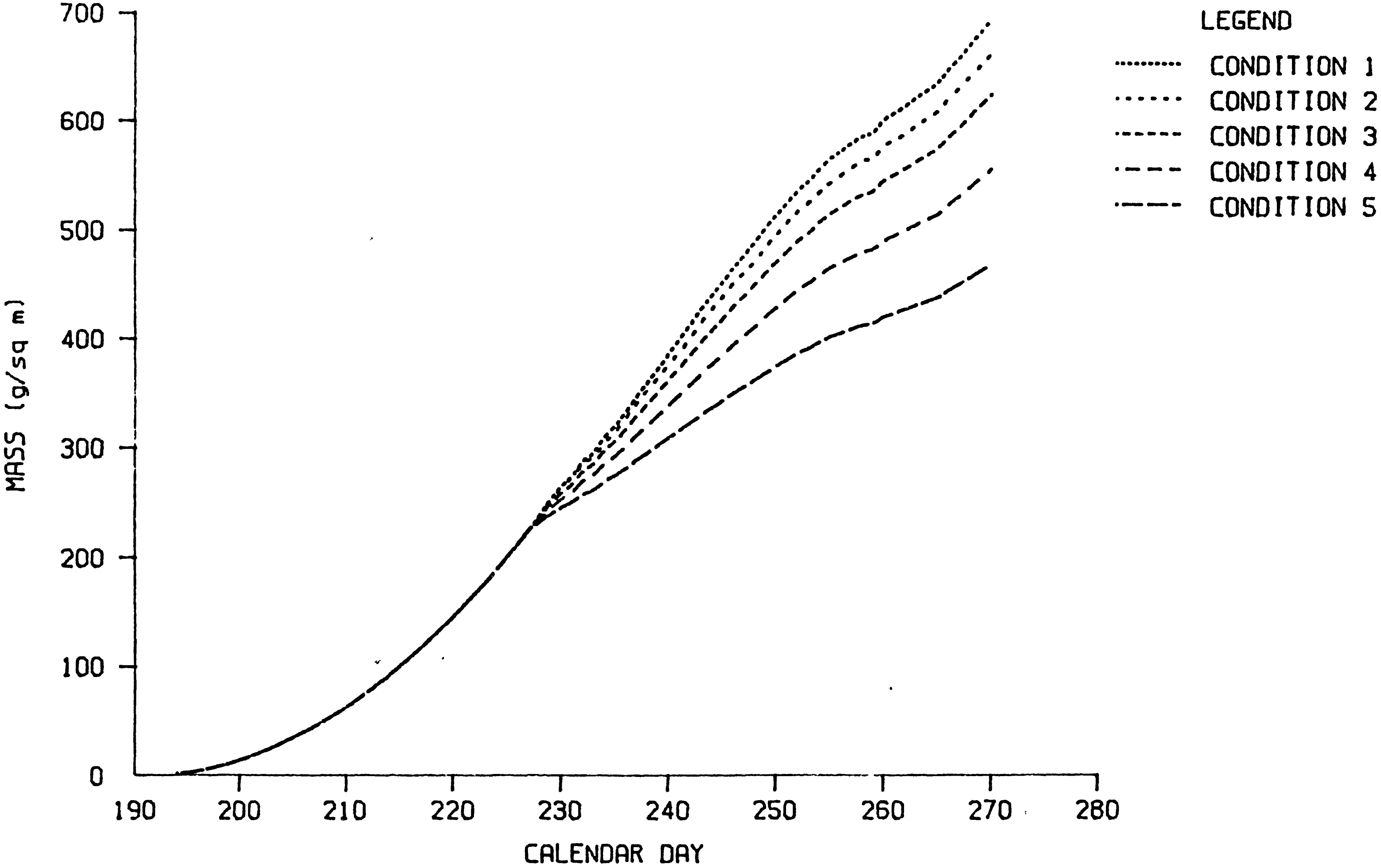

Figure 9. Available Water Effect on Pod Yield using PNUTMOD: Emergence Day 151

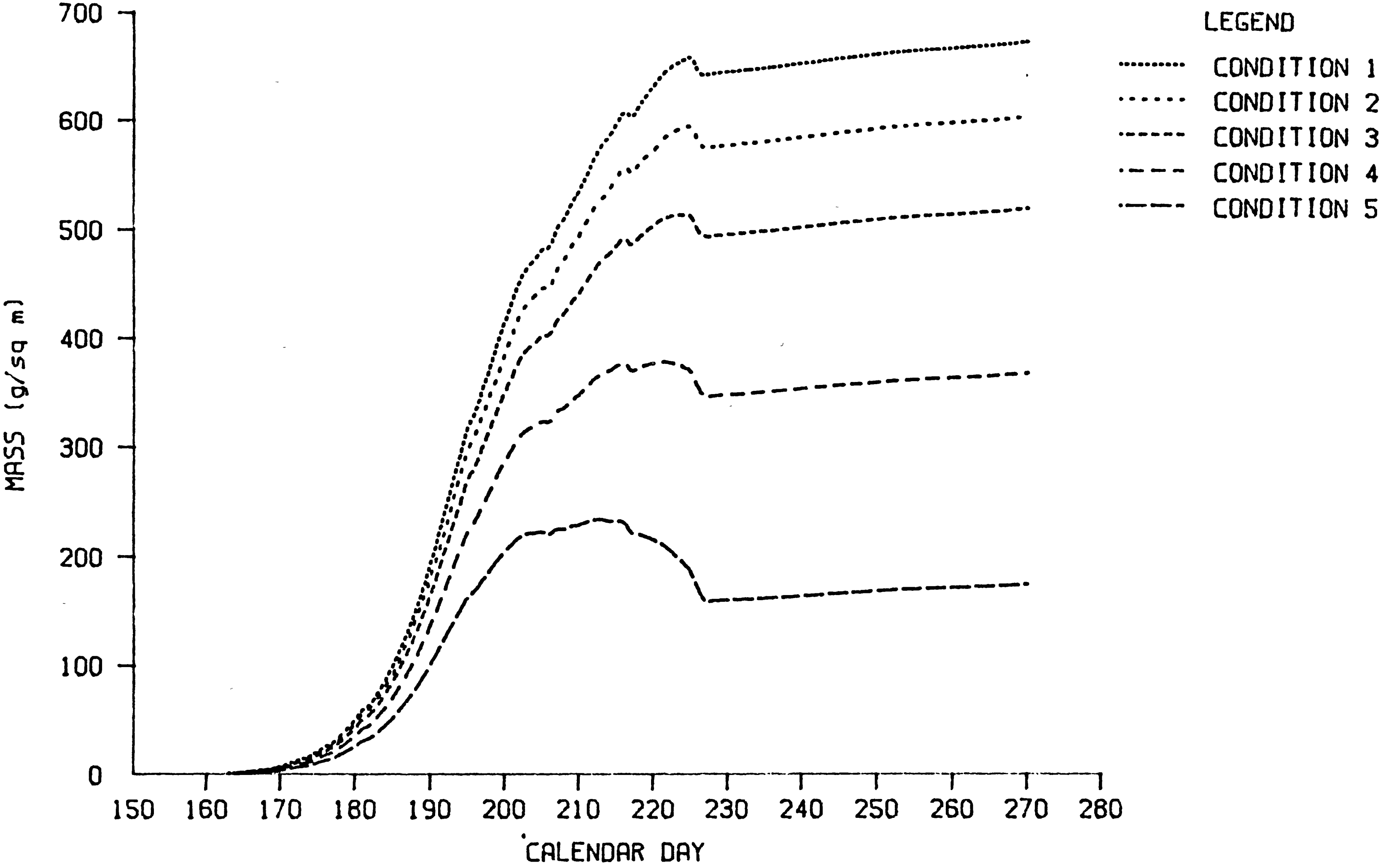

Figure 10. Available Water Effect on Vegetative Growth using PNUTMOD: Emergence Day 151

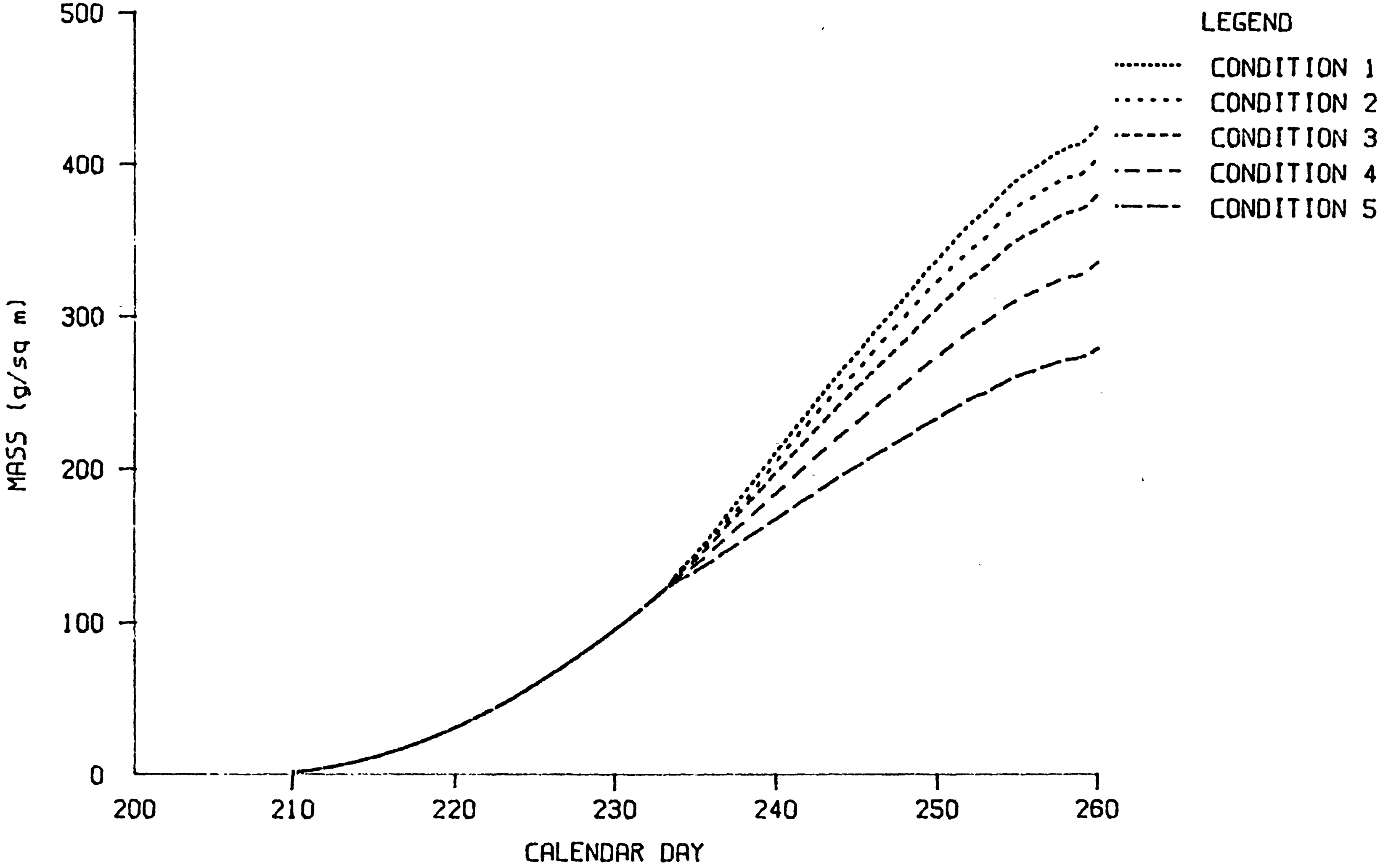

Figure 11. Available Water Effect on Pod Yield using PNUTMOD: Emergence Day 169

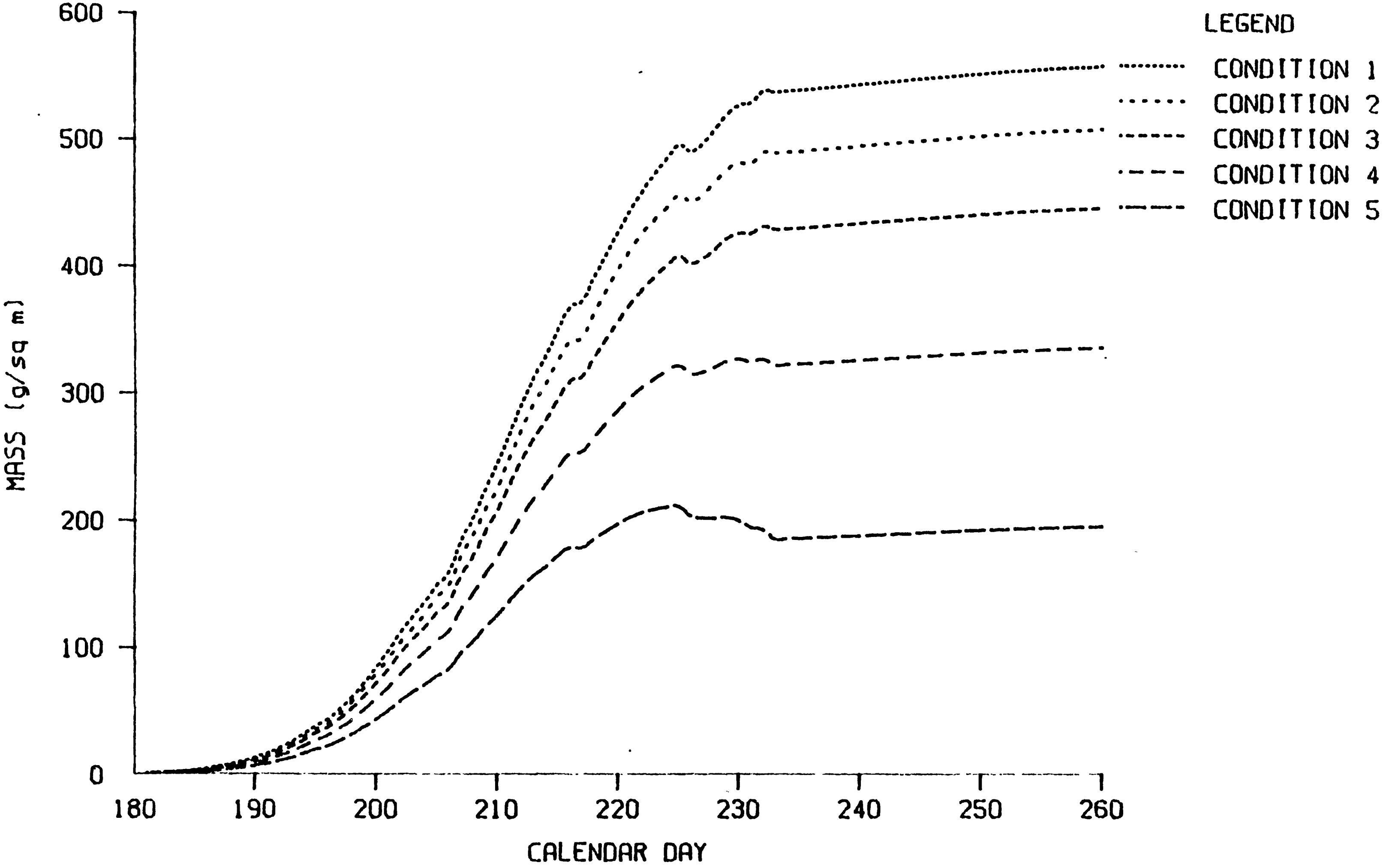

Figure 12. Available Water Effect on Vegetative Growth using PNUTMOD: Emergence Day 169

both emergence dates the effect of lower available water is a great reduction in vegetative growth and a moderate decrease in pod mass after pod set. Simulations using the 1984 weather data produced similar results.

Simulations were also performed to study the effect of varying the emergence date. Calendar days 140, 150, 160, 170, and 180 were selected as emergence dates and used with the 1985 weather data and 100 percent available water throughout the season. Figures 13 and 14 show the results of these simulations. Figures 15 and 16 are the results of simulations using the 1984 weather data. These figures show that PNUTMOD is still sensitive to low radiation days that produce short seasons. For 1984, emergence days 160 and 180 have short seasons while for 1985, emergence day 170 has a short season.

An inspection of Figures 9-12 reveals the two greatest shortcomings of PNUTMOD. The first is that pod mass increase during pod set is only a function of temperature and independent of the level of soil moisture. The second is that vegetative mass can decrease only during pod set despite the known phenomenon that vegetative mass decreases during pod fill. It also appears from Figures 9-12 that pod mass is largely independent of vegetative mass. This is indicated by the curves generated with only 10 percent available water. Although vegetative mass was severely reduced, pod mass was only moderately reduced.

