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GOSSYM: A SIMULATOR OF COTTON CROP GROWTH AND YIELD

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Introduction and Objectives

The feasibility of building simulation models of plant growth and yield has recently been demonstrated and models of cotton, corn, alfalfa, soybeans, peanuts, sugar beets, wheat, and sorghum are now available. Such models have been developed at research locations in the United States, England, Australia, and the Netherlands. They have in common that they are materials balances and that they are process oriented simulation models. Most of this work may be viewed as a natural extension of the growth analysis work in England beginning with Fisher (1921) and Gregory (1917) and the later work of Watson (1947), and in the USSR, the work of Nichiporovich (1954). The experimental research in crop canopy photosynthesis of Musgrave and his students in the U. S. (Moss et al., 1961, Baker et al., 1964), and that of Murata (1961) in Japan, as well as the static modeling of crop canopy photosynthesis by Monsi and Saeki (1953) in Japan, Duncan et al. (1967) in the U. S., de Wit (1965) in the Netherlands, and Ross (1969) and Tooming (1967) in the USSR immediately preceded our work in the effort to predict the dynamics of growth and yield of field crops.

Our objective in developing GOSSYM is to identify and assemble the factors determining cotton growth and yield in a format which will aid system design (breeding and new cultural practices and combinations thereof), crop management decision making at the farm level, and yield forecasting. Thus, we see this effort as an ongoing process of identifying and mathematically testing (sensitivity analysis) the factors determining cotton growth and yield and of synthesis, in which these factors are assembled for rational use by agronomists and farm managers.

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General Model Strategy, Characteristics, Features and Rationale

Since cotton has a tremendous ecological range, the above objectives imply a general model capable of simulating crop growth over a wide range of climates and soils. Since different environmental factors affect different physiological processes in different ways and because we view the model development as an ongoing affair in which new ideas and information about the crop are incorporated as needed and as they become available, a process-related modular structure was indicated.

The model is dynamic because photosynthesis, respiration, and growth change rapidly with temperature, light intensity, and plant water status. Except for pollination and organ abscission, the plant processes are continuous; therefore, the model must be essentially continuous. We have, however, found it permissible and appropriate to use discrete time steps which, depending on the process being simulated, vary in length. This permits great savings in the computer time required to run the model. Length of the time steps for various processes must be determined mathematically by evaluating size and distribution of errors generated by using progressively longer time steps.

GOSSYM, like most simulators of plant growth, is a materials balance. The concept is introduced in Figure 1. Here, standard systems dynamics notation is used, rectangles represent pools of material of definite size, pools of indefinite size are represented by the irregular enclosures, the valve shaped characters represent regulators of the rates of flow between pools, solid lines represent material flows, and dashed lines (to the flow valves) represent information flow. The plant model contains pools of nitrogen and labile carbohydrates which arrive via the transpiration stream and the photosynthetic processes, respectively. These materials flow (through growth) to the leaves, stems, fruit, and roots. Various losses occur as a result of insect damage and the natural plant processes: senescence and abscission occur in response to physiological stress. The model depicts the redistribution (mining) of nitrogen within the plant. The initiation of organs on the plant (not depicted in the figure) occurs as a series of somewhat more discrete events, with rates depending on temperature and the physiological status of the plant.

In general, the plant's responses to environmental factors are as follows: photosynthesis depends on light intensity and canopy light interception and is reduced by water stress. Respiration depends on temperature and plant biomass. Growth is a function of temperature, tissue turgor, and metabolite supply. Thus, plant water status is a determinant of both supply and demand for metabolites. Water stress reduces photosynthesis, transpiration, and nitrogen uptake. Water stress also (at a different level) reduces growth and the demand for nutrients. The supply:demand ratios for carbohydrate and nitrogen are used as indices of stress-induced time delays for morphogenetic events. Here we assume that the metabolite supply:demand status of the plant determines (or shifts) hormone balances which alter the morphogenetic rates. This status also determines or shifts the balance in hormone systems which result in the abscission of fruit. Thus, while morphogenetic rate is driven by temperature, it is affected indirectly by those factors determining the supply and demand for carbohydrate and

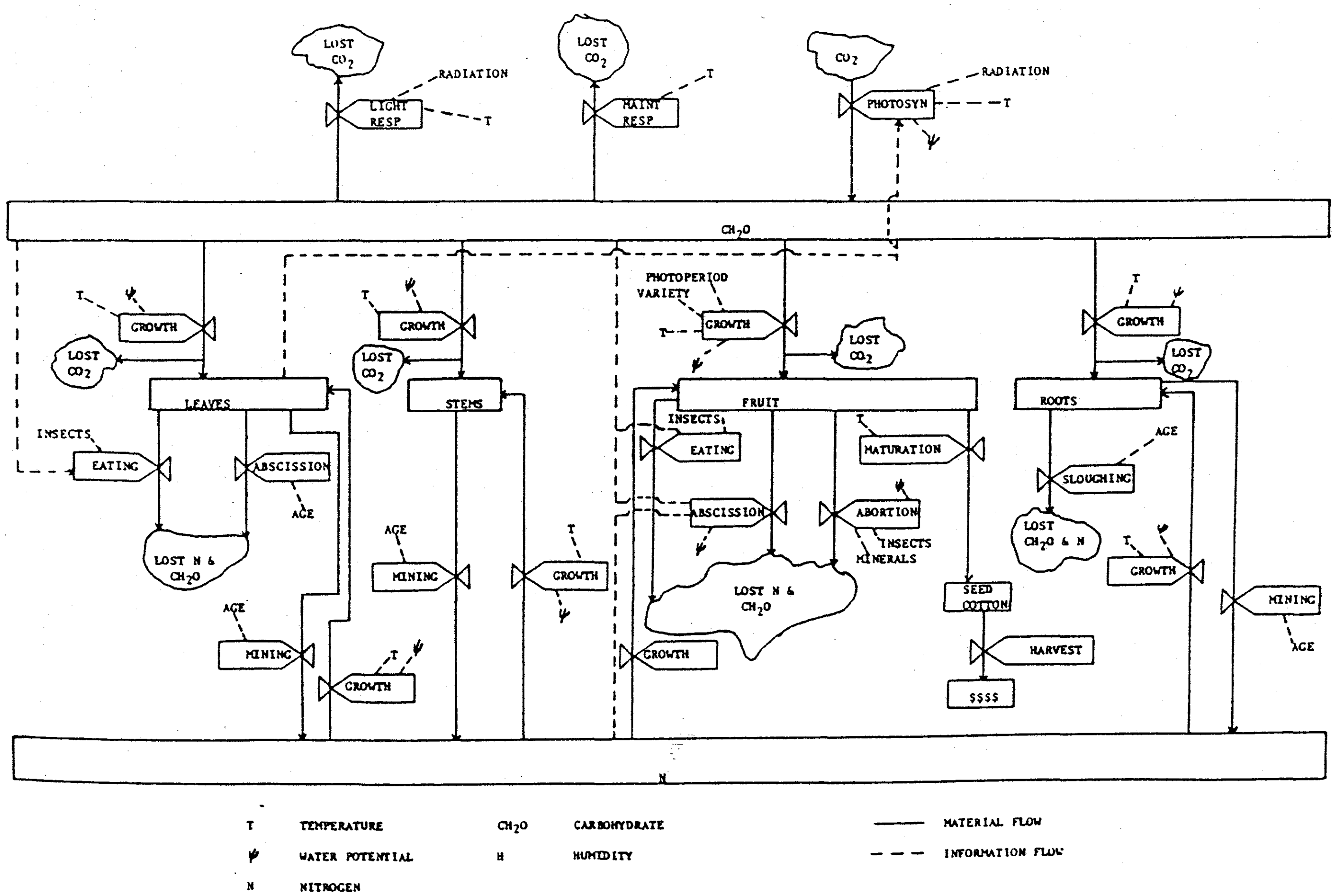


Figure 1. A systems dynamics conceptualization of the nitrogen and carbohydrate materials balance in cotton.

nitrogen. Thus, severe moisture stress and a heavy boll load may combine to stop new node formation, while a mild moisture stress which reduces growth (demand) more than supply (photosynthesis) may have no effect on or may cause a relative increase in morphogenetic rate.