Young's Model

Because the model contains detailed soil water interactions, it was used to simulate the effect of different irrigation scheduling criteria. The 1985 weather data was used in the simulations except that

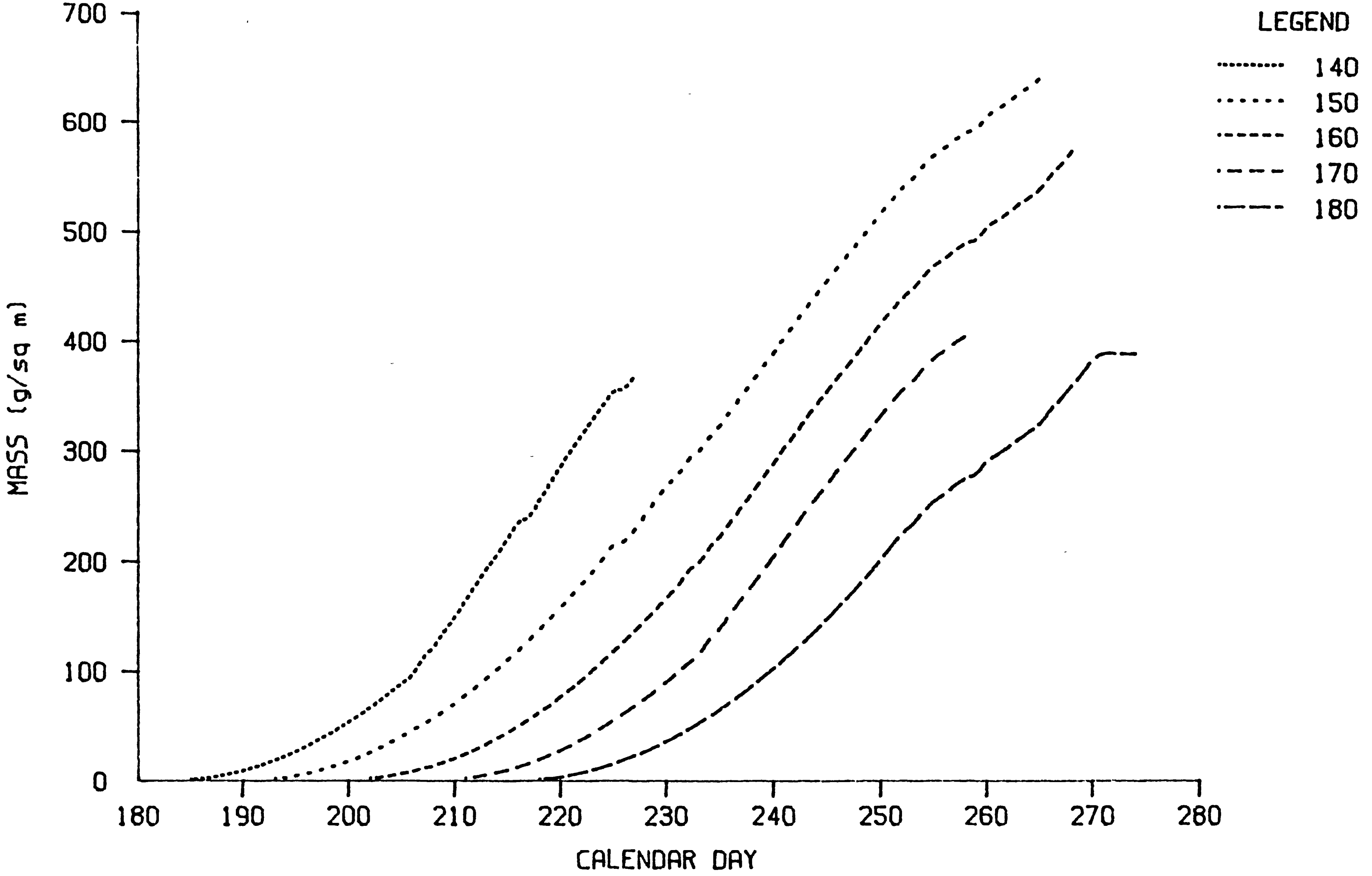

Figure 13. Effect of Emergence Date on Pod Yield using PNUTMOD

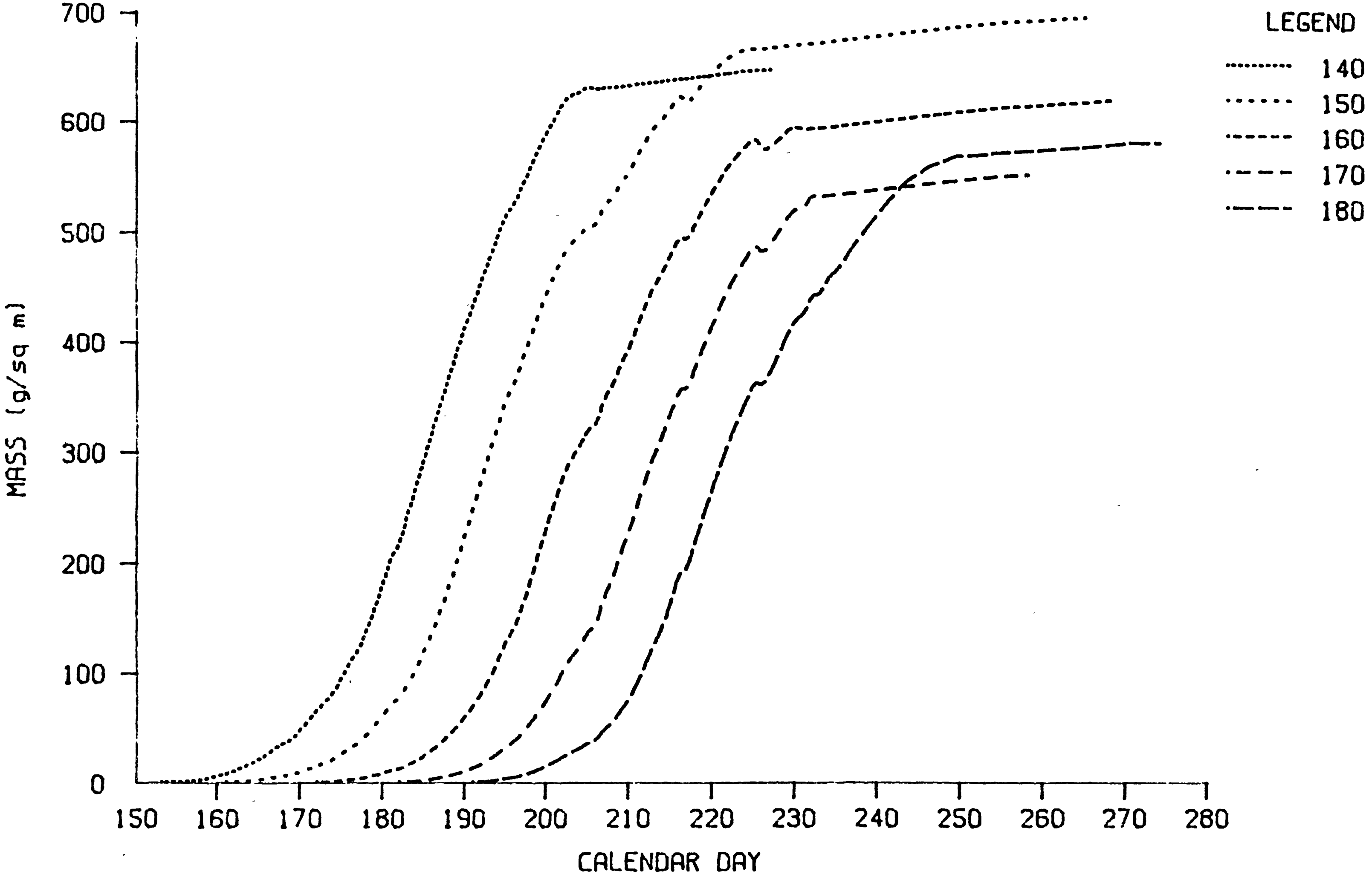

Figure 14. Effect of Emergence Date on Vegetative Growth using PNUTMOD

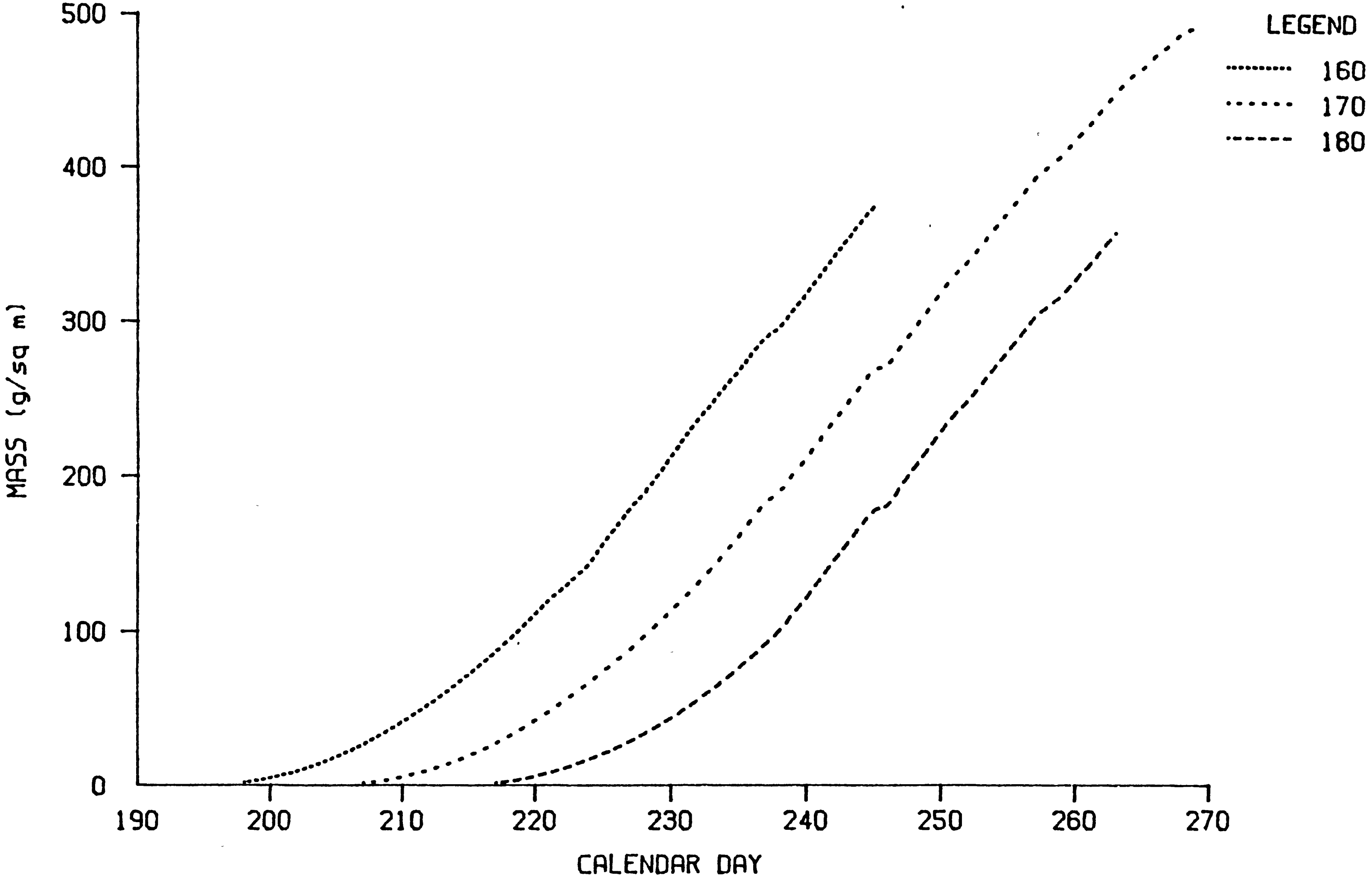

Figure 15. Effect of Emergence Date on Pod Yield using PNUTMOD (1984 Weather Data)

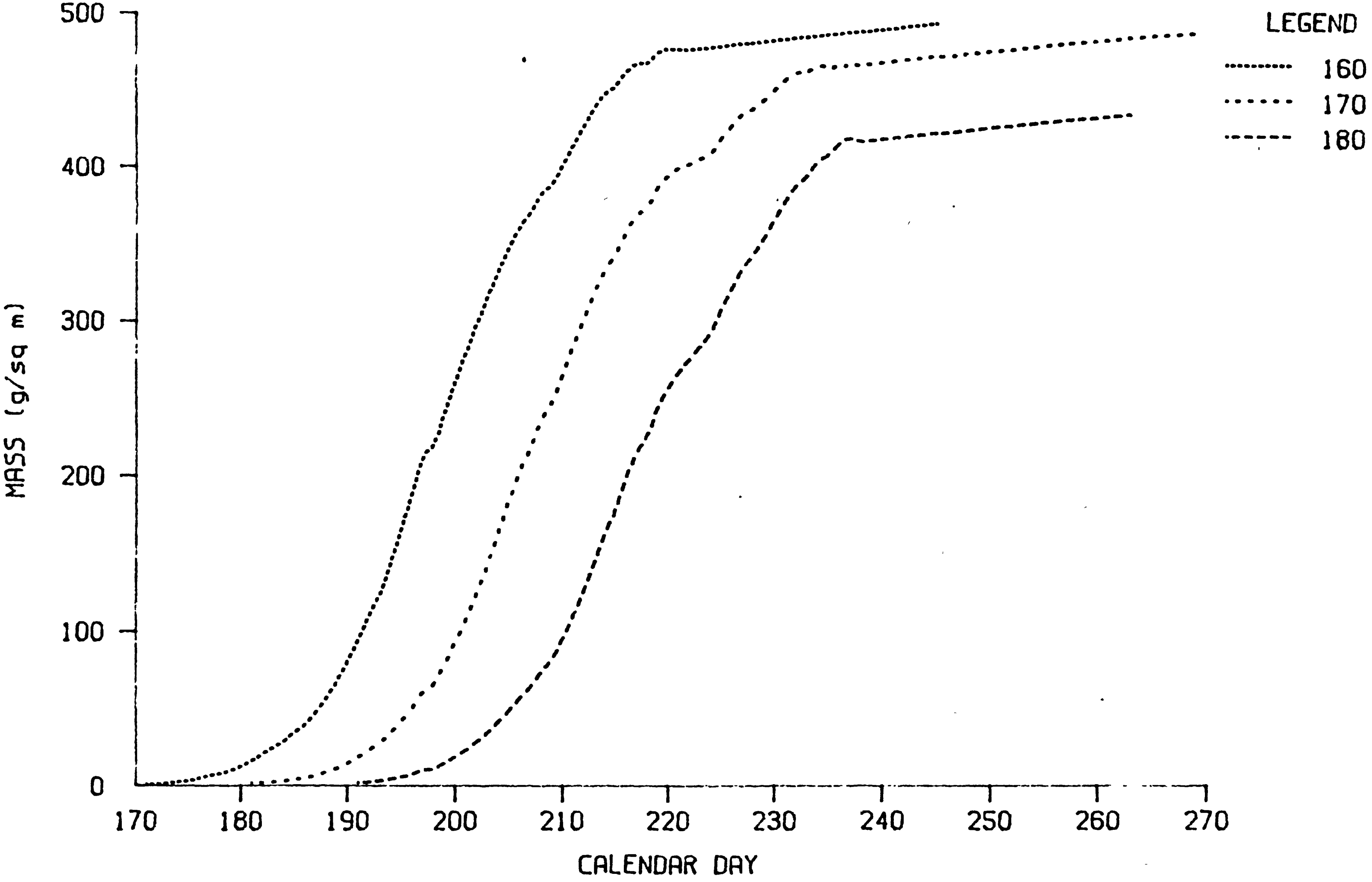

Figure 16. Effect of Emergence Date on Vegetative Growth using PNUTMOD (1984 Weather Data)

rain/irrigation was simulated through keyboard input. The irrigation treatments simulated were:

1. Refilling the root zone when it reached 50 percent available water (% AW).
2. Refilling the root zone when the soil moisture potential at a depth of 30 cm reached -0.6 bar.
3. Refilling the root zone at 50% AW during vegetative growth, -0.6 bar potential during pegging and pod formation, and -2.0 bars potential after pod addition ceased.
4. Adding half of the deficit when 30% AW was reached.
5. Applying water so that moisture was never limiting (soil moisture factor always 1.0).

Treatments 1 and 2 come from Boote (1983) and treatment 3 is the suggestion from Stansell et al. (1976). These five conditions were run with planting dates of calendar days 145 and 164. The simulation for planting day 145 used the soils, planting density, and row spacing of site 4A while planting day 164 used the inputs for site 9A. Tables IX and X give a summary of the simulation results. Figures 17 through 20 show the growth curves obtained from the five conditions for the two planting dates.

For a planting date of calendar day 145, the model showed essentially no difference between treatments 3 and 5. Treatment 3 produced the best net yield per cm of applied water. Net yield is the pod mass that is harvestable (total pod mass less immature pods and pods lost due to detachment from pegs). For a planting date of 164, there was a marked increase for treatment 5 over treatment 3. However, among the other treatments, treatment 3 gave the highest yield for the least

TABLE IX

SUMMARY OF YOUNG'S MODEL SIMULATIONS FOR FIVE IRRIGATION TREATMENTS FOR PLANTING DAY 145

Treatment Number	Applied Water cm	Pod Count #/m^2	Veg. Mass g/m^2	Pod Mass g/m^2	Net Yield kg/ha	Net Yield / Ap. Water kg/ha cm
1	45.5	660	570	500	4600	101
2	49.0	700	620	540	5060	103
3	47.2	740	620	550	5240	111
4	40.6	470	460	360	3300	81
5	59.9	720	550	550	5260	88

TABLE X

SUMMARY OF YOUNG'S MODEL SIMULATIONS FOR FIVE IRRIGATION TREATMENTS FOR PLANTING DAY 164

Treatment Number	Applied Water cm	Pod Count #/m^2	Veg. Mass g/m^2	Pod Mass g/m^2	Net Yield kg/ha	Net Yield / Ap. Water kg/ha cm
1	34.0	680	625	435	3750	110
2	39.6	600	545	405	3600	91
3	33.3	720	660	465	4010	120
4	29.0	300	300	200	1800	62
5	45.7	700	605	520	4770	104

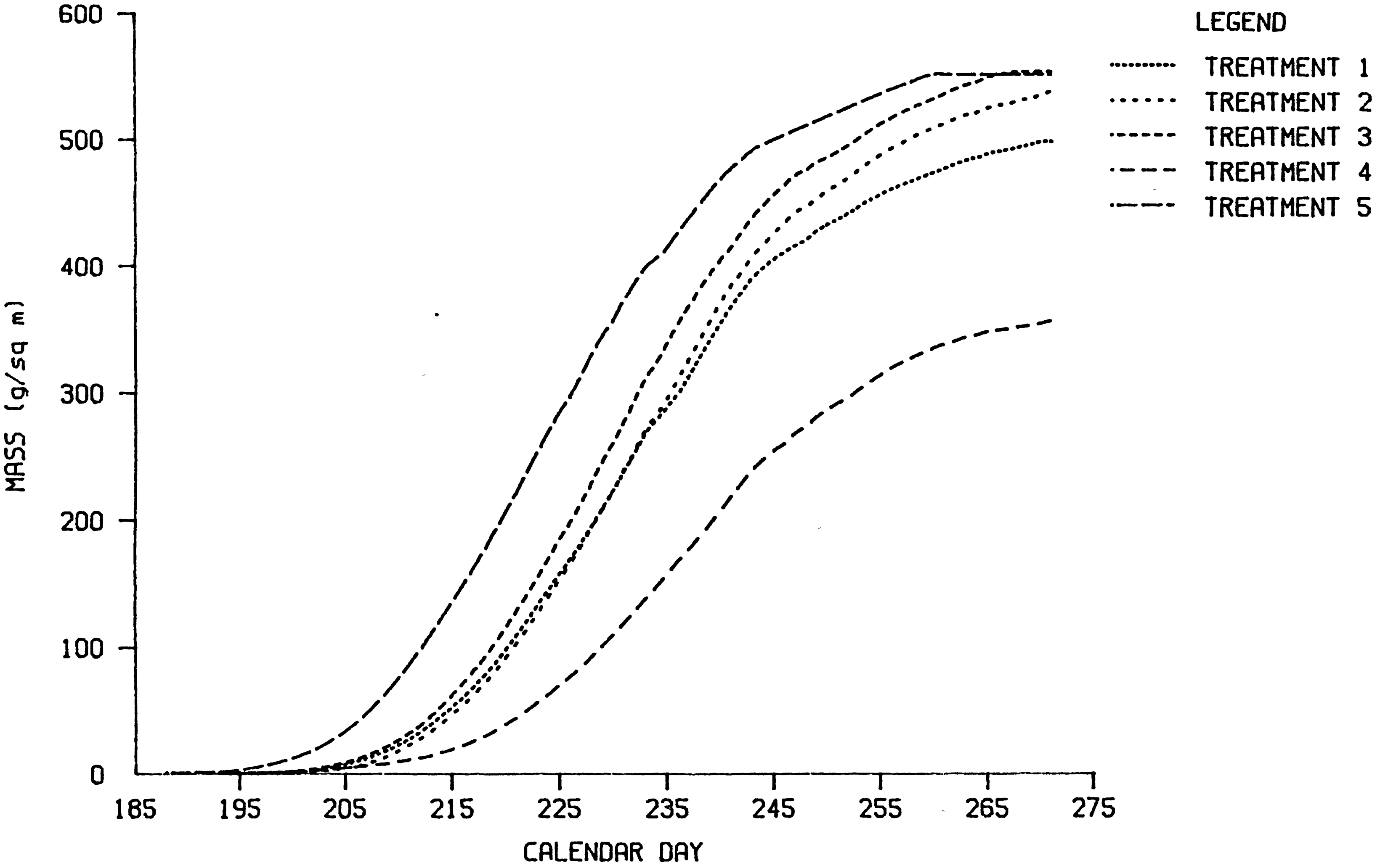

Figure 17. Irrigation Treatment Effect on Pod Yield using Young's Model: Planting Day 145

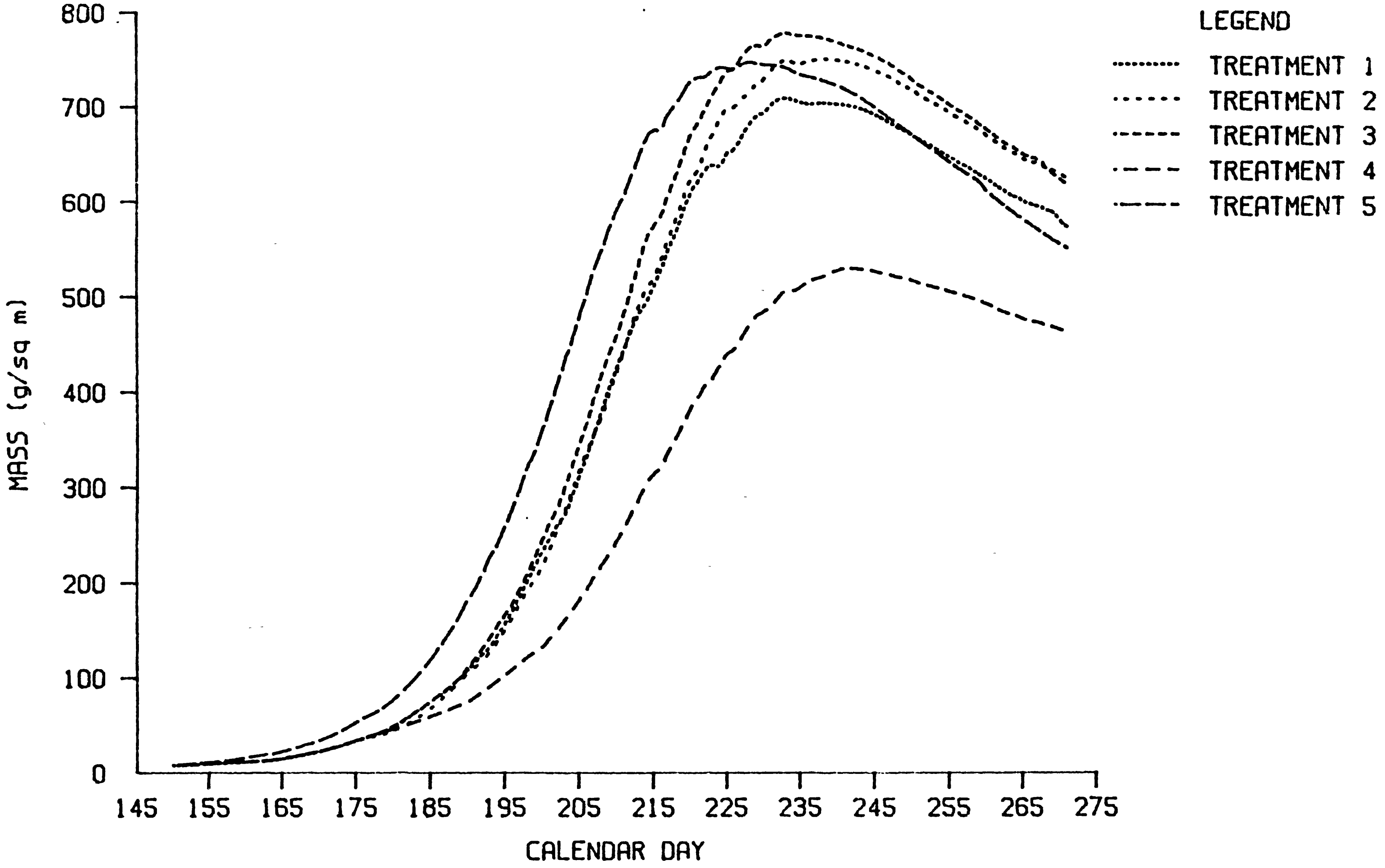

Figure 18. Irrigation Treatment Effect on Vegetative Growth using Young's Model: Planting Day 145

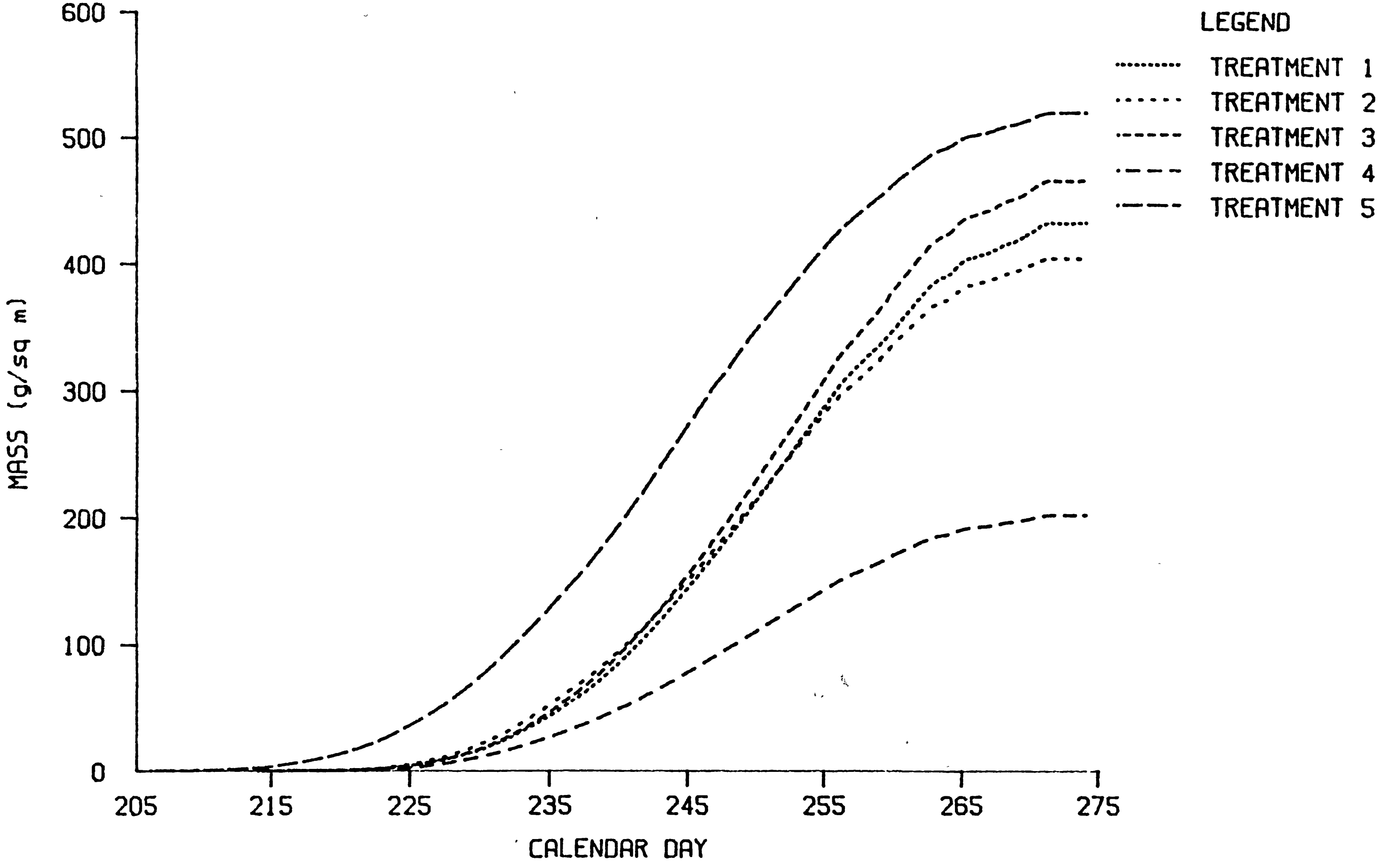

Figure 19. Irrigation Treatment Effect on Pod Yield using Young's Model: Planting Day 164

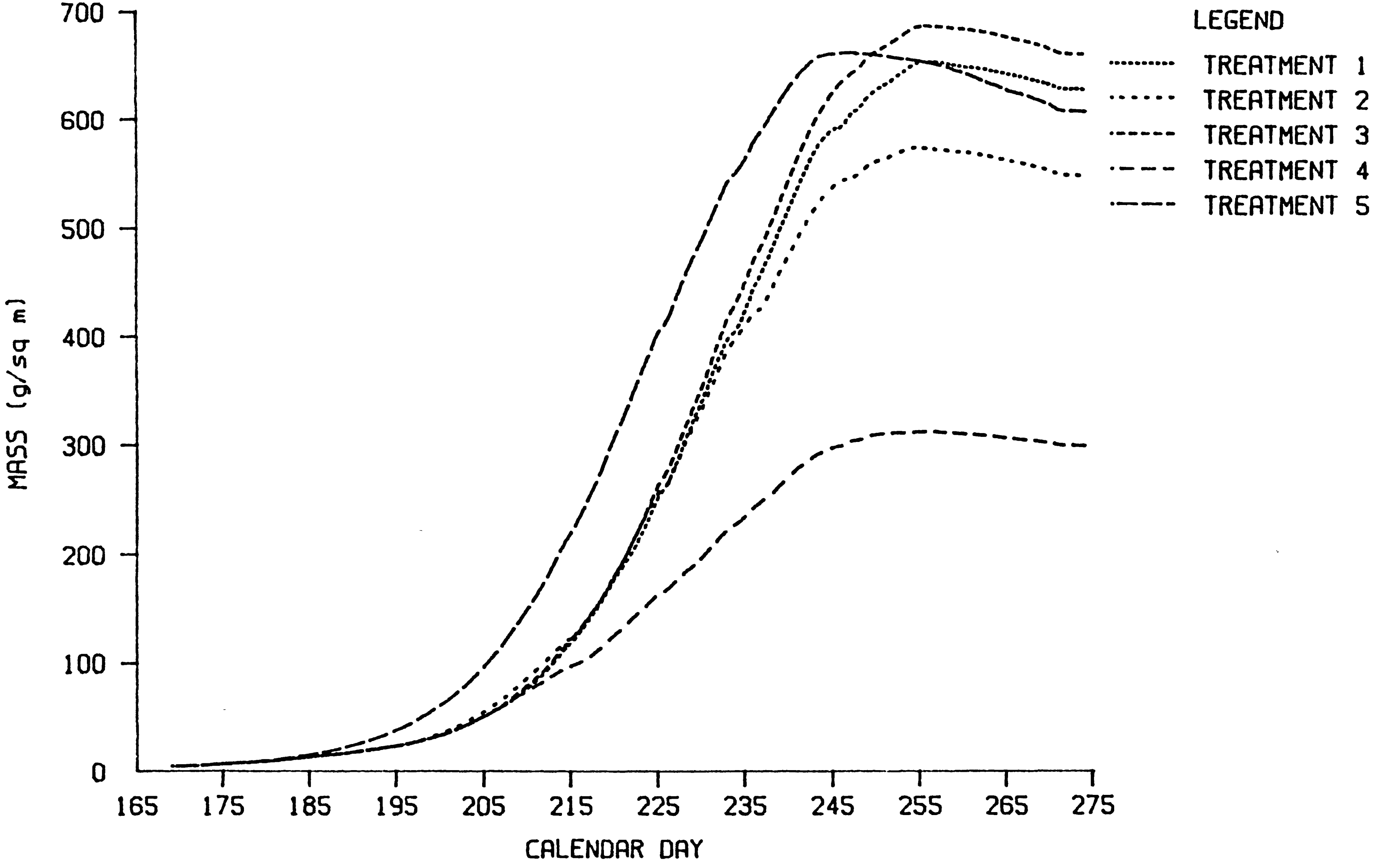

Figure 20. Irrigation Treatment Effect on Vegetative Growth using Young's Model: Planting Day 164

amount of applied water. A comparison of treatment 4 against the others demonstrates the yield increase that can be provided by proper irrigation. Simulations using 1984 weather data produced nearly the same results as the simulations with 1985 weather data.

To simulate the effect of planting date, the model was run using planting dates of calendar days 140, 150, 160, 170. and 180; plant density of 12.0 plants/m; row spacing of 0.9144 m (36 in.); the soils of site 4A; the 1985 weather data; and irrigation according to treatment 3. Table XI and Figures 21 and 22 give the results of the simulations. It appears that there is little difference between planting days 140 and 150 but that planting after day 150 results in a growing season that is too short to allow full development of the crop. Simulations using the 1984 weather data produced the same results.

TABLE XI

SUMMARY OF YOUNG'S MODEL SIMULATIONS FOR FIVE PLANTING DATES

Planting Date	Applied Water cm	Pod Count $\#/m^2$	Veg. Mass g/m^2	Pod Mass g/m^2	Net Yield kg/ha	Net Yield / Ap. Water kg/ha cm
140	52.3	690	510	520	4900	94
150	49.0	690	550	530	4960	101
160	41.7	640	570	470	4190	100
170	35.3	640	590	400	3360	95
180	30.0	630	600	290	1830	61