GOSSYM differs from most other crop models in that it incorporates a rather extensive simulator of the soil processes including root growth, called RHIZOS. While the source listing included here (Appendix A) includes the RHIZOS section, a detailed description is provided in a separate paper (Lambert and Baker, 1984). RHIZOS is designed to serve as a general rhizosphere model for all crops providing the aboveground sections with three parameters: an effective soil water potential which is used to calculate plant water potential, an estimate of metabolite sink strength in the roots, and a nitrogen uptake rate.

The Appendix contains a source listing, a typical input data set, and a dictionary of terms, including those from RHIZOS. The source is heavily commented both to make it readable and to cite the contributions of others. An attempt has been made to cite in the source every person who contributed ideas or data either via publications or personal communications. There are many.

To facilitate program development and updating, labelled commons were chosen as a means of passing information in and out of subroutines. Just after the first block of labelled commons (ref. Appendix A), a block data section appears in which the variables are initialized. These variables are arranged alphabetically by number of characters for accessibility.

The Subroutines

MAIN

MAIN calls the subroutines and performs a few calculations pertaining mostly to input/output. A simplified flow charting of the model appears in Figure 2. A detailed flow chart labelled MAIN follows. This chart also contains detailed notes on the operational steps in MAIN. The first subroutine called is READ, which brings into the model the latitude, the daily weather data for the growing season, and the pertinent cultural data. READ has an error checking section which flags out-of-range weather data. Information on time and rates of application of nitrogen, varietal information, and leaf type are also input in READ.

Most of the subroutines are called daily from the large DO loop labelled 998. SOIL calls most of the RHIZOS subroutines. It calculates soil water potentials and the amount of nitrate taken up by the plant each day.

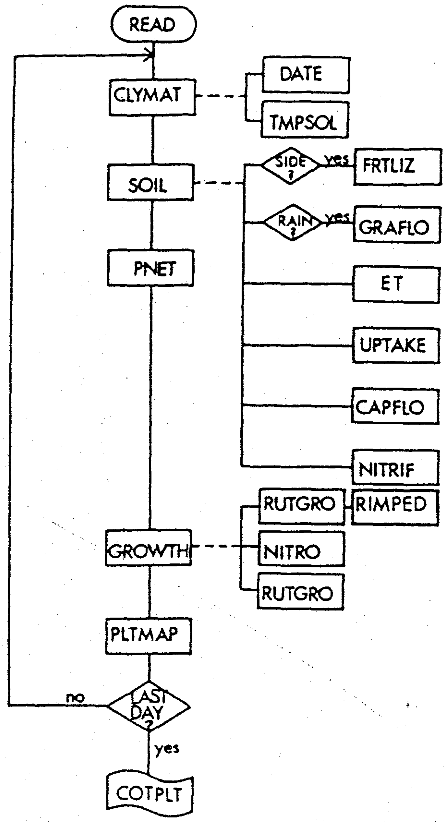


Figure 2. The subroutine structure of GOSSYM.

The daily increment of dry matter produced is calculated in PNET and distributed to the various growing points in the plant in the subroutine GROWTH. GROWTH calls RUTGRO, a RHIZOS subroutine, which calculates root growth. GROWTH also calculates the carbohydrate stress and calls NITRO which calculates nitrogen stress and allocates the nitrogen, which has been taken up, to the various plant parts.

All morphogenetic processes as well as records of the abortion of leaves and fruit are handled in PLTMAP. PLTMAP calls the subroutine COTPLT which produces a facsimile diagram of the aboveground plant structure (cf. Figure 3).

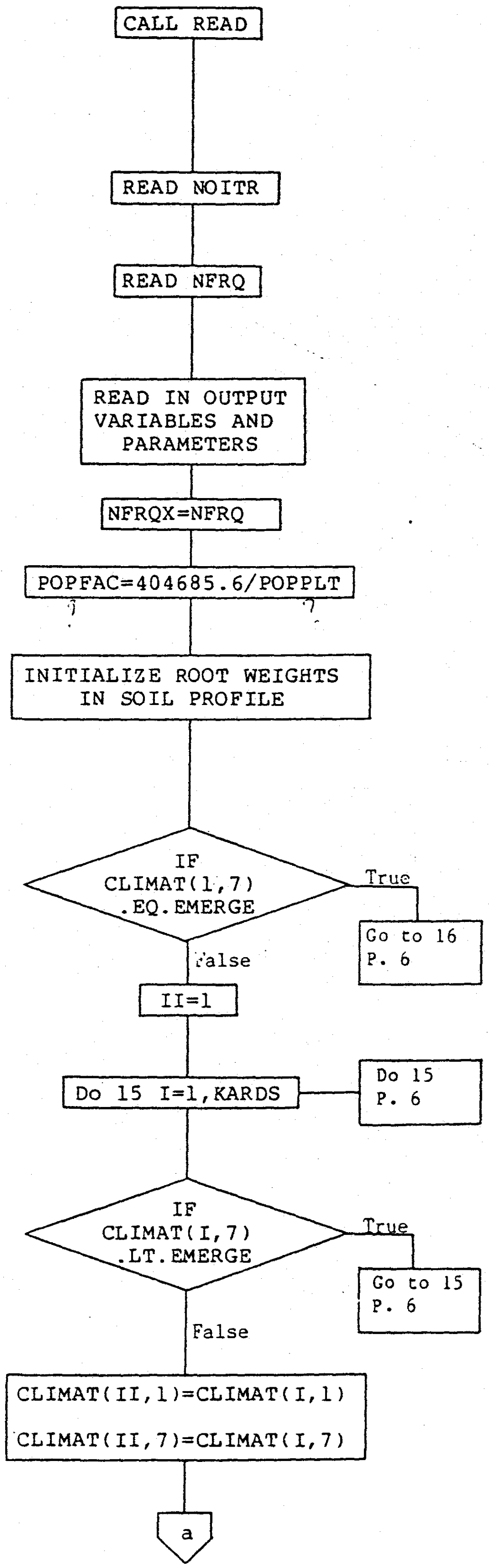
```
          I-X
        X-I
          I-0-X
      X-0-I
          I-0-0-X
    X-0-0-I
          I-0-0-0-X
  X-0-0-0-I
          I-0-0-0-X
X-0-0-0-*-I
          I-0-0-0-0-0
X-0-0-*-0-I
          I-$-0-0-0-X
          I
          I
          I
          I
          I
```

```
    I-X
  0-I
    I-0-X
X-0-I
    I-X-0-0-X
    I
    I
```

Figure 3. A typical daily map of the fruiting in GOSSYM. "I" and "-" represent mainstem and fruiting branch internodes, respectively. "$", "*", "O", and "X" represent nodes with open bolls, green bolls, aborted fruit, and squares, respectively. The figure on the right represents a monopodial structure attached to the fifth mainstem node.

MAIN

Flowchart



Subroutine READ brings in the daily weather data as well as plant population, rowspacing, emergence date, length of season, latitude of the site and varietal information from disc file. Device 2 is an interactive terminal.

NOITR sets the number of iterations per 12 hours for the solution of Darcian flow equations in RHIZOS. ?

NFRQ provides days between output(plant and soil diagrams.)

Parameters read here are used in some rate equations and decisions points to vary performance of the model.

Calculates the dm^2 ground area per plant.