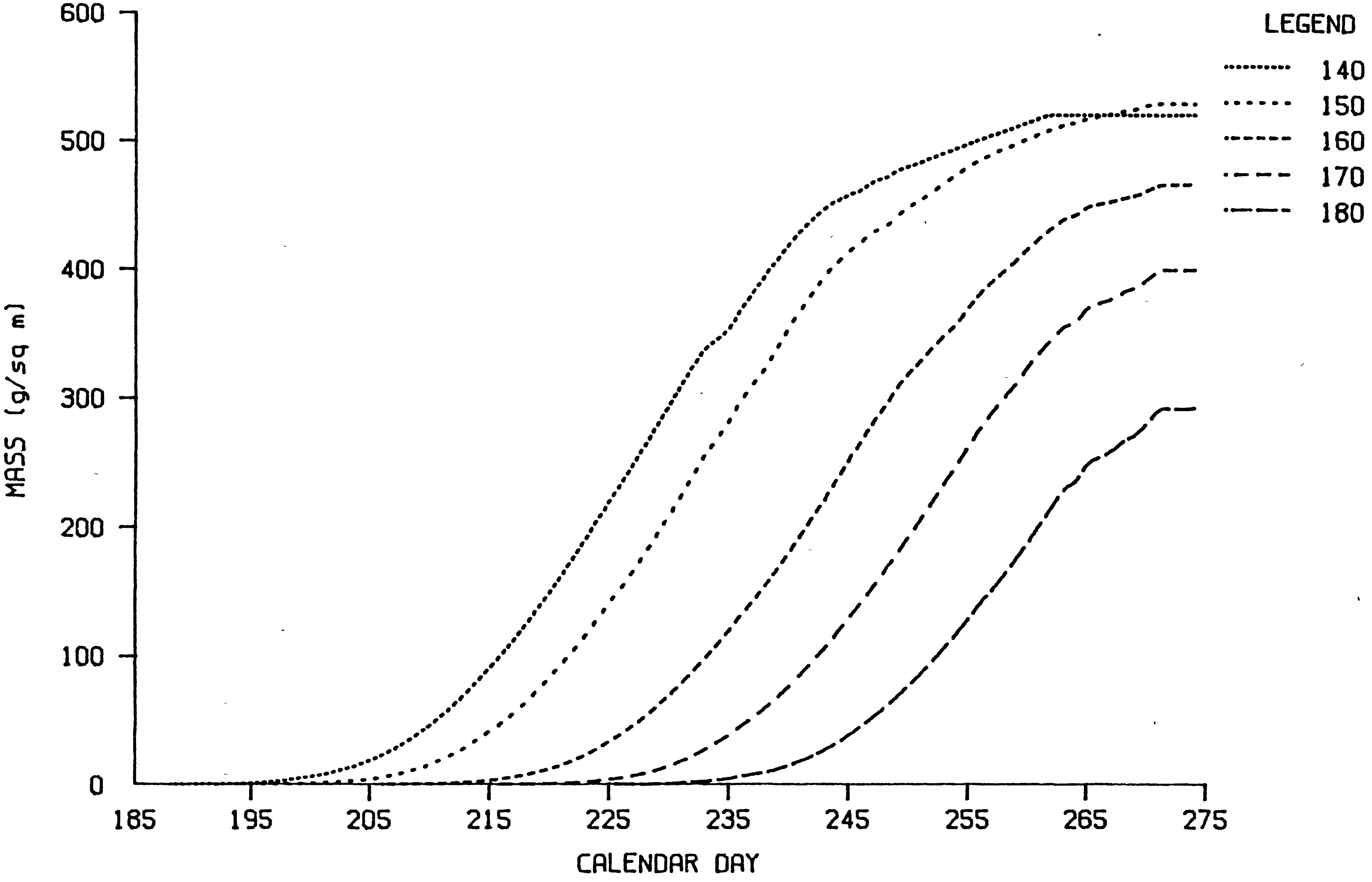

Figure 21. Effect of Planting Date on Pod Yield using Young's Model

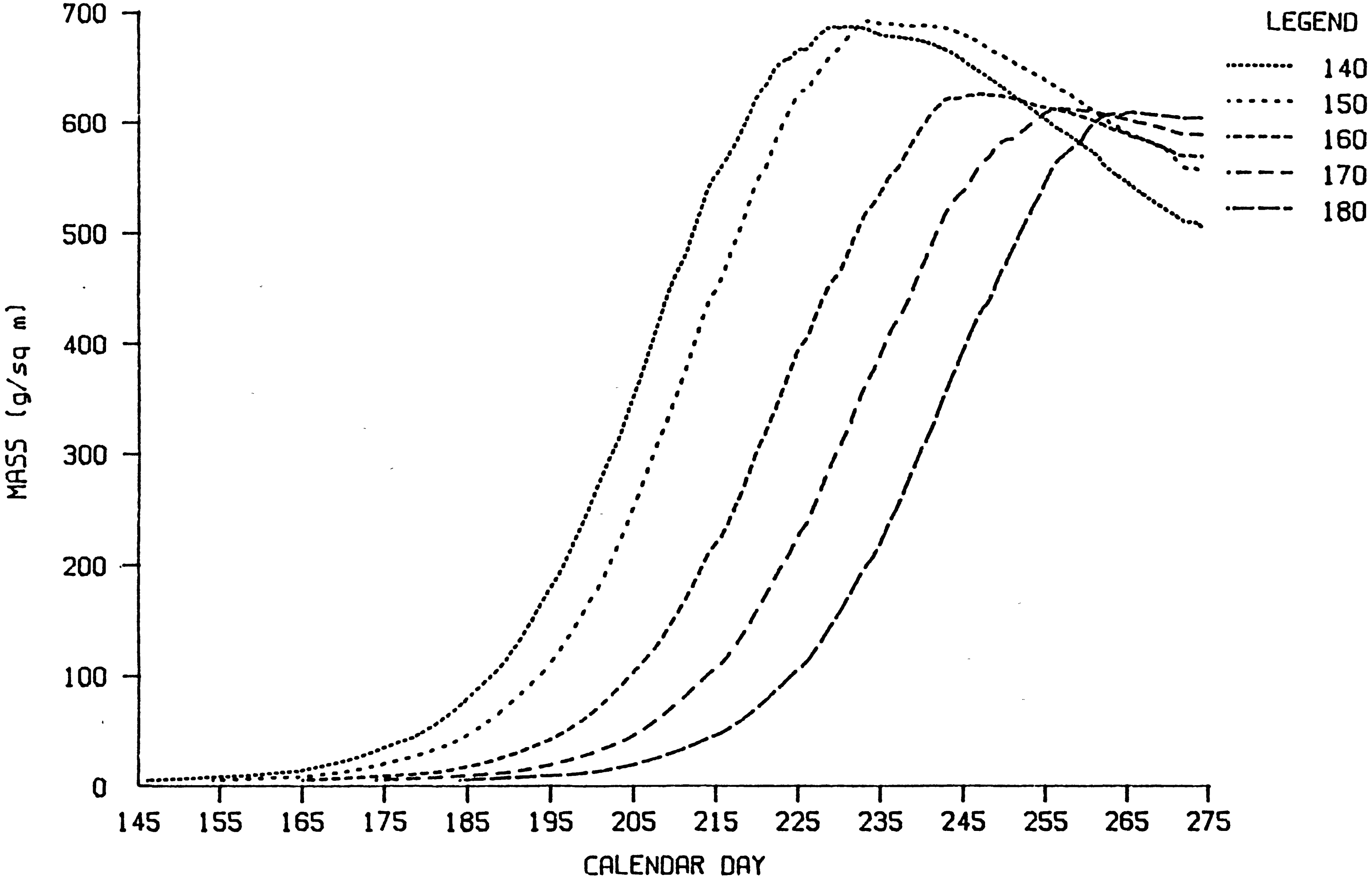

Figure 22. Effect of Planting Date on Vegetative Growth using Young's Model

CHAPTER VI

SUMMARY AND CONCLUSIONS

Summary

To begin this study, the literature was reviewed to identify peanut growth models that had already been formulated. As a result of this review, two peanut growth models were identified that could be used to simulate peanut growth in Oklahoma. These two models are PNUTMOD developed at the University of Florida and the model of Young and associates (Young's model) developed at North Carolina State University.

During the summer of 1985, data were collected that were necessary for execution and calibration of the models. Four field sites in Caddo County were intensively monitored for soil moisture, rainfall and irrigation, and sequential harvest data. Weather data were collected by a weather station location at the Caddo Research Station.

The two models were modified, programmed on a computer, and calibrated against the sequential harvest data. Once calibrated, the two models were used to simulate the effects of different soil moisture levels and planting dates on pod and vegetative growth.

Conclusions

The two models, as calibrated for the spanish type peanut variety used in this study, can adequately simulate peanut growth in Oklahoma.

The parameters listed in Chapter V are those that were found to give the best simulation of the field data for the four field sites.

The two models both simulated pod mass very well. Simulation of vegetative growth is adequate, although Young's model is physiologically more correct because of the senescence of vegetation late in the season.

Using PNUTMOD, the effect of low soil moisture availability is a sharp decrease in vegetative growth and a moderate decrease in pod growth as compared to high water availability. PNUTMOD also predicts a decrease in vegetative mass and a larger decrease in pod mass as the emergence date is increased from calendar day 140 to 180. Periods of low solar radiation however can produce prematurely short seasons.

Simulations using Young's model indicate that the best net yield-applied water combination occurs when the root zone soil moisture reaches 50 percent available water during vegetative growth, 0.6 bar tension at a depth of 30 cm during peg growth and pod formation, and 2 bars tension during pod maturation. Using Young's model, final vegetative mass increases while pod mass decreases as planting date is delayed from calendar day 140 to 180.

Recommendations

Both models could be used as demonstrations to illustrate the effects of soil moisture and planting date on peanut growth. PNUTMOD is a much simpler model and would be more suitable to classroom and laboratory instruction in classes related to agronomic production and plant stress response. Young's model could be used by Extension personnel, consultants, and perhaps farmers themselves in investigating the response of the peanut crop to different weather and management inputs.

Both models have areas needing improvement. PNUTMOD could include some provision for senescence of vegetation late in the season and a reduction in pod mass increase during pod set in response to an environmental stress. The criterion for the termination of pod set needs to be modified so that the model will be less sensitive to periods of low solar radiation. Data input for the current version of Young's model could be improved. Inputs related to soils need to be simpler and easier to obtain. Both models need some way of quantifying and or predicting disease damage and its effect on vegetation and pods. Research done in Caddo County on predicting evapotranspiration could be incorporated into Young's model in subroutine PET.

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APPENDIXES

APPENDIX A

1985 WEATHER DATA

CALENDAR DAY	MAX. TEMP. C	MIN. TEMP. C	SOLAR RAD. Langleys	AVE. REL. HUMIDITY	WIND SPEED m/s
139	26.7	11.1	500	60.0	2.68
140	26.1	15.0	500	60.0	2.68
141	25.0	15.0	500	60.0	2.68
142	25.0	11.7	500	60.0	2.68
143	29.4	8.9	500	60.0	2.68
144	32.2	10.6	500	60.0	2.68
145	34.4	12.8	500	60.0	2.68
146	35.0	18.9	500	60.0	2.68
147	29.1	19.6	529	85.0	4.80
148	32.4	21.4	506	80.0	4.56
149	37.3	22.4	656	60.0	4.34
150	40.5	21.8	708	50.0	5.13
151	32.9	20.0	559	68.0	3.50
152	36.3	19.3	544	65.0	4.12
153	37.0	18.7	635	65.0	4.41
154	31.5	21.7	529	75.4	4.16
155	31.1	18.5	321	83.6	5.00
156	24.5	18.0	205	94.7	2.96
157	28.2	18.5	482	86.8	1.78
158	32.8	24.6	517	73.7	2.58
159	35.5	21.4	708	63.6	3.55
160	34.3	21.6	551	70.1	2.60
161	33.7	20.7	617	68.4	4.31
162	26.8	16.5	598	78.1	3.78
163	25.3	15.0	703	57.3	3.22
164	27.4	11.7	701	63.4	4.12
165	32.2	17.1	696	60.1	5.64
166	33.2	21.3	687	65.3	2.87
167	37.0	20.5	699	62.0	4.80
168	30.9	21.8	438	63.8	4.55
169	28.9	16.6	392	59.7	2.65
170	30.3	14.6	707	56.7	2.33
171	31.3	19.4	672	52.4	6.25
172	32.5	21.0	674	66.2	6.49
173	32.0	22.0	473	74.2	4.99
174	32.9	20.6	494	75.6	5.47
175	33.5	21.3	670	66.4	5.53
176	33.0	21.5	613	68.5	6.29
177	30.7	17.9	438	75.9	5.13
178	26.2	15.8	662	66.7	4.58
179	32.4	12.6	725	60.7	2.09
180	32.5	15.8	711	54.9	3.37
181	34.6	17.3	678	53.3	3.37
182	31.6	19.9	410	62.0	2.34
183	30.5	18.9	645	74.9	2.18
184	34.0	18.3	667	70.2	1.68
185	34.7	18.4	686	62.6	2.88
186	34.1	20.7	689	63.9	2.97
187	34.1	17.6	696	58.9	1.58
188	32.9	17.3	697	60.6	1.84

189	34.9	19.4	695	63.3	3.41
190	36.8	19.5	686	54.9	3.22
191	36.5	22.2	637	52.3	2.64
192	37.4	18.4	683	59.8	1.90
193	37.7	20.3	683	54.1	3.39
194	35.7	20.2	680	55.6	4.37
195	36.2	22.0	677	60.1	4.34
196	36.1	21.2	473	68.7	2.42
197	34.4	22.5	637	72.4	3.05
198	34.0	20.9	640	74.4	3.55
199	36.7	22.4	674	78.2	3.80
200	35.5	21.6	646	75.3	3.05
201	35.7	21.8	620	81.4	2.11
202	35.7	20.8	616	82.9	1.45
203	32.9	22.8	479	81.4	2.11
204	33.5	20.3	389	82.6	2.29
205	33.2	20.9	425	86.0	3.52
206	30.7	21.8	303	87.4	1.98
207	33.0	21.2	645	84.2	2.12
208	33.1	21.2	473	82.3	1.66
209	34.1	22.7	601	83.1	3.37
210	36.5	23.0	561	85.2	2.52
211	36.8	23.2	668	88.9	4.45
212	35.9	22.0	665	53.3	3.88
213	35.7	20.2	624	65.2	2.85
214	35.7	20.6	557	69.2	2.82
215	39.1	23.7	641	54.8	3.60
216	39.1	22.9	599	50.8	4.12
217	29.6	21.8	279	79.4	2.22
218	38.1	21.7	649	65.9	1.88
219	35.0	20.7	656	62.5	3.16
220	35.3	20.5	651	62.5	2.56
221	37.9	23.1	645	48.4	4.48
222	32.6	20.5	622	63.7	3.28
223	36.8	21.3	577	56.4	3.21
224	36.7	21.9	575	42.5	4.49
225	36.6	22.3	521	60.7	3.25
226	24.0	20.2	160	89.0	2.44
227	29.7	19.7	462	79.4	1.62
228	33.8	20.2	588	76.8	2.51
229	36.0	21.5	615	64.6	3.02
230	38.0	22.1	521	60.0	2.37
231	33.6	21.0	411	75.4	3.07
232	35.1	20.9	582	73.6	2.69
233	34.0	22.6	357	64.8	3.14
234	37.6	25.3	593	47.8	4.91
235	38.6	21.2	475	58.7	3.06
236	34.2	20.2	565	66.1	2.66
237	30.8	14.6	594	57.3	2.00
238	31.6	17.5	565	64.0	3.30
239	33.3	19.7	577	59.1	3.46
240	33.4	19.2	579	56.2	3.17
241	34.7	18.6	593	57.8	3.23
242	36.9	19.4	583	51.6	2.41

243	38.0	17.9	592	50.7	2.34
244	39.2	19.8	557	45.5	2.31
245	37.3	21.7	523	52.4	2.95
246	39.4	19.5	557	52.7	2.50
247	38.1	19.8	521	46.0	3.76
248	36.9	24.0	527	49.3	5.44
249	34.0	22.9	559	60.7	5.11
250	36.8	21.9	516	64.1	3.88
251	37.2	21.9	501	54.5	3.05
252	37.4	20.0	496	52.0	2.70
253	35.0	20.0	381	67.8	2.99
254	32.2	20.2	491	70.0	3.35
255	31.5	21.0	413	72.1	3.12
256	32.7	18.3	304	78.3	3.00
257	25.5	17.1	313	79.4	2.21
258	25.1	17.5	269	81.1	2.96
259	27.4	19.5	179	80.2	5.25
260	31.5	19.8	482	64.1	6.37
261	29.4	21.1	284	70.6	5.63
262	29.7	22.4	282	68.5	5.16
263	31.3	13.9	321	75.1	4.46
264	21.0	12.5	300	76.8	2.20
265	29.3	14.8	323	80.9	3.95
266	20.3	10.3	531	65.6	4.30
267	22.4	6.9	460	68.2	3.21
268	22.8	11.7	507	57.2	4.62
269	22.2	8.9	514	50.8	2.36
270	27.4	10.6	503	45.6	5.70
271	25.7	15.4	254	77.1	5.88
272	17.1	5.8	123	86.5	6.49
273	14.1	2.5	493	67.4	3.96
274	17.2	4.0	486	67.3	1.25

APPENDIX B

RAINFALL/IRRIGATION DATA FOR THE FOUR SITES

CALENDAR DAY	RAIN/IRRIGATION (in) SITE 4A	SITE 6B	SITE 9A	SITE 10A
143	-	0.00	-	-
144	-	0.00	-	-
145	0.00	0.00	-	-
146	0.50	0.50	-	-
147	0.00	0.00	-	-
148	0.00	0.00	-	0.00
149	0.00	0.00	-	0.00
150	0.00	0.00	-	0.00
151	0.00	0.00	-	0.00
152	0.00	0.00	-	0.00
153	0.95	0.95	-	0.95
154	0.00	0.00	-	0.00
155	1.69	1.69	-	1.69
156	1.42	1.42	-	1.42
157	0.71	0.71	-	0.71
158	0.00	0.00	-	0.00
159	0.00	0.00	-	0.00
160	0.00	0.00	-	0.00
161	1.50	1.50	-	1.50
162	0.00	0.00	-	0.00
163	0.00	0.00	-	0.00
164	0.00	0.00	0.00	0.00
165	0.00	0.00	0.00	0.00
166	0.00	0.00	0.00	0.00
167	0.00	0.00	0.00	0.00
168	0.00	0.00	0.00	0.00
169	0.00	0.00	0.00	0.00
170	0.00	0.00	0.00	0.00
171	0.00	0.00	0.00	0.00
172	0.50	0.00	0.00	0.00
173	0.00	0.00	0.00	0.00
174	0.00	0.00	0.00	0.00
175	0.00	0.00	0.00	0.00
176	0.00	0.00	0.00	0.00
177	1.00	1.00	0.74	1.20
178	0.00	0.00	0.00	0.00
179	0.00	0.00	0.00	0.00
180	0.00	0.00	0.00	0.00
181	0.00	0.00	0.00	0.00
182	0.00	0.00	0.00	0.00
183	0.06	0.06	0.25	0.07
184	0.00	0.00	0.00	0.00
185	0.00	0.00	0.00	0.00
186	0.00	0.00	0.00	0.00
187	0.00	0.00	0.00	0.00
188	0.00	0.37	0.00	0.00
189	1.50	0.00	0.00	1.50
190	0.00	1.10	0.00	0.00
191	0.00	0.00	0.00	0.00
192	0.69	0.00	0.00	0.00