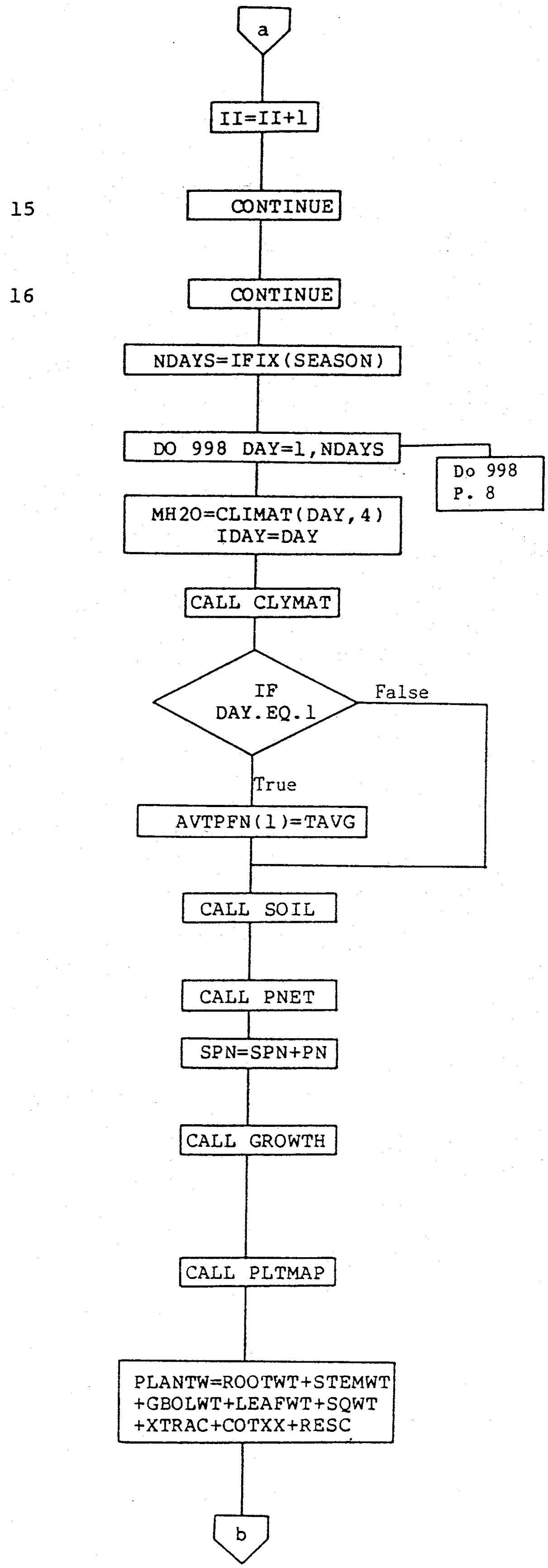
These root weights are in grams per 25 cm^3 of soil.

Has the crop emerged?

Set day number index.

Has the crop emerged?

Remember climate data in terms of days from emergence rather than julian date.



Number of days = integer season.

This is the main do-loop of the model. (Takes daily time steps).

Check the mode of water application (furrow irrigation or rainfall).

Refer to CLYMAT: produce average temperatures in C, net radiation, light interception, and soil temperatures

Initialize the running average temperature of the first node.

Refer to SOIL: produce soil water potentials and the amount of nitrate taken up.

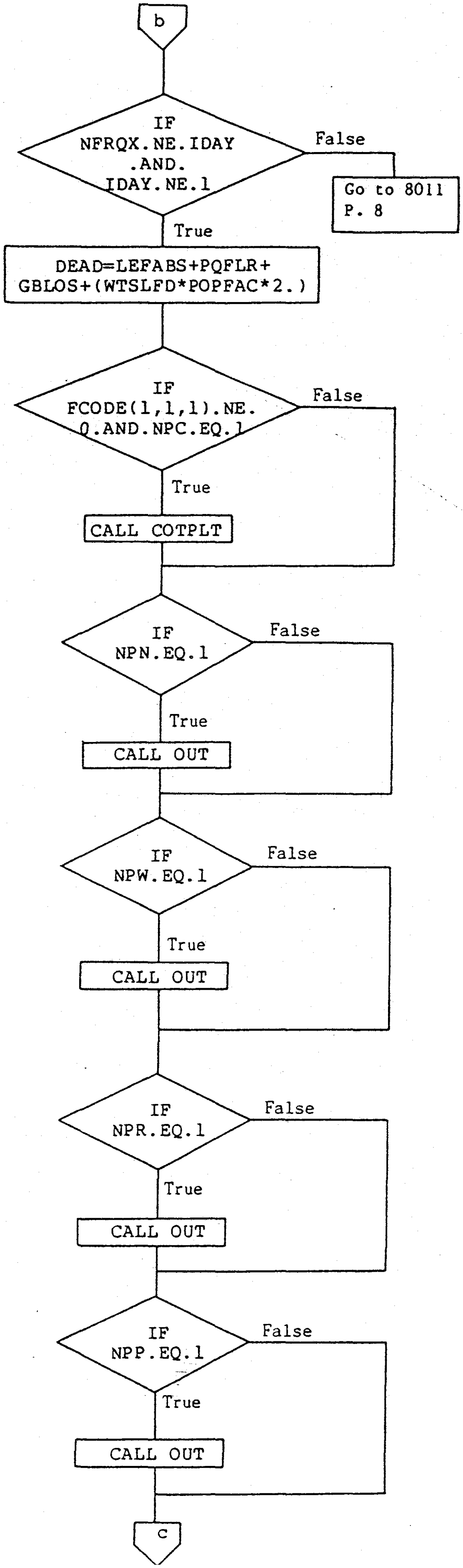
Refer to PNET: produce carbohydrate.

Sum dry matter produced to date.

Refer to GROWTH: allocate carbohydrate and nitrogen to each growing point on the plant. Update the materials balance accounting for sloughing of roots and abscission of leaves and fruit.

Refer to PLTMAP: update ages of all organs. Initiate new organs at appropriate times depending on temperature and metabolic stress levels.

Calculate total plant weight.



Update the running total of dead weight loss from the plant.

If the plant has reached first square and a plant map output is called for on this day,

call COTPLT.

If the output map of nitrate content in soil matrix is called for today,

call OUT.

If the output map of the volumetric water content in the soil matrix is called for today,

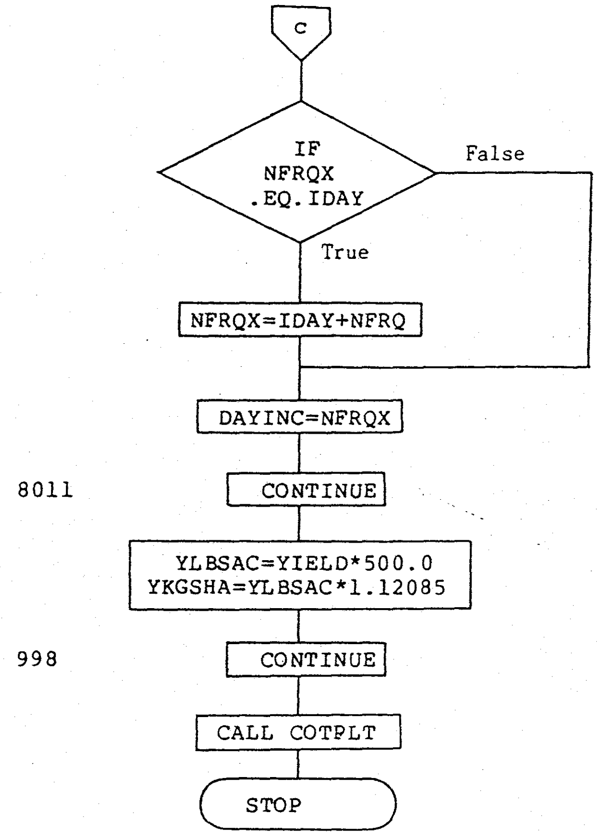
call OUT.

If the output map of the total root weight in each cell of the soil matrix is called for today,

call OUT.

If the output map of the soil water potential is called for today,

call OUT.



YLBSAC = lint yield in lbs. per acre.
YKGSHA = lint yield in kgs. per ha.

On the last day of the season, draw the plant map.

CLIMAT

Daily Class A weather station temperatures are converted to centigrade, and rainfall is converted to millimeters in CLIMAT. Empirical relationships based on data collected in Mississippi over cotton are used to estimate net radiation from solar radiation, and the average temperatures during daytime (TDAY) and nighttime (TNYT) are estimated from the maximum and minimum temperature data. These relationships are somewhat location specific and should be checked before any attempt is made to use the model to simulate crops in other regions.

The data used to establish the relationship between solar radiation (RI) and net radiation (RN) are presented in Figure 4. We found very little scatter in the Aug. 19, 1963, data, but more in the data from Sept. 16 and 18, 1969. A single straight line has been used to fit the pooled data set.