193	0.00	0.00	0.00	0.00
194	0.00	0.00	0.00	0.00
195	0.57	0.70	0.62	0.00
196	0.47	0.58	0.00	0.00
197	0.00	0.00	0.00	0.00
198	0.00	0.00	0.00	0.00
199	0.00	0.00	0.00	1.28
200	0.00	0.35	0.00	0.00
201	0.00	1.16	0.00	0.00
202	1.22	0.00	0.00	0.00
203	0.00	0.00	0.66	0.00
204	0.28	0.12	0.00	0.00
205	1.31	0.85	1.20	1.54
206	0.00	0.00	0.00	0.00
207	0.00	0.00	0.00	0.00
208	0.00	0.00	0.00	0.00
209	0.00	0.00	0.00	0.00
210	0.00	0.00	0.00	0.00
211	0.98	0.00	0.00	0.00
212	0.00	1.21	0.00	0.00
213	0.00	0.00	0.00	2.08
214	0.00	0.00	0.00	0.00
215	0.00	0.00	0.00	0.00
216	0.00	0.00	0.00	0.00
217	2.80	1.18	1.87	1.17
218	0.19	0.19	0.12	0.13
219	0.00	0.00	0.00	0.00
220	0.00	0.00	0.00	0.00
221	0.00	0.00	0.00	0.00
222	0.00	0.00	0.00	0.00
223	0.00	0.00	0.00	0.00
224	0.72	0.00	0.79	0.00
225	1.08	0.50	0.00	0.59
226	0.09	0.63	0.45	0.10
227	0.00	0.00	0.00	0.00
228	0.00	0.00	0.00	0.00
229	0.00	0.00	0.00	0.00
230	1.30	1.04	0.03	0.10
231	0.00	0.00	0.00	0.00
232	0.13	0.31	0.00	0.00
233	0.00	0.00	0.52	1.47
234	0.00	0.00	0.00	0.00
235	0.00	0.00	0.00	0.00
236	1.55	0.93	0.00	0.00
237	0.00	0.00	0.00	0.00
238	0.00	0.00	0.00	0.00
239	0.00	0.00	0.00	0.00
240	0.00	0.00	0.00	0.00
241	0.00	0.00	0.84	0.00
242	1.06	0.00	0.00	1.52
243	0.00	0.00	0.00	0.00
244	1.62	0.00	0.51	0.00
245	0.00	1.33	0.00	0.00
246	0.00	0.00	0.00	0.00

247	0.00	0.00	0.00	0.00
248	2.25	0.00	0.00	0.00
249	0.00	0.95	0.83	0.00
250	0.00	0.00	0.00	1.08
251	0.00	0.00	0.00	0.00
252	1.87	0.00	0.64	0.00
253	0.00	0.00	0.00	0.00
254	0.00	0.00	0.00	0.00
255	0.00	0.00	0.00	0.00
256	0.00	1.08	0.63	0.00
257	0.00	0.00	0.00	0.00
258	0.00	0.00	0.00	0.00
259	0.00	0.47	0.00	0.00
260	0.00	0.00	0.00	0.00
261	0.00	0.00	0.00	0.00
262	0.00	0.00	0.00	0.00
263	1.25	1.00	1.68	1.01
264	0.00	0.00	0.00	0.00
265	0.22	1.20	0.27	0.27
266	0.00	0.00	0.00	0.00
267	0.00	0.00	0.00	0.00
268	0.00	0.00	0.00	0.00
269	0.00	0.00	0.00	0.00
270	0.48	0.37	0.00	0.00
271	0.00	0.00	0.00	0.00
272	3.45	3.45	3.45	3.45
273	0.00	0.00	0.00	0.00
274	0.00	0.00	0.00	0.00

APPENDIX C

NEUTRON PROBE DATA OF TOTAL WATER (in) IN 48 INCH ROOT ZONE

CALENDAR DAY	SITE 4A	SITE 6B	SITE 9A	SITE 10A
160	-	-	-	9.44
161	-	-	-	10.12
162	-	-	-	9.72
163	-	-	-	9.66
164	11.46	-	-	9.45
167	11.46	-	-	9.16
171	-	-	-	8.64
174	11.27	-	-	8.23
176	10.92	-	9.24	7.86
177	11.32	-	9.81	8.63
178	11.21	-	9.56	8.40
181	10.74	-	9.32	8.10
183	10.70	12.12	9.15	7.91
185	10.39	11.88	8.87	7.63
188	-	11.52	-	-
189	10.23	11.43	8.36	7.90
190	-	11.81	-	-
191	-	11.72	8.16	-
192	9.98	11.35	7.95	7.31
195	9.77	11.45	8.02	6.75
196	9.78	-	-	-
198	9.56	11.18	7.69	-
199	9.40	11.05	7.52	6.52
200	-	11.00	-	-
202	9.42	11.53	7.25	6.06
203	-	-	7.35	5.98
204	9.34	11.43	-	-
205	9.88	-	7.85	6.47
206	9.85	11.52	7.86	6.65
209	9.41	11.07	7.41	6.28
211	9.28	10.62	7.03	5.81
212	-	11.06	-	-
217	9.98	11.00	7.08	6.95
218	9.68	-	6.91	6.76
220	9.50	10.60	6.60	6.45
223	8.76	10.23	6.08	5.69
224	8.81	-	6.24	-
225	9.27	-	-	5.54
226	9.37	10.32	6.30	5.60
227	9.20	10.10	6.20	5.43
230	9.37	10.33	5.79	5.19
232	9.16	10.23	-	-
233	-	-	5.68	5.92
234	8.77	9.93	5.48	5.61
238	9.06	9.98	4.99	5.08
242	8.64	9.42	4.89	4.99
245	8.79	9.52	4.69	4.59
249	8.72	9.72	4.64	-
252	9.07	9.36	4.66	4.47
256	8.60	9.46	4.68	4.45
259	8.27	9.53	4.55	4.41

263	8.44	-	5.09	4.44
266	8.38	10.09	5.05	-
270	8.21	9.90	4.81	-
273	-	-	7.56	-

APPENDIX D

PROGRAM LISTING OF PNUTMOD

```
10 CLS
20 INPUT"SIMULATION NAME";A$
30 B$="B:"+A$+".PD"
40 C$="B:"+A$+".VM"
50 INPUT"AVAILABLE WATER FILENAME";D$
60 OPEN "B:WEATH" FOR INPUT AS #1
70 OPEN B$ FOR OUTPUT AS #2
80 OPEN C$ FOR OUTPUT AS #3
90 OPEN D$ FOR INPUT AS #4
100 REM  THE SEVEN VARIETAL PARAMETERS (OKLAHOMA VALUES)
110 DUE=640:PWF=1.85:PCF=.62:PART=.96:PSF=.0196:EX=3.5:PNE=.92
120 CLS
130 PRINT" JD        DU        GC        VDM(G)      PDM(G)       FL      KA"
140 PRINT"__________________________________________________________________"
150 WHILE NOT EOF(1)
160  INPUT #4,PD,AW
170  INPUT #1,JD,ADB,RAD
180 REM IF WEATHER DATA IS BEFORE EMERGENCE DAY KEEP READING UNTIL THEY MATCH
190    IF JD<PD GOTO 170
200 REM  CALCULATE THE MOISTURE FACTOR KA
210    KA=LOG(AW*100+1)/LOG(101)
220 REM  THERE IS NO GROWTH IF ADB IS LESS THAN 10 C
230    IF ADB<10 THEN GOTO 490
240 REM  CALCULATE DU
250    DU=DU+ADB-10
260 REM  CALCULATE GC IF IN EXPANSION PHASE
270    IF DU<DUE THEN GC=(DU/DUE)^EX ELSE GC=1
280   DASMAX=RAD*PNE
290 REM CALCULATE DAILY ASSIMILATE, DAS
300    DAS=RAD*PNE*GC*KA
310 IF GC<1 THEN DVDM=DVDM+DAS ELSE GOTO 340
320 GOTO 490
330 REM  POD SET PHASE
340    IF GC=1 AND PL<1 THEN DPDMI=PSF*(DU-DUE) ELSE GOTO 440
350    DPDM=DPDM+DPDMI
360 REM SKIP PL COMPUTATION ON LOW RADIATION DAY
370     IF RAD<12 GOTO 470
380    PL=(DPDMI/PCF/DASMAX)/PART
390 REM CHECK FOR END OF POD SET AND COMPUTE DUF
400    IF PL>1 THEN DUP=DU-DUE ELSE GOTO 470
410     DUF=.633*PWF*DUP/PART-125
420 GOTO 470
430 REM  POD FILL PHASE
440    DPDMI=DAS*PCF*PART
450    DPDM=DPDM+DPDMI
460    FL=(DU-DUE-DUP)/DUF
470  DVDM=DVDM+DAS-DPDMI/PCF
480 REM  SCREEN OUTPUT
490    PRINT USING"###    ####    #.##     ####.##    ###.##    #.##     #.##";J
D,DU,GC,DVDM,DPDM,FL,KA
500 REM  FILE OUTPUT (DOES NOT WRITE VALUES LESS THAN 1.0 G/M^2)
510    IF DPDM<1! GOTO 530
520     WRITE #2,JD,DPDM
530    IF DVDM<1! GOTO 560
540     WRITE #3,JD,DVDM
550 IF FL>1 THEN GOTO 570
560 WEND
570 PRINT USING"DUF = ###.#";DUF
580 CLOSE
590 STOP
600 END
```