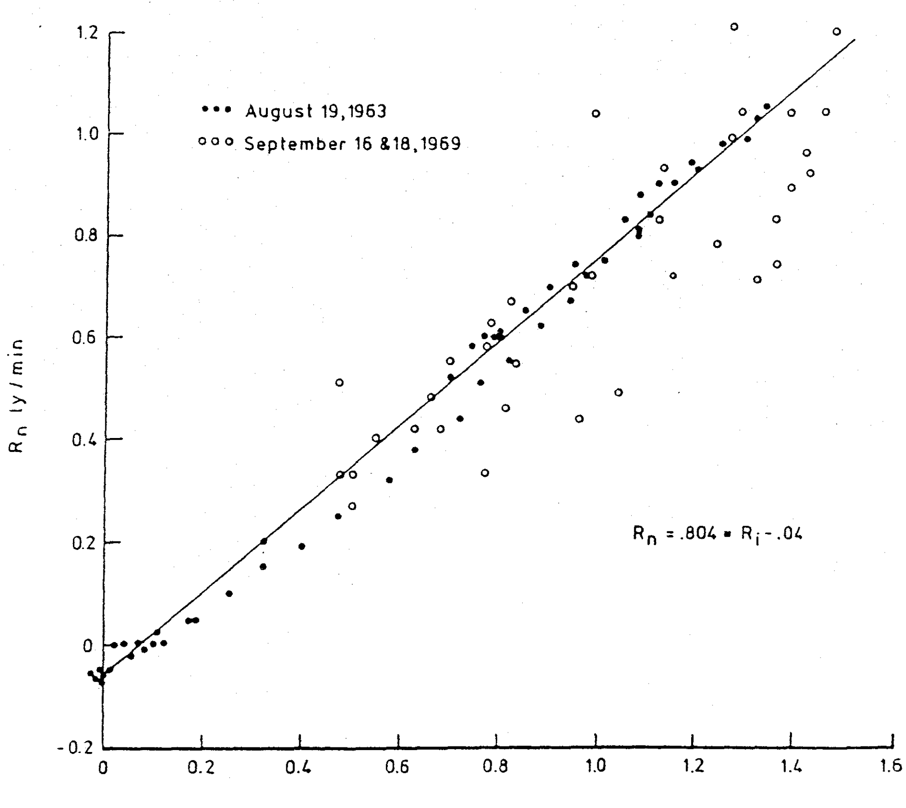
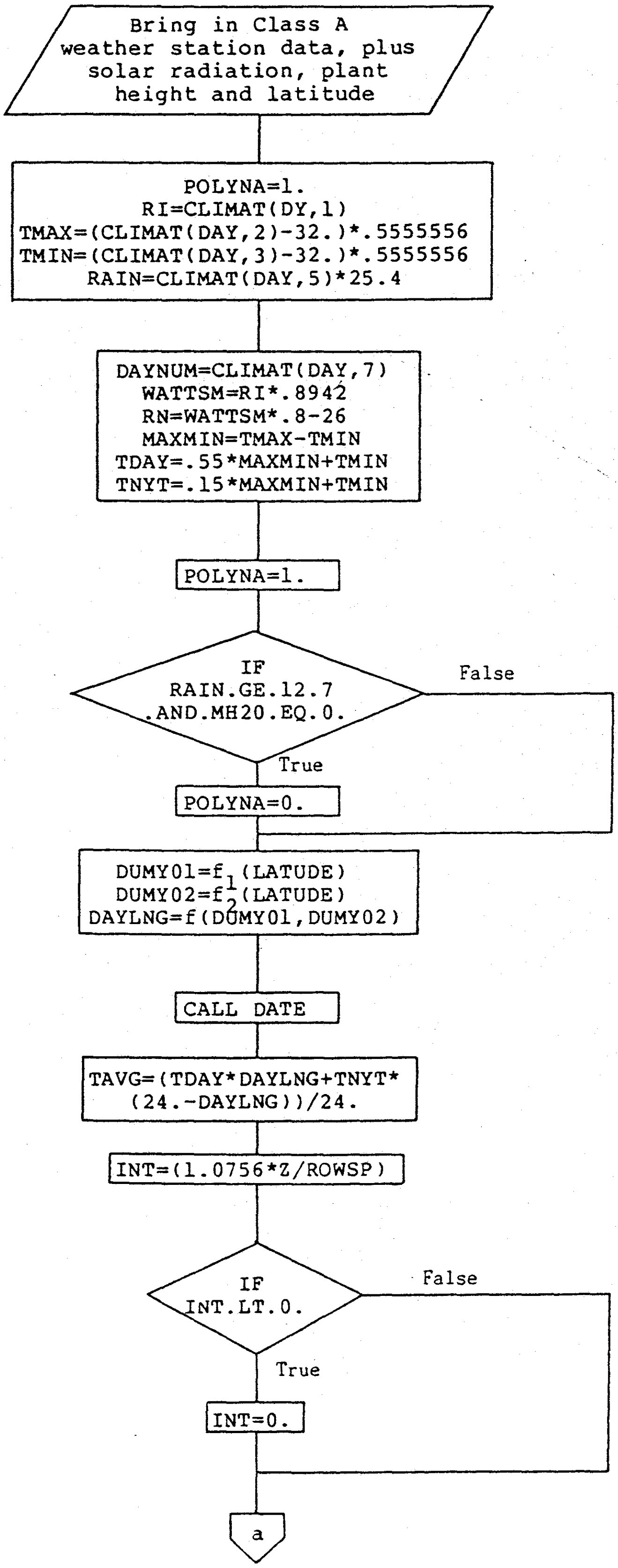


Figure 4. Net radiation flux density in two cotton crops vs. solar radiation flux density.

SUBROUTINE CLIMAT

Flowchart



R_i is in langleys per day. Convert temperatures to degrees C and rain to mm.

Define julian day number, convert daily total solar radiation to average watts/ cm^2, calculate average net radiation and calculate the average temperatures during the daytime and nighttime periods.

If a rain greater than 12.7 mm occurred or an overhead irrigation was applied, set switch to abscise blooms.

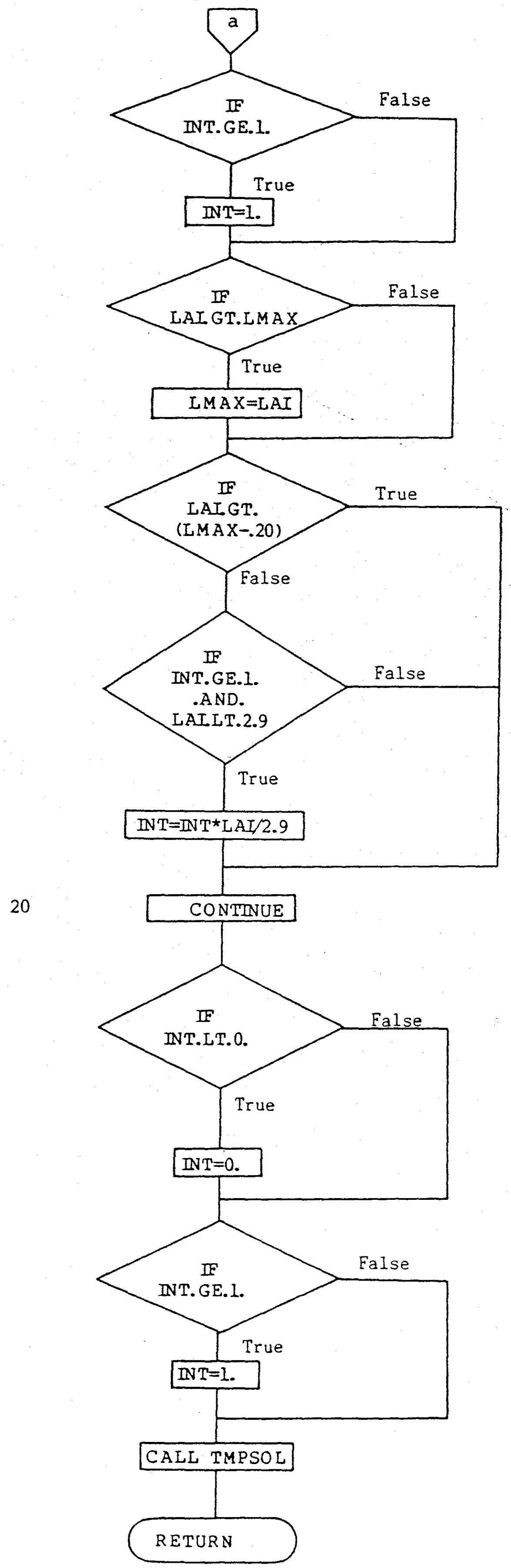
Calculate the photoperiod from latitude of the site and the julian date (see code lines no.'s. 446-448, p. 100).

Call DATE to get month and day from julian date.

Calculate daily average temperatures.

Calculate average daily fractional canopy light interception from plant height and rowspacing.

CLIMAT (2)



Calculate peak leaf area index.

Once we reach peak leaf area index, and we have a closed canopy-and if the leaf area index is below 2.9, redefine INT to allow for light "leakage" throughout the canopy to the soil surface.

SOIL

The reader is referred to *RHIZOS: A Simulation of Root and Soil Processes I.* (Lambert and Baker, 1984) for a detailed description of the subroutines called from SOIL. However, a brief statement of function is offered here.

In general, the purposes of the RHIZOS section of GOSSYM are as follows:

(a) to provide the plant with mineral nutrients (especially nitrogen).

(b) To provide soil water potential information from the root zone for the calculation of plant turgor levels and leaf water potentials. The leaf water potentials, in turn, are used to estimate water stress induced reductions in growth.

(c) to provide the aboveground model with an estimate of the root sink strength for carbon and nitrogen compounds.

RHIZOS, a two-dimensional model, considers a cross section of the soil under one row. Both dimensions of the section are variable, the width being row width, one meter being the commonest depth. This section of soil is one cm thick and is assumed to be longitudinally representative of the row. The section is subdivided into a 20X20 matrix. It keeps a daily record of the amount of water, nitrate and ammonium nitrogen, and root material in each cell of the matrix. An age vector of root mass is maintained and used to estimate root growth and water uptake.

Fertilizer may be added at any depth and either broadcast or banded any distance from the row. If fertilizer is to be added on a given day, FRTLIZ is called.

If rainfall or irrigation occurs, GRAFLO is called to distribute the water vertically in the profile. Ammonium ions are assumed to be stationary and adsorbed on soil colloids. Nitrate nitrogen, on the other hand, is assumed to be in solution and to move vertically with the soil water.

An evapotranspiration routine (ET) adapted from Ritchie (1972) is used to provide an empirical estimate of water removed from the profile each day. This amount of water is simply imposed on the UPTAKE subroutine.

During stage I drying, water is removed from the sunlit cells of the top layer of the matrix in UPTAKE.

Transpiration losses occur from those cells containing roots. The amount taken from a given cell depends on the amount and age distribution (permeability) of the roots in the cell.

Redistribution of water and nitrate nitrogen within the soil profile occurs in CAPFLO.

The mineralization of organic nitrogen and the nitrification of ammonium nitrogen to nitrate occurs in NITRIF.

PNET

As stated earlier, GOSSYM is a materials balance model, i.e., each day of the growing season an increment of dry matter is produced and distributed to the growing points in the plant. The end point yield, then, is the dry weight of the lint (or lint plus seed).

We have recently reviewed the subject of canopy photosynthesis (Baker et al., 1978). A number of factors were considered in the choice of approach to the problem of estimating canopy photosynthesis. The static models cited on page 1 consider the leaf as the basic photosynthetic element. They treat an exceedingly complex subject requiring a vast amount of input data describing the physical location, the microclimate, and the angular orientation of each leaf element in the canopy, and this information must be provided continuously throughout the day. To accurately estimate total canopy performance, these static models also require the age, the developmental history, and the current nutritional status of each leaf element. All this can be provided in a model, but at considerable expense.

In addition to the complexity involved, these static leaf element models present three other difficulties. First, none of them has ever been validated. The best that has been done is to compare them with weekly dry matter accumulation data–which is somewhat analogous to using a calendar rather than a stop watch to measure the pulse rate of a heart patient. Second, they do not correctly account for plant respiration. They simply assume that some fixed fraction of photosynthate is consumed in respiration. This becomes a fatal error in the attempt to use these static models in a dynamic form since respiration is a function of quantity of biomass. Finally, these static models assume a horizontally uniform distribution of leaves which is not appropriate in a row crop.

All of these difficulties could have been overcome with effort, but the result would have been a rather inconsistent patchjob at best. We chose instead to take a more empirical approach, treating the entire intact plant canopy as the photosynthetic element. There is abundant precedent for this approach in the literature (Baker, 1978) and it leads more directly and more precisely to the quantity of dry matter produced by the crop. This approach depends, however, on the availability of a set of canopy photosynthesis-respiration data collected in a crop of known biomass.

In 1971 Hesketh et al., (1971) and in 1972, we (Baker et al., 1972) published a data base for the calculation of respiration and photosynthesis under abundant soil moisture conditions. A correction for the effect of water stress effects was derived from other (unpublished c.f. Baker et al., 1969) data.

In September of 1970 an experiment was conducted in which canopy gas exchange rates were measured under conditions of abundant soil moisture and fertility. The apparent photosynthesis data (P_N) were fitted to a multiple regression model with linear and quadratic terms for light intensity, air temperature, vapor pressure deficit, and all first order interactions. A multiple R^2 of 0.96 was obtained. This model was used to calculate the points in Figure 5. This experiment encompassed measurements on two different 4 m^2 sections of crop (two setups, one later than the other) with differing biomasses. The data from the two are pooled. Soil suction was maintained at or above -0.4 bars, temperature ranged from 25 to 40°C, light intensity ranged from dark to full sun, and vapor pressure deficits ranged up to 23 mb.

After the apparent photosynthesis measurements were completed in each setup, a series of respiration measurements was made. The chamber, after 20-minute periods of photosynthesis at various temperatures and light intensities, was quickly darkened and the rate of CO_2 evolution from the crop was measured. Those data are presented in Figure 6. Expressed on a per unit dry weight of plant basis, there is no difference in the results obtained in the two setups although the second setup had a heavier fruit load.

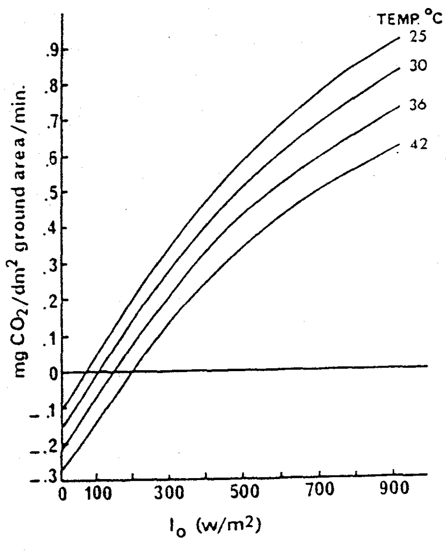
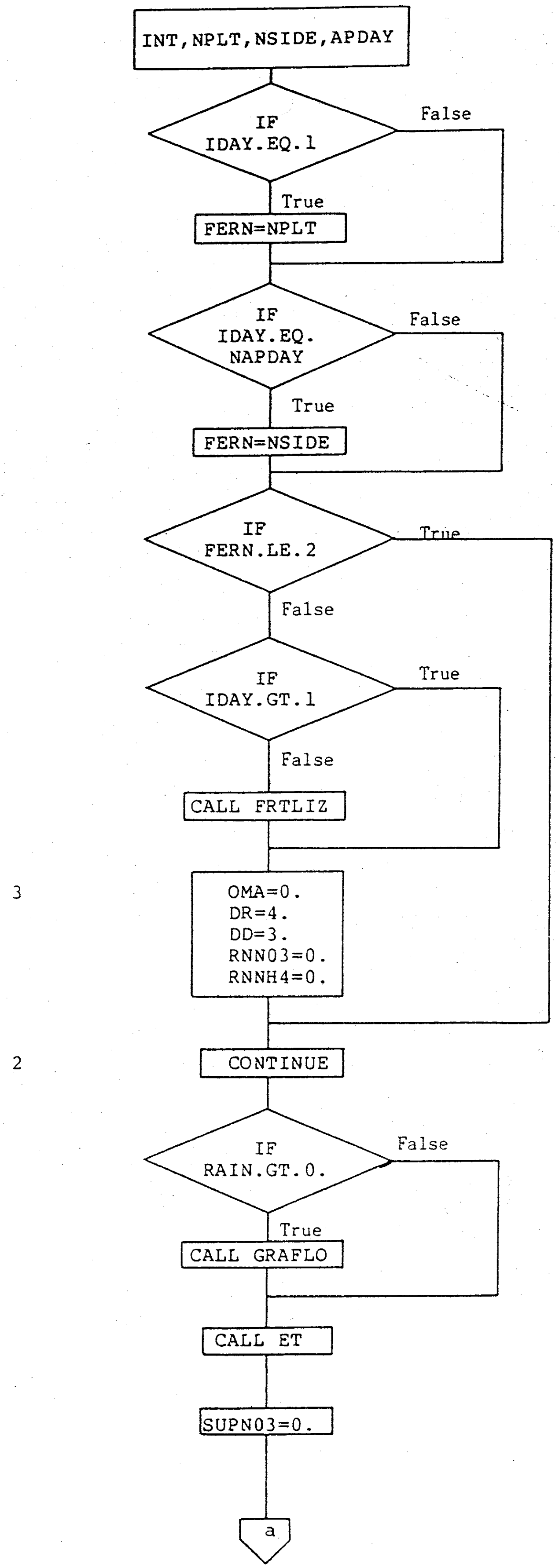


Figure 5. Apparent photosynthesis vs. light intensity at a vapor pressure deficit of 10 mb.