APPENDIX E

SUBROUTINE LISTINGS FOR YOUNG'S MODEL

```
    BLOCK DATA
   COMMON /BLOCK9/ RB(65),RBDR(65),TRB,TSMD,TC(65),AMD(65).DCUM.
 +                  UPPERU,UTSMD,RBDI(20),RRGF(65),AEP(65)
       COMMON /BLOCKC/ FIRST
       COMMON /BLOCKB/ THIRD
        COMMON /BLOCKD/ FOURTH
       LOGICAL FIRST,THIRD,FOURTH
        REAL*8 RB,RBDR,TRB,TSMD,TC,AMD,DCUM,
 1      UPPERU,UTSMD,RBDI,RRGF,AEP
        DATA FIRST/.TRUE./,THIRD/.TRUE./,FOURTH/.TRUE./
       DATA RB/65*0.0D0/,RBDR/65*0.0D0/.TRB/0.0D0/,TSMD/0.0D0 .
 1             TC/65*0.0D0/,AMD/65*0.0D0/,DCUM/0.0D0/,
 2           UPPERU/0.0D0/,UTSMD/0.0D0/,RBDI/20*0.0D0/,
 3          RRGF/65*0.0D0/,AEP/65*0.0D0/
    END
  IMPLICIT REAL*8(A-H,O-Z)
    LOGICAL FIRST,THIRD,FOURTH
  DIMENSION P(100),TMIN(200),TMAX(200),R(200),XM(65)
 1.PILOS(200)
   COMMON /BLOCK1/ VSMCA(65),TPWP(65),TMPWR(65),VSMCFC(65),
 1    VSMCWP(65).COEFFB(65).EXPA(65).DLAYER,ISLOAM,ILOAM
    COMMON /BLOCK2/ RH(200),WSPEED(200).SUNSIN(200),RF(200),H
     COMMON /BLOCK3/ WAP,CE,CLAI,ES,EP,STAGE,TIME2
   COMMON /BLOCK5/ RPF,RPGA,RBG,CKE,WTD,VSMCAD(65),NORDZ,IAGE,MROOTD
      COMMON /BLOCK6/ CLAIF,ALPHA,CUMES1,CUMES2
       COMMON /BLOCK7/ ZSMCA(65),ZSMCFC(65),ZSMCWP(65),EXPAA(65),
 1                        TCOEFB(65),CONST2(65),CONST1
   COMMON /BLOCK9/ RB(65),RBDR(65),TRB,TSMD,TC(65),AMD(65),DCUM,
 +                  UPPERU,UTSMD,RBDI(20),RRGF(65),AEP(65)
       COMMON /BLOCKC/ FIRST
      COMMON /BLOCK8/ GAMMA,SPT,SVPSPT,SVPW
       COMMON /BLOCKB/ THIRD
        COMMON /BLOCKD/ FOURTH
  EPSI=0.000001
  EPS=0.0001
   OPEN(UNIT=1,FILE='PARMET')
   OPEN(UNIT=3,FILE='CON')
   OPEN(UNIT=7,FILE= SOIL')
   OPEN(UNIT=8,FILE='WEATHER')
   OPEN(UNIT=10,FILE='TOPMASS')
   OPEN(UNIT=12,FILE='PODMASS')
  READ(1,23)NP
23 FORMAT(I2)
  READ(1,26)(P(I),I=1,NP)
26 FORMAT(8F10.5)
  WRITE(3,33)(P(I),I=1,NP)
33 FORMAT(3X,    P(1)       P(2)       P(3)       P(4)       P(5)       P(
 16)       P(7)       P(8)       P(9)       P(10)      P(11)      P(12)',/
 3,3X,12F10.5,
 4 //,    3X,'   P(13)      P(14)      P(15)      P(16)      P(17)      P(
 518)      P(19)      P(20)      P(21)      P(22)      P(23)      P(24)',/
 6,3X,12F10.5,
 7 //,    3X,'   P(25)      P(26)      P(27)      P(28)      P(29)      P(
 830)      P(31)      P(32)      P(33)      P(34)      P(35)      P(36) ,/
 9,3X,12F10.5,
 1 //,    3X,'   P(37)      P(38)      P(39)      P(40)      P(41)      P(
 142)      P(43)      P(44)      P(45)      P(46)      P(47)      P(48)',/
 2,3X,12F10.5,
```

```
     1  ,/  3X,'    P(49)     P(50)     P(51)     P(52)     P(53)     P(
     354)     P(55)     P(56)     P(57)     P(58)     P(59)     P(60)',/
     2,3X,12F10.5,
     3 / ,  3X,'     P(61)     P(62)     P(63)     P(64)     P(65)',/
     4,3X,5F10.5,/)
C ALPHA = PROPORTIONALITY CONSTANT IN SOIL EVAPORATION EQUATION.
         ALPHA = F(49)
C CLAIF = COEFFCIENT IN EQUATION FOR CALATING LEAF AREA INDEX.
         CLAIF = F(51)
C DLAYER = DEPTH OF EACH LAYER.
           DLAYER = P(53)
C CKE = EXTINCTION COEFFICIENT USED IN SUBROUTINE ESDIST.
           CKE = P(55)
C UPPERU = UPPER LIMIT FOR STAGE2 EVAPORATION.
           UPPERU = P(56)
C NORDZ = # OF ZONES THE RIHZOSPHERE IS DIVIDED INTO
          NORDZ = P(54)
C INRZ = INITIAL NUMBER OF ROOT ZONES
        INRZ = P(6)
C
C READ INITIAL ROOT BIOMASS DISTRIBUTION
C
          READ(1,25) (RBDI(I), I=1,INRZ)
   25     FORMAT(8F10.2)
          WRITE(3,27) (RBDI(I), I=1,INRZ)
   27     FORMAT(3X,'    RBDI(1)    RBDI(2)    RBDI(3)    RBDI(4)    RBDI(5)
     1  RBDI(6)    RBDI(7)    RBDI(8)',/,1X,8F10.2)
       CALL DATA(ICHEK,TMIN,TMAX,R,XM,NDAY,IDAY,IDAY2,ND)
        CLOSE(UNIT=8)
         CALL SOILS(VSMCA,TPWP,TMPWR,VSMCFC,VSMCWP,VSMCAD,COEFFB,EXPA,
     +                  DLAYER,NORDZ,ISLOAM,ILOAM,TC,WTD,P)
        CLOSE(UNIT=7)
   15 READ(1,42)IDAY1,IDAYF,IYEAR,PLPFT,ROWSP,ITREAT
   42 FORMAT(3I5,2F10.5,I5)
      IF(ITREAT.EQ.0)GO TO 99
      WRITE(3,46)IDAY1,IYEAR,IDAYF,PLPFT,ROWSP,ITREAT
   46 FORMAT(//3X,'PEANUTS PLANTED ON JULIAN DATE',I4,  OF',I5/
     13X,'FINAL DAY OF SEASON WAS JULIAN DATE',I4/
     23X,'PLANTS PER METER OF ROW=',F10.5/
     43X,'ROW SPACING=',F10.5,' METERS'/
     53X,'TREATMENT NUMBER',I3//)
      IDA=IDAY1-NDAY+1
      KK=IDAYF-NDAY+1
      IF(IDA.LT.IDAY)GO TO 90
      IF(KK.GT.IDAY2)GO TO 90
      CALL PENUT(IDA,KK,P,TMIN,TMAX,R,XM,AX1,BX1,CX1,AX2,BX2,CX2,AN1,
     1BN1,CN1,AN2,BN2,CN2,PLPFT,ROWSP,EPSI,EPS,NDAY)
      GO TO 15
   90 WRITE(3,91)
   91 FORMAT(10X,'TEMPERATURE,MOISTURE,RADIATION AND WEIGHT DATA ARE FOR
     1 DIFFERENT DATES')
      WRITE(3,50)IDA,IDAY,KK,IDAY2
   50 FORMAT(4I10)
   99 STOP
      END
C
      SUBROUTINE DATA(ICHEK,TMIN,TMAX,R,XM,NDAY,IDAY,IDAYF,ND)
      IMPLICIT REAL*8(A-H,O-Z)
```

```
      DIMENSION TMIN(200),TMAX(200),R(200),XM(65)
       COMMON /BLOCK2/ RH(200),WSPEED(200),SUNSIN(200),RF(200),H
      ICHEK=0
      READ(8,32)NDAY,NDAYF,H
      ND=NDAYF-NDAY+1
      IDAY=1
      IDAYI =NDAYF-NDAY+1
      DO 50 I=1,ND
   50 READ(8,80)TMAX(I),TMIN(I),R(I),RH(I),WSPEED(1),RF(I)
      READ(1.4000)SOLCNT.XLAT.AR.BR
      XLAT=XLAT*2.0*3.1415926/360.0
      WRITE(3.2000)SOLCNT.XLAT.AR.BR
 2000 FORMAT(5X,  SOLCNT= ,F10.5,     XLAT=',F10.5,'     AR=',
     1F10.5,     BR='.F10.5//3X,'DAY',4X,'R'.8X,'SUNSIN )
      DO 105 I=1,ND
      DECLIN=0.4092797*DSIN(2.0*3.1415926*DBLE(283+I+NDAY)/365.)
      WS=DACOS(-DTAN(XLAT)*DTAN(DECLIN))
      RO=24.0*SOLCNT*(1.0+0.033*DCOS(2.0*3.1415926*DBLE(I+NDAY-1)/
     1365.0)*(DCOS(XLAT)*DCOS(DECLIN)*DSIN(WS)+WS*DSIN(XLAT)*DSIN(DECLIN
     2)))/3.141596
      SUNSIN(I)=(R(I)/RO-AR)/BR
      IF(SUNSIN(I).LT.0.0)SUNSIN(I)=0.0
      IF(SUNSIN(I).GT.1.0)SUNSIN(I)=1.0
      L=I+NDAY-1
C       IF(P(48).LT.1.0) GOTO 105
C     WRITE(3,300)L,R(I),SUNSIN(I)
  105  CONTINUE
  300 FORMAT(16.2F10.5)
   32 FORMAT(10X,2I10,F10.2)
   80 FORMAT(5X,6F10.5)
 4000   FORMAT(10X,5F10.5)
      RETURN
      END
```

```
      SUBROUTINE PENUT(IDA.KK,P,TMIN,TMAX,R,XM,AX1.BX1,CX1,AX2,BX2,CX2,
     1AN1.BN1.CN1,AN2,BN2.CN2.PLPFT,ROWSP,EPSI,EPS,NDAY)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION TOPINC(200),          PODACC(200),PEGCT(200),PODCT(200),
     1   WTLEAF(200),PGMACT(200).PEGWT(200),PODWT(200).HARVWT(200),
     2 PTOPWT(200),PPODWT(200),FC(200),P(100),TMIN(200),TMAX(200).R(200)
     3 .XM(65).FLPOOL(200),STPOOL(200),PMAX(200),MAT(200),PILOS(200)
     4,PBLOSS(200),BLOSS(200),PSTR(200)
      COMMON /BLOCK3/RWAP,CE,CLAI,ES,EP,STAGE,TIME/
       COMMON /BLOCK5/ RPF,RPGA,RBG,CKE,WTD,VSMCAD(65),NORDZ,IAGE,MROOTD
       COMMON /BLOCK9/ RB(65),RBDR(65),TRB,TSMD,TC(65).AMD(65),DCUM.
     +                 UPPERU,UTSMD,RBDI(20),RRGF(65),AEP(65)
          XMF = 1.0D0
      IP11 = P(11)
      IP24=P(24)
      GROPOD = 0.0
      DROPLF = 0.0
      XMATPD = 0.0
      IAC = 0
      IACC = 0
      TFL = 0.0
      PDROP = 0.0
      TPEGCT = 0.0
      GPEGCT = 0.0
      TPODCT = 0.0
      GPODCT = 0.0
      XMPGCT = 0.0
      TPEGAC = 0.0
      TPGWT=0.0
      F = 0.0
      ITOP = 0
      IPOD = 0
      IFLOWR = 0
C
C EMERGENCE, AS A FUNCTION OF TEMPERATURE
C NOTE: THE STATEMENTS EMERGE=0, TLFWT=0, AND CFIX=0 HAVE BEEN
C ADDED TO SUPPLY SUBROUTINE WUPTAK THESE VALUES UNTIL EMERGENCE
C
         EMERGE = 0.0
         TLFWT = 0.0
         CFIX = 0.0
      DO 9 I=IDA,KK
      IF(I.LT.IDA)GO TO 10
      TAV=(0.5D0*(TMIN(I)+TMAX(I))+460.0D0)*5.0D0/9.0D0
      F=F+1.0/DEXP(((P(3)-TAV)/P(4))*((P(3)-TAV)/P(4)))
      IF (F.GT.P(1)) GO TO 11
C
C P(1) IS THE FRACTION SUMMATION FROM THE TEMPERATURE EQUATION
C FOR EMERGENCE
C
   10 CALL WUPTAK(I,NDAY,XMF,R,TMAX,TMIN,XM,TLFWT,EMERGE,P,PLPFT,
     +ROWSP)
    9 CONTINUE
C
C  EMERGENCE OCCURED, INITIALIZE THE DAILY VARIABLES
C
   11 J = I
      EMERGE = 1.0
```

```
      KK=K
      KD=K
          DO 3 I = K,KK
      FMAX(I)=999.99
      MAT(I)=0
      PPODWT(I) = 0.0
      FGMACT(I)=0.0
      FEGWT(I)=0.0
      PODACC(I) = 0.0
      PODCT(I) = 0.0
      PODWT(I)=0.0
      HARVWT(I)=0.0
      PBLOSS(I)=0.0
      BLOSS(I)=0.0
      PSTR(I)=P(43)
      PEGCT(I) = 0.0
      FC(I) = 0.0
      PTOPWT(I)=0.0
      TOPINC(I) = 0.0
      FLPOOL(I)=0.0
      STPOOL(I)=0.0
    3     CONTINUE
      POOL=0.0
      PTOPWT(K) = P(2)*PLPFT/ROWSP
      WTLEAF(K) = PTOPWT(K) * P(32)
      TLFWT = WTLEAF(K)
      STMWT=PTOPWT(K)-TLFWT
      EM = 0.0
C
                    DO 20 I=K,KK
      ISTRES=0
      EM = EM + 1.0
C
C  COMPUTE CFIXED (NET PHOTOSYNTHESIS)
C
      TAV=(0.5D0*(TMIN(I)+TMAX(I))+460.0D0)*5.0D0/9.0D0
      TF = 1.0 / DEXP(((P(3)-TAV)/P(4))*((P(3)-TAV)/P(4)))
      RFAC=1.0D0-DEXP(-P(5)*R(I))
C
C TF IS TEMPERATURE FACTOR
C RFAC IS THE RADIATION FACTOR
C
      SF=1.0D0
      X = TLFWT
      IF(X.GE.P(8))SF=(P(8)+P(9))/(X +P(9))
C
C SF IS A SHADE FACTOR AND IS RELATED TO THE TOTAL LEAF WEIGHT
C CALL SUBROUTINE WUPTAK TO GET THE SOIL MOISTURE FACTOR (XMF)
C
       CALL WUPTAK(I,NDAY,XMF,R,TMAX,TMIN,XM,TLFWT,EMERGE,P,PLPFT,
     2ROWSP)
      FK=P(10)*TF*RFAC*XMF*SF
      TLFWT = 0.0
      ATLFWT = 0.0
      DO 5 LFINDY = K,I
      AF = 1.0
      IF (I-LFINDY.GE.IP11) AF = 1.0 - P(12) * (I-LFINDY-IP11)
C
```

```
C AF IS AGING FACTOR
C LFINDY IS THE LEAF INITIATION DAY
C IF11 IS THE NUMBER OF DAYS BEFORE AGING BEGINS
C P(12) IS A RATE FACTOR FOR AGING
C
         IF(AF.LT.0.0)AF=0.0
      ATLFWT = ATLFWT + WTLEAF(LFINDY) * AF
      TLFWT = TLFWT + WTLEAF(LFINDY)
    5 CONTINUE
      RESPMR = P(14)*DEXP(1000*P(15)*(1.0/293.0-1.0/TAV))
      TRESPM = RESPMR*(STMWT+ATLFWT+TRB+GROPOD+XMATPD)
      CFIX=FI *ATLFWT
      CFIXED=CFIX-TRESPM
      IF (CFIXED.LT.0.0)  CFIXED =0.0
C
C CALL SUBROUTINE ROOTGR TO SUPPLY IT WITH ITS SHARE OF PHOTOSYNTHATE
C
         CALL  ROOTGR(P,CFIXED,XMF)
      CFIXED=CFIXED*(1.000-RPF)
C
C RPF IS THE ROOT PHOTOSYNTHATE FACTOR AND EQUALS THE FRACTION OF
C DAYS PHOTOSYNTHATE WHICH GOES TO THE ROOT SYSTEM.
C CFIXED IS THE PHOTOSYNTHATE AVAILABLE AFTER MAINTENANCE
C REQUIREMENTS. GM/M*M*DAY
C
      DECLF = 0.0
      DECSTM = 0.0
      P16=(P(16)+P(40)*TAV/301.5+P(42)*TAV*TAV/(301.5*301.5))*P(18)
      DEMAND=P16*GPODCT
C
C P16 IS THE DAILY POD REQUIREMENT FOR PHOTOSYNTHATE, GM/DAY*POD
C
      IF(CFIXED.GE.DEMAND)GO TO 50
      CALL STORAG(ISTRES,REMOVE,DEMAND,CFIXED,P,KP,I,FLPOOL,STPOOL,DECLF
     1,DECSTM,POOL,WTLEAF.TLFWT.STMWT,PTOPWT)
C
C             INCREASING THE POD MASS
C
   50 PODINC=0.0
      IF(TPODCT.LE.0.0)GO TO 25
      CALL PODMAS(I.IACC,PODINC,GPODCT,P,CFIXED,PODACC,JPOD,JP,PODWT,
     1HARVWT,PODCT,XMATPD,GROPOD,PPODWT,KK,EPS,P16,PMAX,MAT)
      IF(HARVWT(I).GT.0.0)CALL PEGSTR(I,IACC,P,PODCT,PODWT,PBLOSS,MAT,
     1PSTR.BLOSS(I).TAV.XM(1))
   25 CAVAIL = CFIXED - PODINC
C
C POD GROWTH HAS PRIORITY, CAVAIL NOW = G/M*M*DAY FOR OTHER USES
C                   INCREASING THE POD NUMBER
C
      IF(XMPGCT.LE.0.0)GO TO 36
      PODCT(I) = CAVAIL / P(17)
      IF (PODCT(I).GT.XMPGCT) PODCT(I) = XMPGCT
C
C THE # OF PODS TO DEVELOP CAN BE NO GREATER THAN THE # PEGS READY
C
      JJ1=I-IP24
      JJ1=MAX0(JJ1,K)
      JJ2=I-IAC-1
```

```
      PODS=PODCT(I)
      DO 51 JJ3=JJ1.JJ2
        IF(PGMACT(JJ3).GE.PODS)GO TO 52
        PODS=PODS-PGMACT(JJ3)
        XMPGCT=XMPGCT-PGMACT(JJ3)
   51 PGMACT(JJ3)=0.0
   52 XMPGCT=XMPGCT-PODS
      PGMACT(JJ3)=PGMACT(JJ3)-PODS
      PODS=0.0
      GPODCT = GPODCT + PODCT(I)
      TPODCT = TPODCT + PODCT(I)
C
C INCREASING THE PEG MASS
C
   36 PEGINC=0.0
      IF(TPEGCT.LE.0.0)GO TO 103
      CALL PEGMAS(I,IAC,PEGINC,P,GPEGCT,CAVAIL,EPSI,PEGACC,PEGWT,PGMACT
     1,PEGCT,IP24,XMPGCT,K)
      TPGWT=TPGWT+PEGINC/P(22)
  103 CAVAIL = CAVAIL - PEGINC
C
C INCREASING THE PEG NUMBER
C
      IF(TFC.LE.0.0)GO TO 17
      PEGCT(I) = CAVAIL/P(25)
C
C THE REMAINING CAVAIL DETERMINES THE NUMBER OF NEW PEGS
C P(25) IS A FACTOR TO DETERMINE THE NUMBER OF NEW PEGS
C
      IF(PEGCT(I).LT.0.0)PEGCT(I)=0.0
      IF (PEGCT(I).GT.FC(I-7)) PEGCT(I) = FC(I-7)
C
C THE NUMBER OF PEGS FORMING CAN BE NO GREATER THAN THE FLOWERS
C
      GPEGCT=GPEGCT+PEGCT(I)
      TPEGCT=TPEGCT+PEGCT(I)
C
C REDUCING THE PEG COUNT IF DRY WHEN THEY REACH THE SOIL.
C XMGPEG = MOISTURE FACTOR FOR PEG DEVELOPMENT.
C XM(1)= MOISTURE TENSION IN TOP LAYER (BARS).
C
      XMFPEG=1.0D0-((XM(1)/P(26))**P(27))
      IF (XMFPEG.LT.0.0) XMFPEG = 0.0
      IF(I-K.LT.10) GO TO 18
      GPEGCT = GPEGCT - PEGCT(I-7) + PEGCT(I-7) * XMFPEG
      PEGCT(I-7) = PEGCT(I-7) * XMFPEG
C
C PEGCT IS REDUCED AT AGE 7 DAYS IF THE SOIL IS DRY
C COUNTING THE FLOWERS ON THAT DAY
C
   17 IF(I-K.LT.3)GO TO 18
      TFFLR = 1.0D0 / DEXP(((P(35)-TAV)/P(36))*((P(35)-TAV)/P(36)))
C
C CALCULATE MOISTURE FACTOR FOR FLOWERING (XMFLR)
C
         XMFLR=XMF
      IF(XMFLR.LT.0.0)XMFLR=0.0
      IF(TOPINC(I-3).GT.P(28)) FC(I)=(TOPINC(I-3)-P(28)*PLPFT/ROWSP)*
```

```
     1P(29)*TFFLF*XMFLF
C