SUBROUTINE SOIL

Flowchart



Bring in these variables.

If today is the day of emergence, then the fertilizer to be applied is broadcasted at planting.

If today is a day of fertilizer application, the fertilizer applied is side-dressing.

If today is the day for side-dressing,

call FRTLIZ.

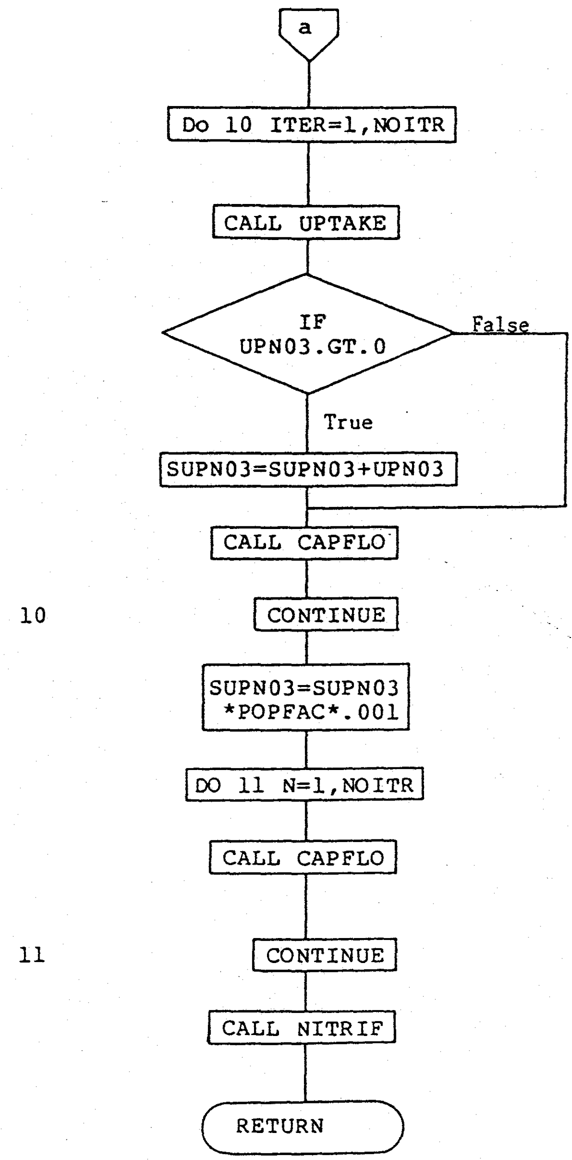
At emergence, deposit residual organic matter in top 20 cm of soil and broadcast at planting fertilizer in the top 20 cm. If side-dressing, place fertilizer at proper depth and proper distance from the row, and define amount of organic matter and locations of fertilizer band for side-dressing.

If it rained today,

Call GRAFLO, to distribute water vertically in the profile.

Call ET to calculate evapotranspiration from crop surface today.

SOIL (2)



call UPTAKE to remove water from each of the cells in the soil matrix in proportion to the amount and age of the roots in each cell.

Total the nitrate taken up from all of the soil cells.

Redistribute remaining soil water and nitrate.

Convert nitrate taken up from a per unit ground area basis to a per plant basis.

Call CAPFLO to finish the redistribution (nighttime) of water and nitrate in the soil profile.

call NITRIF to perform soil nitrogen transformations in each soil cell.

Close inspection of the data in Figure 6 revealed that all the points well above the line had been obtained after exposure to very bright light, and the points below the line were obtained after exposure to rather low light intensities. Therefore, we fitted these data to the model $R = a + b_1 I_o + b_2 T + b_3 I_o^2 + b_4 T^2 + b_5 I_o T$, where I_o and T were the average light intensity and temperature respectively, during the measurement period. Assuming that at $I_o = 0$, P_N is entirely respiration, we included the four P_N values for $I_o = 0$ from Figure 5 among the data. As expected the terms containing I_o in this analysis were all highly significant. Again, a multiple R^2 of 0.96 was obtained.

Entering this model with appropriate light intensity and temperature data, a respiration rate was calculated for each of the P_N values. Gross photosynthesis (P) was then computed from the expression,

$$P = P_N + RW \qquad (1)$$

where W is dry plant biomass and R is respiration coefficient. These data points are graphed in Figure 7. They represent crops of differing biomass (respiration rates) and differing conditions of temperature and vapor pressure deficit. We fitted these data to a multiple regression model to separate the effects of temperature and VPD over this range. The analysis showed both factors to be significant but neither changed the estimate of P by as much as 5% over the range of the experimental conditions. Therefore, we have used a simple quadratic to fit the curve in Figure 7 as the basis for the next step in the development.

Finally, because of the large response in cotton photosynthesis to CO_2 and, because of the fact that large geological reserves of nearly pure CO_2 exist, (Baker et al., 1970) suggesting a possibility of CO_2 fertilization, special experiments have been done to establish the application

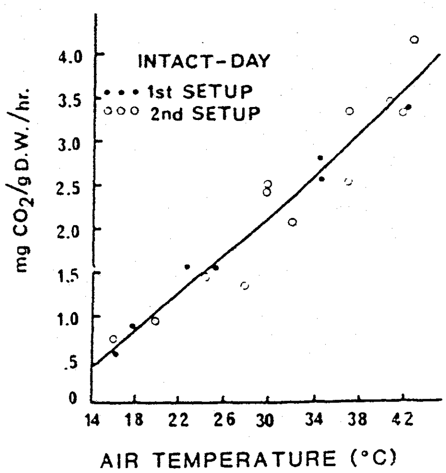


Figure 6. Respiration vs. air temperature. Total dry weights of above-ground plant parts for the first setup and second setup were 3542 g and 3910 g respectively.

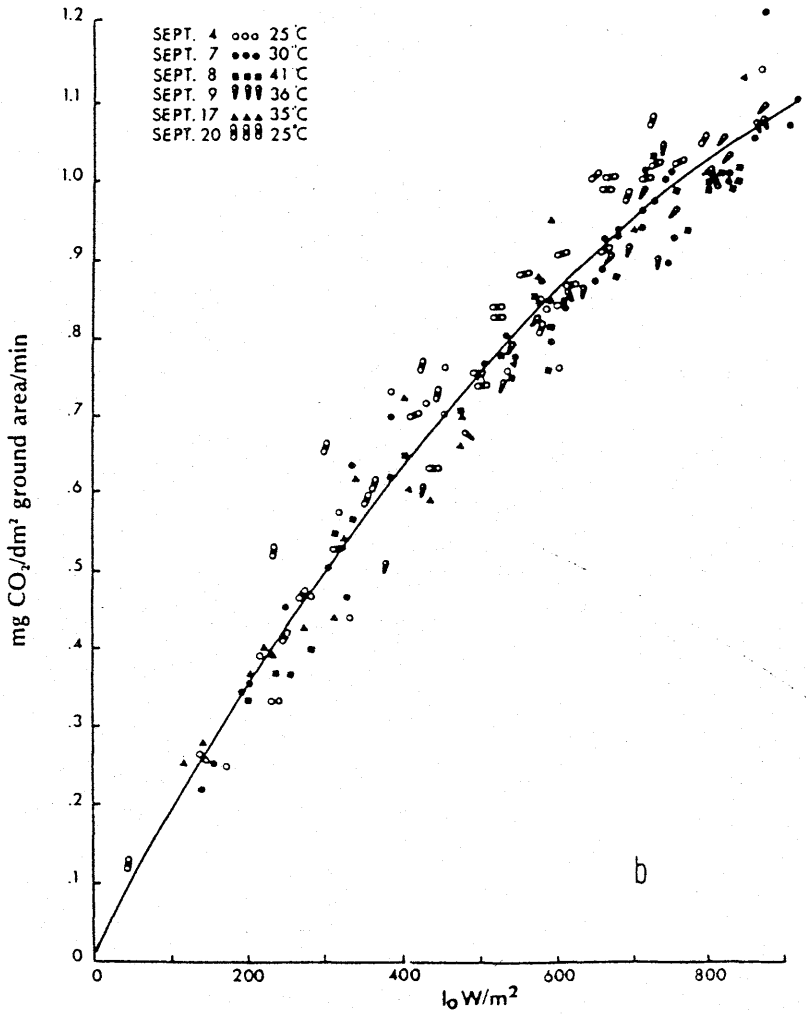


Figure 7. Gross photosynthesis vs. light intensity in cotton crops of different weights and at various air temperatures and vapor pressure deficits.

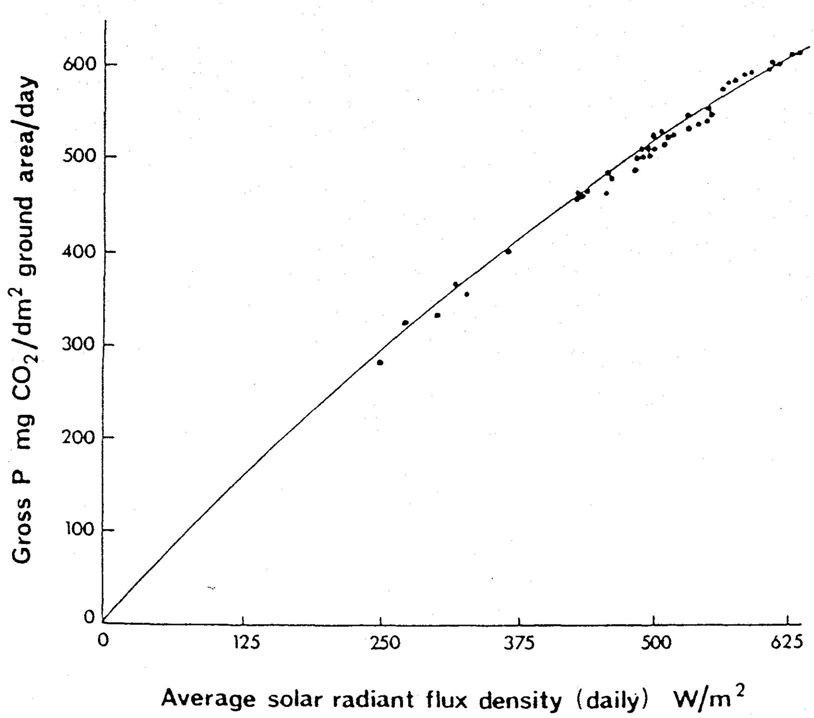


Figure 8. Photosynthesis vs. solar radiation flux density.

rates needed to elevate the CO_2 concentrations in cotton canopies (Harper et al., 1973). Based on the data from those experiments, an adjustment in photosynthetic efficiency has been added to PNET to account for the effect of adding 222.6 kg/ha/hr of CO_2 over the 6-hour midday period. The added CO_2 results in an increase in daily photosynthate yield of 40.5 percent.

Application of this model in most cases, e.g. farm management decision making, requires that it operate satisfactorily on solar radiation daily totals since hourly or quarter hourly values are unlikely to be available. The next step, then, was the random selection of 47 days of solar radiation data from the summer of 1970. The data were for dates from June 11 to October 1. Daily radiation totals ranged from 277 (Langleys) on a continuously overcast rainy day to 698 on a perfectly clear day. Sunrise to sunset hourly values of potential canopy photosynthate production were calculated using the quadratic equation above. The hourly photosynthate yields were then summed over each day and the daily totals were graphed against daily total solar radiation (Figure 8). The equation of that line, then, is found on line 1275 of the code (PNET).

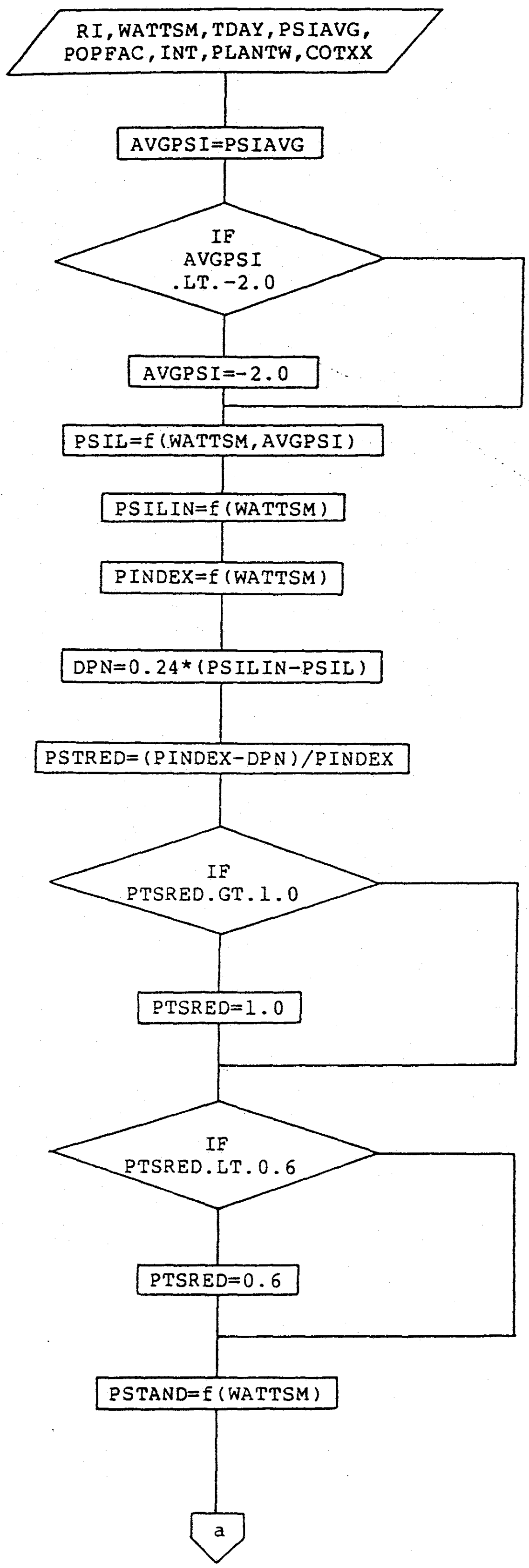
Three points need to be made here. First, the data base described above for potential canopy photosynthesis was obtained at 300 ppm v/v CO_2. Typical daily CO_2 concentration minimums in Mississippi are about 335 ppm. We used unpublished data on daily CO_2 concentration time courses and the data in an earlier paper (Baker, 1965) describing the photosynthetic response to CO_2 in cotton to develop the 6% correction in line 1276 of the code.

Secondly, PNET has no capability to respond to changes in leaf nitrogen concentration. Leaf N ranges from over 6% early in the season to under 2% at harvest (Thompson et al., 1976). We have measured canopy photosynthesis in cotton during several years at fertilizer rates similar to those used in commercial cotton plantings and similar to those in the Thompson experiments and have found no change in photosynthetic efficiency (Baker and Meyer, 1966) as long as the crop continued some vegetative development. This will be true in nearly all cotton crops, and we believe, therefore, that no adjustment for plant nitrogen status is necessary.

Finally, PNET contains no reduction in canopy photosynthetic efficiency associated with starch accumulation or vein loading. After several years of study of canopy photosynthesis in cotton under a large variety of environmental and physiological conditions, only in one data set (Baker, 1965) was there ever found any decline in photosynthetic efficiency which resembled what is caused by starch buildups in other species.

SUBROUTINE PNET

Flowchart



Notes

Bring in these variables.

To get proper plant responses to soil moisture, set the AVGPSI (in the rooted soil cells) equal to PSIMAX (there) but photosynthetic response levels off at -1.5 bar.

Leaf water potential is a function of solar radiation and soil suction (see code lines no.'s 1261-1263, p. 109).

Calculate an index (well watered state) of leaf water potential (see code line no. 1264, p. 109).