C P(28) IS THE THRESHOLD LEVEL FOR FLOWERING
C P(29) WILL DETERMINE THE NUMBER OF FLOWERS FORMED
C
      IF (FC(I).LT. 0.0) FC(I) = 0.0
      TFC = TFC + FC(I)
C
C ACCOUNTING FOR LEAF DROP DUE TO STRESS AND DROPPING OLDEST
C
   18 DROPLF = 0.0
      TOPINC(I) = CAVAIL/P(22)
C
C P(22) IS 1.0 + THE PEG AND TOP GROWTH RESPIRATION RATE
C
      IF(TOPINC(I).LT.0.0)TOPINC(I)=0.0
      CAVAIL = 0.0
      IF(ISTRES.NE.0)DROPLF=REMOVE*P(30)
      DROPLF=DMIN1(DROPLF,P(41)*TLFWT)
C
C P(41) = MAXIMUM PERCENTAGE OF LEAVES WHICH CAN BE DROPPED ON A DAY
C P(30) IS A PROPORTIONALITY FACTOR TO DETERMINE ACTUAL LEAF DROP
C
      FDROP = FDROP + DROPLF
C
C DROPLF IS THE LEAVES DROPPED, G/M*M
C
      PTOPWT(I)= PTOPWT(I) + TOPINC(I) + PEGINC/P(22) - DROPLF
      PTOPWT(I+1) = PTOPWT(I)
      RLFTOT=P(32)+P(33)*TLFWT+P(34)*STMWT
      WTLEAF(I+1)=TOPINC(I)*RLFTOT
      IF(WTLEAF(I+1).LT.0.0)WTLEAF(I+1)=0.0
      FLPOOL(I+1)=WTLEAF(I+1)*P(31)
      STPOOL(I+1)=(TOPINC(I)-WTLEAF(I+1))*P(31)
C
C P(31) = FRACTION OF NEW TOP GROWTH WHICH ENTERS PHOTOSYNTHATE POOL
C
      POOL=POOL+FLPOOL(I+1)+STPOOL(I+1)
      TLFWT = TLFWT + WTLEAF(I+1) - DROPLF
      IF (TLFWT.LT.0.0) TLFWT=0.0
      STMWT=STMWT+TOPINC(I)-WTLEAF(I+1)
      RLFTOP=TLFWT/PTOPWT(I)
      DO 6 LD = KD,I
      IF(WTLEAF(LD).LT.DROPLF)GO TO 7
      WTLEAF(LD)=WTLEAF(LD)-DROPLF
      DROPLF=0.0
      GO TO 8
    7 DROPLF=DROPLF-WTLEAF(LD)
      WTLEAF(LD)=0.0
    6 CONTINUE
    8 KD=LD
      L=I+NDAY-1
         IF ( P(64).GT.1.0D0 ) GOTO 99
       WRITE(3,15)
   15  FORMAT(1X,'DAY       CFIX      PEGCT    TOTPEGCT     PODCT',
     1'    TOTPODCT     TOPWT      PODWT     HARVWT')
      WRITE(3,4)L,CFIX,PEGCT(I),TPEGCT,PODCT(I),TPODCT,PTOPWT(I),
     1PPODWT(I),HARVWT(I)
```

```
    4 FORMAT(I4,8F10.2/)
   99 WRITE(10.3000)L.PTOPWT(1)
         IF(PPODWT(1).EQ.0)GO TO 20
         WRITE(12.3000)L.PPODWT(I)
 3000  FORMAT(I5,F10.4)
   20 CONTINUE
C
       CLOSE(UNIT=10)
       CLOSE(UNIT=12)
      WRITE(3,75)
   75 FORMAT(/3X,'DAY  PODCT   PODWT    PMAX   PSTR    PBLOSS   DAY   PODCT  ,
     2    PODWT    PMAX   PSTR    PBLOSS   DAY   PODCT   PODWT    PMAX  .
     3'   PSTR    PBLOSS  )
      WRITE(3,70)(I,PODCT(I),PODWT(I),PMAX(I),PSTR(I),PBLOSS(I),I=JP,KK)
   70 FORMAT(3(I6,5F7.2))
      HARV=HARVWT(KK)*10.
      BLOSS(KK)=BLOSS(KK)*10.
      YIELD=HARV-BLOSS(KK)
      WRITE(3.85)HARV,BLOSS(KK),YIELD
   85 FORMAT(//5X,'HARVESTABLE YIELD=',F7.1,' KG PER HECTARE'/
     1          5X.'BELOW GROUND LOSS=',F7.1.  KG PER HECTARE'/
     2          5X, NET HARVESTABLE YIELD=',F7.1,' KG PER HECTARE )
      RETURN
      END
```

```
      SUBROUTINE WUPTAK(I,ISDAY,CXMF,R,TMAX,TMIN,XM,TLFWT,EMERGE,
     2P,PLPFT,POW3P)
          IMPLICIT REAL*8(A-H,O-Z,$)
           LOGICAL FIRST
              DIMENSION  RWUF(65),WUR(65),XM(65),
     +                  RBGF(65),
     1              R(200),TMAX(200),TMIN(200),P(100),EX(65)
      COMMON  /BLOCK1/ VSMCA(65),TPWP(65),TMPWR(65),VSMCFC(65),
     +          VSMCWP(65),COEFFB(65),EXPA(65),DLAYER,ISLOAM,ILOAM
      COMMON /BLOCK3/ RWAP,CE,CLA1,ES,EP,STAGE,TIME2
      COMMON /BLOCK5/ RPF,RPGA,RBG,CKE,WTD,VSMCAD(65),NORDZ,IAGE,MROOTD
      COMMON /BLOCK7/ ZSMCA(65),ZSMCFC(65),ZSMCWP(65),EXPAA(65),
     +                     TCOEFB(65),CONST2(65),CONST1
      COMMON /BLOCK9/ RB(65),RBDR(65),TRB,TSMD,TC(65),AMD(65),DCUM,
     +                    UPPERU,UTSMD,RBDI(20),RRGF(65),AEP(65)
     COMMON /BLOCKC/ FIRST
          IF(.NOT.FIRST) GO TO 275
           FIRST=.FALSE.
C
C  CONVERT SOIL MOISTURE PERCENT BASIS TO AMOUNT PER 2.5 CM DEPTH
C  PER CM SQ SURFAE AREA.
C
           CONST1 = DLAYER/100.0D0
        DO 270 K = 1,NORDZ
           ZSMCA(K) = VSMCA(K)*CONST1
           ZSMCFC(K)  = VSMCFC(K)*CONST1
           ZSMCWP(K)  = VSMCWP(K)*CONST1
           TCOEFB(K)  =COEFFB(K)*CONST1
           EXPAA(K)  =  1.0D0/EXPA(K)
           CONST2(K)  = TPWP(K)-TMPWR(K)
  270     CONTINUE
C
C  CHECK  IF  INITIAL  MOISTUREE  DISTRIBUTION  IS  ABOVE  F.C.  FOR  ANY  DEPTH
C     IF  YES  MAKE  IT   EQUAL  TO  F.C.  VALUE.
C
          DO 272  K=1,NORDZ
               EXCEED = ZSMCA(K)-ZSMCFC(K)
                 IF (EXCEED) 273,273,274
  273                EXCEED = 0.0D0
                      GO TO 272
  274             ZSMCA(K)  =  ZSMCFC(K)
                    KK  = K+1
                     ZSMCA(KK)  =  ZSMCA(KK)+EXCEED
  272      CONTINUE
C
C  CALCULATE  MOISTURE  DEFICIT  IN  EACH  ZONE.
C
          TAMD = 0.0
           DO 280 K = 1,18
              AMD(K)  = ZSMCFC(K)-ZSMCA(K)
  280      TAMD  = TAMD+AMD(K)
C
C  INITIALIZE  IAGE
C
           IAGE  = 0
C
C  NOTE:   CONTROL  WILL  ALWAYS  RETURN  TO  THE  FOLLOWING  STEP  EXCEPT  THE
C          THE  FIRST  TIME  THIS  SUBROUTINE  IS  CALLED.
```

```
  275      CONTINUE
C
C WRITE THIS MORNING S SOIL WATER CONTENT & WATER TENSION
C
             JDAY = I+ISDAY-1
C  WRITE(14,4010)JDAY,(VSMCA(N),N=1,NORDZ)
C CALL EVAPOTRANSPIRATION SUBROUTINE (EVAPO) TO GET THE POTENTIAL
C EVAPOTRANSPIRATION VALUE FOR THE DAY.
C
          CALL PET(1,R,TMAX,TMIN,TLFWT,TAMD,UPPERU,EMERGE,TAET,P)
C
C  CALL SOIL EVAPORATION SUBROUTINE (SEVAP2) TO ASSIGN DAY S
C  EVAPORATION TO DIFFERENT LAYERS.
C
           CALL  ESDIST(ZSMCA,CKE,NORDZ,DLAYER,VSMCAD,ES,EX)
C
C  CHECK FOR RAINFALL + IRRIGATION, UPDATE SOIL MOISTURE IF NEEDED
C
          IF (RWAP.LE.0.0) GO TO 300
                 RWAP = RWAP/10.0D0
             DO 320 K = 1,NORDZ
                  ZSMCA(K) = ZSMCA(K)+RWAP
                  EXCESS = ZSMCA(K)-ZSMCFC(K)
                    IF (EXCESS) 300,340.340
  340                  ZSMCA(K) = ZSMCFC(K)
             RWAP = EXCESS
  320 CONTINUE
  300    RWAP=0.0
C
C  CHECK FOR EMERGENCE.  IF YES, INITIALIZE THE VARIABLES.
C
            IF (EMERGE.EQ.0.0) GO TO 450
               TRWUF = 0.0
               TRGF = 0.0
               TAEP = 0.0
C  SET UP A COUNTER FOR CROP AGE.
           IAGE = IAGE+1
           IF (IAGE.GT.1) GO TO 305
C
C  TOTAL ROOT-BIO-MASS AT EMERGENCE
C
           TRB=0.55D0*P(2)*PLPFT/(ROWSP*0.45D0)
C
C   IP6 = THE DEPTH TO WHICH ROOTS REACH AT EMERGENCE TIME.
C
        IP6=P(6)
        IF (IP6.LT.1) IP6=1
C
C  EACH ZONE IS ASSIGNED INITIAL ROOT WEIGHT ON EMERGENCE DAY.
C
        DO 302 K=1,IP6
  302   RB(K)=TRB*RBDI(K)/100.0D0
 305     CONTINUE
C
C  SET UP A COUNTER FOR ROOT DEPTH.
C
           DIAGE=IAGE
```

```
            MROOTD = IF6H1+INT((IAGE-1)*2.5/DLAYER)
            IF (MROOTD.GT.NORDZ) MROOTD=NORDZ
C
C   CALCULATE RELATIVE WATER UPTAKE FACTOR (RWUF).
C
          DO 350 K = 1,MROOTD
             IF (TC(K)-IMPWR(K)) 355,355,356
  355           RWUF(K) = 1.0
                 GO TO 357
  356          IF (TC(K)-TPWP(K)) 9000,9001,9001
 9000           RWUF(K) = (TPWP(K)-TC(K))/CONST2(K)
                 GO TO 357
 9001            RWUF(K) = 0.0
  357           CONTINUE
          TRWUF = TRWUF+RWUF(K)
  350 CONTINUE
C
C   CALCULATE WATER UPTAKE RATIO (WUR).
C
            DO 360 K = 1,MROOTD
  360       WUR(K) = RWUF(K)/TRWUF
C
C   CALCULATE ROOT- DISTRIBUTION RATIO (RBDR) AND ROOT GROWTH
C   FACTOR (RBGF) FOR EACH LAYER.
C
          DO 370 K = 1,MROOTD
             RBDR(K) = RB(K)/TRB
             RBGF(K) = WUR(K)*RBDR(K)
  370     TRGF = TRGF+RRGF(K)
C
C   CALCULATE RELATIVE ROOT GROWTH FACTOR (RRGF) AND ASSIGN DAY'S
C   ROOT-PHOTOSYNTHATE TO DIFFERENT ROOT ZONES.
C
            DO 380 K = 1,MROOTD
  380          RRGF(K) = RBGF(K)/TRGF
C
C   CALCULATE ACTUAL TRANSPIRATION (TAEP) AND AMOUNT OF WATER EXTRACTED
C   FROM EACH LAYER. ADJUST THE AMOUNT IN EACH LAYER AFTER EXTRACTION.
C
            IF (EP.LE.0.0) GO TO 450
          DO 399 K = 1,MROOTD
             AEP(K) =EP*RRGF(K)*RWUF(K)
             ZSMCA(K) = ZSMCA(K)-(AEP(K)/10.000)
              TAEP = TAEP+AEP(K)
  399   CONTINUE
C
C   CALCULATE SOIL MOISTURE STRESS FACTOR (CXMF).
C
            IF(TAEP.LE.0.0) TAEP=0.0
            CXMF = TAEP/EP
  450     CONTINUE
                    TAET = ES+TAEP
                     PPET = ES+EP
C
C    SUPERIMPOSE SOIL EVAPORATION AND TRANSPIRATION FOR EACH LAYER.
C
                  DO   451 K = 1,NORDZ
  451                  AEP(K)= AEP(K)+EX(K)
```

```
C
C   UPDATE PSEUDO SOIL MOISTURE DEFICIT (TSMD).
C
              TSMD = TSMD+(TAET/10.0D0)
C
C   CALCULATE EVENING SOIL MOISTURE TENSION AND WATER CONTENT.
C    AND CONVERT WATER EVAPORATED PER 2.3 CM DEPTH PER CM 2O.
C    AREA TO PERCENT WATER LOSS.
C
         DO 420 K = 1,NORDZ
            TC(K) = (TCOEFB(K)/ZSMCA(K))**EXPAA(K)
         VSMCA(K) = ZSMCA(K)/CONST1
            EX(K) = EX(K)/CONST1
  420    XM(K) = TC(K)
C ESTIMATE SOIL MOISTURE SUCTION IN EACH ZONE AFTER OVERNIGHT
C REDITRIBUTION UNDER DYNAMIC HYDRAULIC POTENTIALS.
C  ADAPTED FROM DR. WISER S WORK ON SORGHUM MODEL.
C
              DFRAC=DLAYER/1020.0D0
             NK = NORDZ-1
            DO 400 K = 1,NK
        SAVE1=ZSMCA(K)
         IF (EXPA(K).NE.EXPA(K+1)) GOTO 400
        TC(K)=TC(K)+P(7)*(TC(K+1)-TC(K)+DFRAC)
        ZSMCA(K)=TCOEFB(K)/(TC(K)**EXPA(K))
        ADJ2=ZSMCA(K)-SAVE1
        ZSMCA(K+1)=ZSMCA(K+1)-ADJ2
        TC(K+1)=(TCOEFB(K+1)/ZSMCA(K+1))**EXPAA(K+1)
  400 CONTINUE
C
C  CALCULATE MOISTURE CONTENT IN PERCENT.
C
         DO 410 K = 1,NORDZ
  410    VSMCA(K) = ZSMCA(K)/CONST1
           IF (P(65).GT.1.0D0) GOTO 560
         WRITE(3,4000)
 4000    FORMAT(8X,'ES',8X,'EP',6X,'TAEP',5X,'CXMF',5X,'RPF'
     1   ,6X,'RPGA',5X,'RBG',6X,'TRB',6X,'CLAI',3X,'IAGE')
         WRITE(3,1000)JDAY,ES,EP,TAEP,CXMF,RPF,RPGA,RBG,TRB,CLAI,IAGE
         WRITE(3,13)
   13    FORMAT('     6 IN     12 IN    18 IN    24 IN    30 IN    36 IN',
     1      42 IN     48 IN')
         WRITE(3,14)(VSMCA(K),K=1,NORDZ)
         WRITE(3,14)(TC(K),K=1,NORDZ)
         WRITE(3,14)(RB(K),K=1,NORDZ)
   14    FORMAT(8F8.2)
  560    RETURN
 1000    FORMAT(1X,I3,9F9.3,I5)
 4010    FORMAT(3X,I5,65F9.4)
         END
```

```
      SUBROUTINE PET(J,RC,TMAX,TMIN,CTLFWT,TAMD,UPPERU,EMERGE,
     1 TAET,P)
      IMPLICIT REAL*8(A-H,O-Z,$)
       LOGICAL THIRD
       DIMENSION RC(200),TMAX(200),TMIN(200),P(100)
      COMMON /BLOCK2/ RH(200),WSPEED(200),SUNSIN(200),
     1 RF(200),H
       COMMON /BLOCK3/ RWAP,E,CCLAI,ES,EP,STAGE,TIME2
      COMMON /BLOCK6/ CLAIF,ALPHA,CUMES1,CUMES2
        COMMON /BLOCK8/ GAMMA,SPT,SVPSPT,SVPW
         COMMON /BLOCK8/ THIRD
        IF(.NOT.THIRD) GO TO 5
         THIRD=.FALSE.
C
C  CONVERT TOTAL MOISTURE DEFICIT (TAMD) TO MM.  ( 1CM = 10 MM.)
C
         TAMD1 = TAMD*10.0D0
          CUMES = TAMD1-UPPERU
C
C  CHECK FOR STAGE OF EVAPORATION. IF TAMD1>UPPERU THEN EVAPORATION
C  IS TO PROCEED IN STAGE2.
C
        IF (CUMES)240,240,230
  230               CUMES1 = UPPERU
                    CUMES2 = CUMES
C
C  CALCULATE TIME IN DAYS SINCE EVAPORATION HAS BEEN IN STAGE2.
C
           TIME2 = (CUMES2/ALPHA)**2.0
                      STAGE = 2.0D0
              GO TO 250
  240                CUMES1 = TAMD1
                        STAGE = 1.0D0
C
C  ASSIGN VALUES TO PARAMETERS IN MODIFIED PENMAN EQUATION FOR
C  POTENTIAL EVAPOTRANSPIRATION.
C   SPT = STEAM POINT TEMPERTURE, KELVIN; SVPSPT = SATURATION VAPOR
C   PRESSURE AT SPT IN MILLIBARS.
C
  250        CONTINUE
      GAMMA=0.27D0
      SPT=373.16D0
      SVPSPT=1013.246D0
       SVPW=DLOG10(SVPSPT)
    5 TMEAN=(TMAX(J)+TMIN(J))*0.5D0
      XKEL=(TMEAN+460.0D0)*5.0D0/9.0D0
      DELTA=0.09784D0+TMEAN*TMEAN*(0.6368D-4+0.6695D-6*TMEAN)
      TR=SPT/XKEL
C
C  THE FOLLOWING EXPRESSION CALCULATES SATURATION VAPOR PRESSURE
C  AT MEAN AIR TEMPERATURE
C
      SVPL=-7.90298D0*(TR-1.0D0)+5.02808D0*DLOG10(TR)
     2-1.3816D-7*(10.0D0**(11.344D0*(TR-1.0D0)/TR)-1.0D0)
     3+8.132D-3*(10.0D0**(-3.49149*(TR-1.0D0))-1.0D0)+SVPW
      SVP=(10.0D0**SVPL)*0.7500616D0
      AVP=RH(J)*SVP/100.0D0
C
```

```
C   ALBDOS = SOIL ALBEDO.  CALCULATE LEAF AREA INDEX (CCLAI).
C
      ALBDOS=0.10D0
         CCLAI = CTLFWT/CLAIF
      ALBEDO=ALBDOS+0.25D0*(0.23D0-ALBDOS)*CCLAI
C
C  RNO = NET SOLAR RADIATION AFTER ADJUSTING FOR REFLECTION AND
C        LONG WAVE EMISSION TO ATMOSPHERE.
C
       RNO=(RC(J)/59.0D0)*(1.0D0-ALBEDO)-(0.2101D-8*XKEL**4.
     2)*(0.56D0-0.092D0*DSQRT(AVP))*(0.1D0+0.9D0*SUNSH(J))
C
C   CALCULATE WIND SPEED U2 IN M/S AT 2M HEIGHT.
C
      U2=(WSPEED(J)*DLOG10(6.6D0)/DLOG10(H))/2.237D0
      EA=0.35D0*(1.0D0+0.54D0*U2)
     2*SVP*(1.0D0-RH(J)/100.0D0)
      DOVERG=DELTA/GAMMA
C
C  EO = POTENTIAL EVAPOTRANSPIRATION.
C
      EO=(DOVERG*RNO+EA)/(DOVERG+1.0D0)
          IF(EO.LT.0.0D0)  EO = 0.0D0
C
C   CALCULATE  EO USING THOM & OLIVER MODICATION OF PENMAN FORMULA
C
      EATHOM=0.65D0*(1.0D0+0.54D0*U2)
     2*SVP*(1.0D0-RH(J)/100.0D0)
      EOTHOM=(DOVERG*RNO+EATHOM)/(DOVERG+1.0D0)
C
C   RNS = NET RADIATION AT THE SOIL SURFACE BELOW THE CANOPY.
C   ESO = POTENTIAL EVAPORATION AT THE SOIL SURFACE.
C
      RNS=RNO*DEXP(-.398D0*CCLAI)
      ESO=(DELTA/(DELTA+GAMMA))*RNS
C
C  NOTE: WHEN THERE ARE NO PLANTS STAGE1 EVAPORATION NEED TO BE
C          CALCULATED WITHOUT IGNORING THE AERODYNAMIC TERM IN THE
C          PENMAN EQUATION.
C
            IF  (EMERGE.LT.1.0)   ESO = EOTHOM
                IF  (ESO.LT.0.0D0)   ESO = 0.0D0
      IF(CUMES2)300.300,310
  300 CUMES1=CUMES1+TAET
      IF(CUMES1.LE.UPPERU)GO TO 320
      CUMES2=CUMES1-UPPERU
      CUMES1=UPPERU
  315 TIME2=(CUMES2/ALPHA)**2.0
      GO TO 320
  310 CUMES2=CUMES2+TAET
      GO TO 315
C
C   CONVERT RAINFALL + IRRIGATION TO MM
C
  320 CWAP=RF(J)*25.48D0
        RWAP=CWAP
C
C   CHECK FOR STAGE OF EVAPORATION.
```

```
C
      IF(CUMES1-UPPERU)10,20,20
C
C   CHECK IF RAINFALL IS ENOUGH TO FILL IN THE STAGE1 DEFICIT
C
  20     IF(CWAP-CUMES2)50,60,60
  60      CWAP=CWAP-CUMES2
         CUMES1=UPPERU-CWAP
      IF(CUMES1)40,70,70
  10    IF(CWAP-CUMES1)30.40,40
  40    CUMES1=0.0D0
         GO TO 70
  30    CUMES1=CUMES1-CWAP
  70   CUMES1=CUMES1+ESO
C
C   CHECK IF TODAY'S EVAPORATION PUSHES SOIL EVAPORATION IN STAGE2
C   OR NOT.  IF YES GO TO STATEMENT '90'
C
          IF(CUMES1-UPPERU)80,80,90
  80        ES=ESO
            STAGE = 1.0D0
               GO TO 85
C
C   NOTE: WHEN THE DAY'S EVAPORATION PUSHES SOIL EVAPORATION FROM
C   STAGE1 TO STAGE2 ADJUST EVAPORATION ASSUMING 60% OF THE AMOUNT
C         OVER STAGE1 LIMIT WILL ACTUALLY EVAPORATE.
C
  90    ES=ESO-0.4D0*(CUMES1-UPPERU)
             CUMES2=0.6D0*(CUMES1-UPPERU)
C
C   CALCULATE THE TIME IN DAYS SINCE EVAPORATION HAS BEEN IN STAGE2
C
             TIME2=(CUMES2/ALPHA)**2.0
                 CUMES1=UPPERU
             STAGE = 2.0D0
                 GO TO 85
  50         TIME2=TIME2+1.0D0
C
C      CALCULATE AMOUNT OF EVAPORATION IN STAGE2.
C
               ES=ALPHA*(DSQRT(TIME2)-DSQRT(TIME2-1.0D0))
          IF(CWAP)100,100,110
C
C   ADJUST STAGE2 EVAPORATION FOR SMALL AMOUNTS OF RAINFALL
C
 110          ESX=0.8D0*CWAP
                 IF(ESX-ES)120.120,130
 120               ESX=ES+CWAP
 130                 IF(ESX-ESO)140,140,150
 150                     ESX=ESO
 140                      ES=ESX
                            GO TO 160
 100          IF(ES-ESO)160,160,170
 170             ES=ESO
 160           CUMES2=CUMES2+ES-CWAP
                TIME2=(CUMES2/ALPHA)**2.0
C
C   CALCULATIONS FOR  EP'.
```

```
C    NOTE: IF LEAF AREA INDEX (CCLAI) IS < 0.1 THEN TRANSPIRATION
C             IS ASSUMED TO BE NEGLIGIBLE. ( EP =0.0 ).
C
  185    IF(CCLAI-0.1D0)180.190,190
C
C    FOR (CCLAI > 0.1) CALCULATE  EF  AS FOLLOWS.
C
  190          EP=EO*(-0.21D0+0.7D0*DSQRT(CCLAI))
C
C     CHECK THAT  EF  DOES NOT EXCEED THE POTENTIAL TRANSPIRATION
C     VALUE.
C
                 IF(EF.LE.(EO-ES)) GO TO 210
                  EP=EO-ES
                   GO TO 210
  180                    EP=0.0D0
  210          E=ES+EP
            IF ( P(65).GT.1.0D0 ) GOTO 399
C
C   WRITE THE WEATHER PARAMETERS BEING USED FOR THE DAY.
C
            WRITE(3,5001) TMAX(J),TMIN(J),RC(J),RH(J),WSPEED(J),
     +                       SUNSIN(J),RF(J)
 5001   FORMAT(10X,'TMAX=',F5.1,2X,' TMIN=',F5.1,2X,'RAD=',F5.1,2X,
     + 'RH=',F5.1,2X,'WIND=',F4.1,2X,'SUNSIN=',F4.2,2X,'RAIN=',F4.2)
              WRITE(3,5000) EO,EOTHOM
 5000     FORMAT(10X,'POT. ET=',F6.3,15X,'THOM & OLIVER ET=',F6.3)
  399         RETURN
        END
```

```
      SUBROUTINE SOILS(VSMCA.TPWP,TMPWR,VSMCFC,VSMCWP,VSMCAD.COEFFB,
     +                         EXPA.DLAYER,NORDZ.ISLOAM,ILOAM,TC.WTD,P)
       IMPLICIT REAL*8(A-H,O-Z,$)
        DIMENSION VSMCA(65),TPWP(65),TMPWP(65),VSMCFC(65),
     +  VSMCWP(65).VSMCAD(65),COEFFB(65),EXPA(65),TC(65),P(100)
C
C READ IN MOISTURE CONTENT AT SOWING, AIR DRY M.C., EXPA, AND
C COEFFB FOR EACH SOIL LAYER
C
             DO 1040 J = 1,NORDZ
                READ(7,1015)VSMCA(J),VSMCAD(J),EXPA(J).COEFFB(J)
 1015           FORMAT(4F10.2)
                TPWP(J)=P(61)
                TMPWR(J)=P(62)
         VSMCFC(J)  = COEFFB(J)/(.1**EXPA(J))
         VSMCWP(J)  = COEFFB(J)/(TPWP(J)**EXPA(J))
 1040    CONTINUE
C
C  CALC. SOIL MOISTURE TENSION (BARS) AT PLANTING
C
         DO 1050 K = 1,NORDZ
 1050     TC(K)  =  (COEFFB(K)/VSMCA(K))**(1:0D0/EXPA(K))
C
C   WRITE THE SOIL PARAMETERS GENERATED BY THIS SUBROUTINE
C
          WRITE(3,1070)
 1070  FORMAT(1X,'LAYER',5X,'TPWP',5X,'TMPWR',5X,'VSMCAD',3X,'VSMCFC',
     +4X.'VSMCWP',4X,'COEFFB',4X,'EXPA',8X.'VSMCA',5X,'TC(BARS)')
           DO 1080 I = 1.NORDZ
           WRITE(3,1090)I,TPWP(I),TMPWR(I),VSMCAD(I),VSMCFC(I),VSMCWP(I),
     +                    COEFFB(I),EXPA(I),VSMCA(I),TC(I)
 1080       CONTINUE
 1090     FORMAT(2X,I2,7F10.2,2X,2F10.2)
           RETURN
           END
```

```
          SUBROUTINE  ROOTGR(P,CCFIX,XMF)
           IMPLICIT REAL*8(A-H,O-Z,$)
            DIMENSION  P(100)
           COMMON /BLOCK1/ VSMCA(65),TPWP(65),TMPWR(65),VSMCFC(65),
     1     VSMCWP(65),COEFFB(65),EXPA(65),DLAYER,ISLOAM,ILOAM
         COMMON /BLOCK5/ RPF,RPGA,RBG,CKE,WTD,VSMCAD(65),NORDZ,IAGE,MROOTD
         COMMON /BLOCK9/ RB(65),RBDR(65),TRB,TSMD,TC(65),AMD(65),OCUM,
     +                  UPPERU,UTSMD,RBDI(20),RRGF(65),AEP(65)
C
C    THIS SUBROUTNE ALLOCATES DAILY PHOTOSYNTHATE AVAILABLE FOR
C    ROOT GROWTH TO EACH SOIL PROFILE ZONE.
C    CALCULATE ROOT PHOTOSYNTHATE FACTOR (RPF) AND ROOT PHOTOSYNTHATE
C    FACTOR FOR GEOTROPISM ACTIVITY (RPGA).
C
             RPFP = P(57)*DEXP(P(58)*IAGE)
C
C   CALCULATE MOISTURE STRESS EFFECT ON PARTITIONING
C
             RPF=RPFP+(1.0D0-RPFP)*(1.0D0-XMF**P(63))
                   IF (RPF.LT.0.015D0)   RPF = 0.015D0
C
C ROOT GROWTH PHOTOSYNTHATE AFTER MEETING GROWTH RESPIRATION
C CONVERSION EFFICIENCY =P(22)
C
             RBG = RPF*CCFIX/P(22)
             RPGA = P(59)*DEXP(P(60)*IAGE)
                 LDRG=NORDZ*DLAYER/2.5-P(6)*DLAYER/2.5
                    IF (IAGE.GT.LDRG)   RPGA = 0.0D0
C
C    ASSIGN THE DAY'S ROOT PHOTOSYNTHATE TO DIFFERENT ROOT ZONES.
C
               DO 1410 K = 1,MROOTD
                   RB(K) = RB(K)+RRGF(K)*RBG*(1.0D0-RPGA)
 1410          CONTINUE
C
C   ASSIGN ROOT PHOTOSYNTHATE FOR GEOTROPISM ACTIVITY.
C
             RB(MROOTD)=RB(MROOTD)+RPGA*RBG
 1412           TRB = TRB+RBG
          RETURN
          END
```

```
C    THIS SUBROUTINE ALLOCATES BARE SOIL EVAPORATION TO DIFFERENT
C    SOIL LAYERS OF THE PROFILE.
C
         SUBROUTINE ESDIST(ZSMCA.XKE,NORDZ,DLAYER,VSMCAD,ES,EX)
          IMPLICIT REAL*8(A-H,O-Z.$)
           DIMENSION PX(65),ZSMCA(65),VSMCAD(65).EX(65)
C
C     INITIALIZE THE VARIABLES
C
          DO 2000 K=1,NORDZ
2000        EX(K)-0.0D0
            TSUM = 0.0D0
         DO 2010 K = 1.NORDZ
               RK = K
              WLIM = (VSMCAD(K)*DLAYER)/100.0D0
               ZX = (RK*DLAYER-(DLAYER/2.0D0))/100.0D0
             PX(K) = (ZSMCA(K)-WLIM)*DEXP(-XKE*ZX)
 2010        TSUM = TSUM+PX(K)
C
          DO 2020 K = 1,NORDZ
                FX = PX(K)/TSUM
                EX(K) = FX*ES/10.0D0
 2020        ZSMCA(K) = ZSMCA(K)-EX(K)
          RETURN
          END
```

```
      SUBROUTINE STORAG(ISTRES,REMOVE,DEMAND,CFIXED,P,KP,I,FLPOOL,STPOOL
     1,DECLF,DECSTM,POOL,WTLEAF,TLFWT,STMWT,PTOPWT)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION P(100),FLPOOL(200),STPOOL(200),WTLEAF(200),PTOPWT(200)
      ISTRES=1
      REMOVE=(DEMAND-CFIXED)*P(13)
C
C P(13) IS MAXIMUM FRACTION OF PHOTOSYNTHATE DEFICIENCY WHICH CAN
C   BE SUPPLIED FROM STORAGE
C
      DO 55 LD=KP,I
      FPOOL=(FLPOOL(LD)+STPOOL(LD))*P(22)
      IF(FPOOL.LT.REMOVE)GO TO 110
      DECLF=DECLF+FLPOOL(LD)*REMOVE*P(22)/FPOOL
      DECSTM=DECSTM+STPOOL(LD)*REMOVE*P(22)/FPOOL
      WTLEAF(LD)=WTLEAF(LD)-FLPOOL(LD)*REMOVE/FPOOL
      FLPOOL(LD)=FLPOOL(LD)*(1.0-REMOVE/FPOOL)
      STPOOL(LD)=STPOOL(LD)*(1.0-REMOVE/FPOOL)
      POOL=POOL-REMOVE/P(22)
      REMOVE=0.0
      GO TO 56
  110 REMOVE=REMOVE-FPOOL
      POOL=POOL-FPOOL/P(22)
      DECLF=DECLF+FLPOOL(LD)*P(22)
      DECSTM=DECSTM+STPOOL(LD)*P(22)
      WTLEAF(LD)=WTLEAF(LD)-FLPOOL(LD)
      FLPOOL(LD)=0.0
      STPOOL(LD)=0.0
   55 CONTINUE
   56 KP=LD
      IF(REMOVE.LE.0.0)ISTRES=0
      TLFWT = TLFWT - DECLF/P(22)
      STMWT=STMWT-DECSTM/P(22)
      PTOPWT(I)=PTOPWT(I)-(DECLF+DECSTM)/P(22)
      CFIXED = CFIXED + DECLF + DECSTM
      RETURN
      END
```

```
      SUBROUTINE PODMAS(I,IACC,PODINC,GPODCT,P,CFIXED,PODACC,JPOD,JP,
     1PODWT,HARVWT,PODCT,XMATPD,GROPOD,PPODWT,KK,EPS,P16,PMAX,MAT
C  SUBROUTINE PODMAS COMPUTES THE DAILY INCREASE IN POD MASS
C  DETERMINES WHEN PODS ARE MATURE, AND CALCULATES HARVESTABLE
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION P(100),PODACC(200),PODWT(200),HARVWT(200),PODCT(200),
     1PPODWT(200),PMAX(200),MAT(200)
      PODINC = GPODCT * P16
C
C  PODINC IS THE G/M*M*DAY GOING TO POD DEVELOPMENT
C  GPODCT IS THE TOTAL NUMBER OF DEVELOPING PODS
C   P16    IS THE MAXIMUM RATE OF FILL FOR ONE POD
C
      IF (PODINC.GT.CFIXED) PODINC = CFIXED
      IF (PODINC.LT.0.0) PODINC = 0.0
      IF (GPODCT.GT.EPS) PODACC(I) = (PODINC/P(18))/GPODCT
C
C     P(18) IS 1 + THE POD GROWTH RESPIRATION RATE
C     PODACC(I) IS THE G ADDED TO EACH POD ON DAY I
C
      IF(IACC.GT.0)GO TO 59
      IF(GPODCT.GT.0.0)IACC=I-1
      JPOD=KK-1
      JP=I-1
C
C  PODCT(I) IS THE NUMBER OF PODS FORMED ON DAY I
C  PODWT(I) IS THE MASS OF PODS INITIATED ON DAY I
C  PMAX(I) IS THE MAXIMUM WEIGHT PODS MAY REACH BASED
C  ON THEIR MASS AT 28 DAYS
C  IACC IS DATE OF INITIATION OF OLDEST PODS
C
   59 JP2=I-1
      JP1=IACC
      DO 61 JJJ=JP1,JP2
      IF(PODWT(JJJ).LT.PMAX(JJJ))PODWT(JJJ)=PODWT(JJJ)+PODACC(I)
      IF(PODWT(JJJ).GT.P(39))HARVWT(I)=HARVWT(I)+PODWT(JJJ)*PODCT(JJJ)
C  P(39) IS THE MINIMUM POD MASS CONSIDERED HARVESTABLE
      IF(PODWT(JJJ).LT.PMAX(JJJ))GO TO 60
      IF(MAT(JJJ).GT.0)GO TO 61
      MAT(JJJ)=1
      GPODCT=GPODCT-PODCT(JJJ)
      XMATPD=XMATPD+PODCT(JJJ)*PODWT(JJJ)
      GROPOD=GROPOD-PODCT(JJJ)*PODWT(JJJ)
   60 GROPOD=GROPOD+PODCT(JJJ)*PODACC(I)
   61 CONTINUE
      IF(I.GT.28)PMAX(I-28)=PODWT(I-28)*P(19)
C
C     THIS LOOP MATURES PODS WITH MASS GREATER THAN PMAX(JJJ),
C  GPODCT IS REDUCED ACCORDINGLY, AND A MASS (G/M*M) OF MATURE
C    IS ACCUMULATED
C   XMATPD=TOTAL WT. OF MATURE PODS
C   GROPOD = TOTAL WT. OF GROWING PODS
C
      PPODWT(I) = XMATPD + GROPOD
      RETURN
      END
```

```
      SUBROUTINE PEGMAS(I,IAC,PEGINC,P,GPEGCT.CAVAIL,EPSI,PEGACC,PEGWT,
     1PGMACT.PEGCT.IP24,XMPGCT,K)
C
C    SUBROUTINE PEGMAS COMPUTES THE DAILY INCREASES IN PEG MASS .
C     DETERMINES WHEN PEGS ARE MATURE, AND KILLS OLD PEGS
C
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION  PEGWT(200),PGMACT(200).PEGCT(200),P(100)
      PEGINC = GPEGCT * P(21)
C
C     PEGINC IS THE G/M*M*DAY GOING TO PEG DEVELOPMENT
C
      IF (PEGINC.GT.CAVAIL) PEGINC = CAVAIL
      IF (PEGINC.LT.0.0) PEGINC = 0.0
      IAC=IAC+1
      IF(GPEGCT.LT.EPSI)GO TO 10
      PEGACC=(PEGINC/P(22))/GPEGCT
C
C     PEGACC     IS THE WEIGHT ADDED TO ONE PEG ON DAY I
C
      JJ1=I-IAC
      JJ3=I-1
      DO 36 JJ2=JJ1,JJ3
      PEGWT(JJ2)=PEGWT(JJ2)+PEGACC
      IF(PEGWT(JJ2).LT.P(23))GO TO 36
      GPEGCT=GPEGCT-PEGCT(I-IAC)
      XMPGCT=XMPGCT+PEGCT(I-IAC)
C
C    XMPGCT IS NUMBER OF PEGS THAT ARE AVAILABLE FOR POD FORMAT
C
      PGMACT(I-IAC)=PEGCT(I-IAC)
      PEGCT(I-IAC)=0.0
      IAC=IAC-1
   36 CONTINUE
   10 IF(IAC.LT.IP24)GO TO 38
      GPEGCT=GPEGCT-PEGCT(I-IAC)
      IAC=IP24-1
      GO TO 103
   38 IF(I-IP24.LT.K)GO TO 103
      XMPGCT=XMPGCT-PGMACT(I-IP24)
      PGMACT(I-IP24)=0.0
  103 RETURN
      END
```

```
      SUBROUTINE PEGSTR(I,IACC,P,PODCT,PODWT,PBLOSS,MAT,PSTR,BLOSS,TAV,
     1XM)
      IMPLICIT REAL*8(A-H,O-Z)
      DIMENSION P(48),PODWT(200),PODCT(200),MAT(200),PBLOSS(200),
     1PSTR(200)
      C=P(44)*(TAV-273.0)/XM
      IF(C.LT.0.0)C=0.0
      C2=P(45)/(P(46)+XM)  +P(47)*XM*XM
      DO 30 J=IACC,I
      IF(MAT(J).EQ.1)PSTR(J)=PSTR(J)*DEXP(-C)
      IF(PODWT(J).LT.P(39))GO TO 30
      PBLOSS(J)=C2*PODWT(J)/PSTR(J)
      IF(PBLOSS(J).GT.1.0)PBLOSS(J)=1.0
      BLOSS    =BLOSS    +PODWT(J)*PODCT(J)*PBLOSS(J)
   30 CONTINUE
      RETURN
      END
```

APPENDIX F

YOUNG'S MODEL SOIL INPUTS FOR THE FOUR SITES

Site	Initial M. C.	Coeff. A	Coeff. B
4A	19.0	0.12	15.0
	22.0	0.16	16.0
	25.0	0.14	20.0
	26.0	0.13	20.0
	24.0	0.12	19.0
	24.0	0.11	19.0
	23.0	0.05	21.0
	23.0	0.05	20.0
6B	16.0	0.18	11.3
	21.2	0.15	15.7
	34.0	0.10	27.4
	32.0	0.10	25.4
	28.8	0.13	21.5
	26.0	0.12	19.8
	23.4	0.11	18.2
	22.0	0.12	17.0
9A	18.0	0.25	14.0
	21.0	0.20	14.0
	20.0	0.18	14.0
	20.0	0.17	14.0
	20.0	0.16	14.0
	20.0	0.15	14.0
	19.0	0.13	14.0
	18.0	0.12	14.0
10A	26.0	0.29	15.0
	30.0	0.21	19.0
	25.0	0.17	17.1
	20.0	0.17	14.0
	17.5	0.20	13.0
	15.6	0.16	12.0
	15.0	0.17	11.6
	14.0	0.17	10.6

M. C. = Moisture content (% by volume)

VITA

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