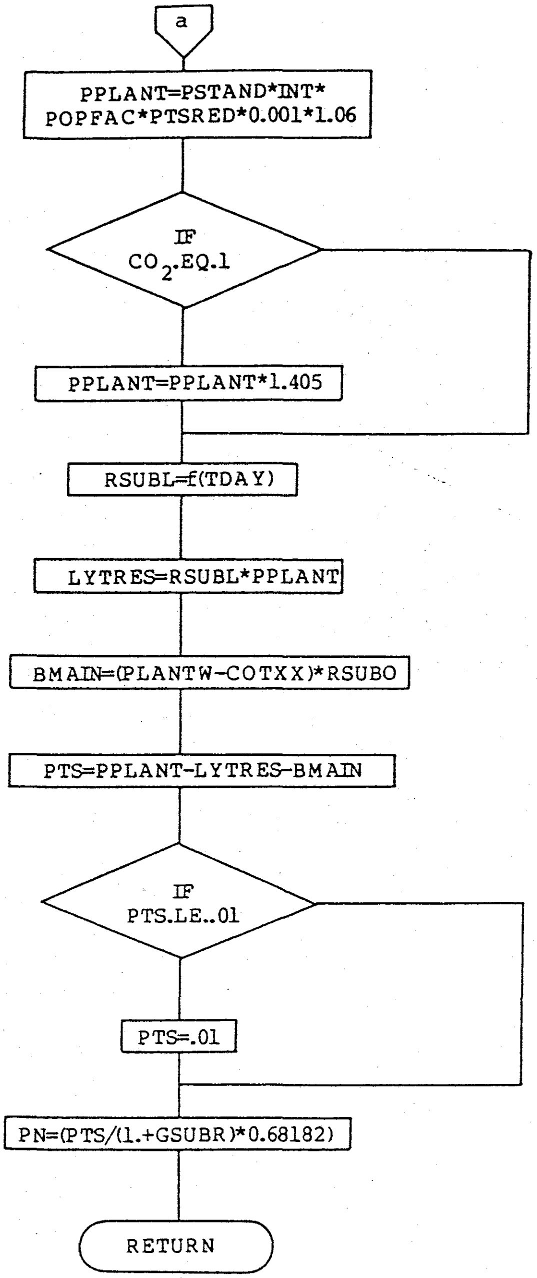
Calculate an index (well watered state) of canopy photosynthesis increment for the day (see code line no. 1265, p. 109).

Calculate the decrease in daily phytosynthesis production due to moisture stress.

Calculate the fractional decrease in photosynthate production.

Potential daily total canopy photosynthesis is a function of solar radiation (see code line no. 1275, p. 109).

PNET (2)



Adjust canopy gross photosynthate production for light interception, plant population, and water stress to get per plant photosynthate production. .0001 convert to grams. 1.06 adjusts for fact that real atmosphere at 330 PPM CO_2 and not 300 as in the canopy photosynthesis experiments in which the light response curve was desired.

IF CO_2 fertilizer is added, increase the daily photosynthate producton 40.5%.

Rate of light respiration is a function of temperature.

Light respiration is proportional to photosynthate production.

Maintenance respiration is proportional to the green biomass.

Calculate photosynthate available for the growth process.

Subtract the respiratory loss associated with growth and convert from CO_2 to CH_2O dry matter.

GROWTH

This subroutine calculates potential and actual daily increments of growth of each of the organs on the plant. The data base is from phytotron experiments for the temperature responses and from field and laboratory experiments for water stress responses. Root growth is handled in a separate (RHIZOS) subroutine which is called twice from GROWTH. In RUTGRO the soil water potential in those parts of the soil profile containing roots is used along with climate information to calculate water stress parameters described below.

Growth strategy is as follows:

a) the plant is inventoried and a potential growth rate for each of the organs is calculated as a function of temperature, assuming no shortage of photosynthate or nitrogen. A total carbohydrate demand (CD) is calculated as the sum of potential growth increments of all the plant organs. Plant attributes used in this calculation include organ weights and ages (since initiation). Potential growth is calculated for day and night periods separately, using temperature and water stress inputs appropriate to those time periods.

b) After the calculation of potential carbohydrate requirements, the NITRO subroutine is called from GROWTH. NITRO will be described in detail later; however, its function is to estimate the nitrogen required for the assimilation of the amount of carbon just estimated for each of the organs. These nitrogen requirements are summed for the vegetative parts (NV) and the fruiting parts (NF) and the sums are used in the denominators of nitrogen supply:demand ratios to estimate the maximum fraction of the potential carbohydrate that can actually be assimilated, considering the nitrogen limitations. The fraction allows calculation of a reduced or refined estimate of potential organ growth increments.

A carbohydrate supply:demand ratio is calculated as follows:

CPOOL = PN + RESC (2)

CSTRES = CPOOL/CD (3)

where CPOOL is the total available pool of carbohydrate from today's increment of photosynthate production, plus reserve carbon (RESC) carried in from earlier days, and CSTRES is the carbohydrate supply: demand ratio.

d) Actual growth of each of the organs on the plant, then, is calculated as the product of potential growth of that organ multiplied by CSTRES. This partitions photosynthate to each organ on the plant purely on the basis of that organ's contribution to the total demand. No preference is assumed in the allocation of dry matter on the basis of age or proximity to the photosynthetic sites. There is little debate in the literature over any limitation to growth resulting from limitations in translocation capacity of phloem elements in cotton. There is, however, some controversy over whether or not bolls should be given precedence over other organs. We, ourselves, have been ambivalent on this. Our earlier model (SIMCOT II) gave preference to boll growth, and we now have under development an Acala cotton model which does the same. NITRO does give preference to the bolls in the allocation of available nitrogen.

Subroutine GROWTH is flowcharted on pages 18 to 34. Water stress terms, defined in subroutine RUTGRO, for daytime and nighttime along with day and nighttime average temperatures are brought in from MAIN. The top half of the flow chart on page 18 is concerned with the calculation of growth parameters used in the remainder of the subroutine. The small nested DO loop on page 18 calculates the potential growth in terms of area and weight of each of the mainstem leaves below the first fruiting branch younger than 16 days age. The same parameters are used for all leaves on the plant, and they are graphed in Figure 9. The phytotron data of Hesketh and Low (1968) are used here. Leaf area growth is essentially exponential for the first 16 days after initiation, and then leaf expansion virtually ceases under field conditions. Thus,

PFDALD(J) = PFAL(J)*DUMY04, (4)

DUMY04 = RADAY*DAYTYM*WSTRSD, and, (5)

RADAY = f(TDAY), [111, 1516-1518][1] (6)

where PFDALD(J) and PFAL(J) are the potential change in area and the current area of the leaf at prefruiting node J, respectively. The conversion of the potential increment of area growth to an increment of weight is calculated as follows:

DAYWTF = f(TDAY), where, (7)

PFDWLD(J) = PFDALD(J)*DAYWTF, (8)

PFDWLD(J) and DAYWTF are the potential leaf growth in weight and specific leaf weight respectively.

After the calculation of potential leaf growth at the nodes below the first fruiting branch, a nested DO loop is entered for the calculation of potential leaf and fruit growth at the fruiting nodes on the plant. Square growth is calculated first. We use the slope of the upper segment of the ln W line from Hesketh et al. (1971). A weight increment for two succeeding days is calculated from the equation for this line (Figure 10). This value then is adjusted for temperature effects. We did not have square data collected over a range of temperatures. Therefore, we have used the temperature response for growth of very young bolls. The temperature factor (TFACSQ) is calculated as follows:

TFACSQ = $(\Delta W_T/\Delta t)/(\Delta W_{26}/\Delta t)$ (9)

where W_T and W_{26} are the weight increments in very young bolls (c.f. Baker et al., 1969, pp. 34-36) at the average temperature and at 26°C respectively. Δt is the time increment, in this case one day. The data base for the temperature response in young boll growth is presented in Figure 11. For exponential growth, the change in weight with time can be expressed as

dW/dt = W, or d(lnW)/dt = b, where(b is the slope of the exponential gro\ curve. The vertical axis in Figure 11, th is b. The R^2 value in this data set is 0 The equation of the line is found in I MY06. The potential change in weigh the square, then, accounting for the fect of temperature is,

PDWSQ(K,L,M,) = EXP(-3.875 + .1 *AGE(K,L,M,))*TFACSQ- EXP(-3.875 + .125 *(AGE(K,L,M,) -1.))*TFACSQ

The data base above is used for the ca lation of potential growth in y

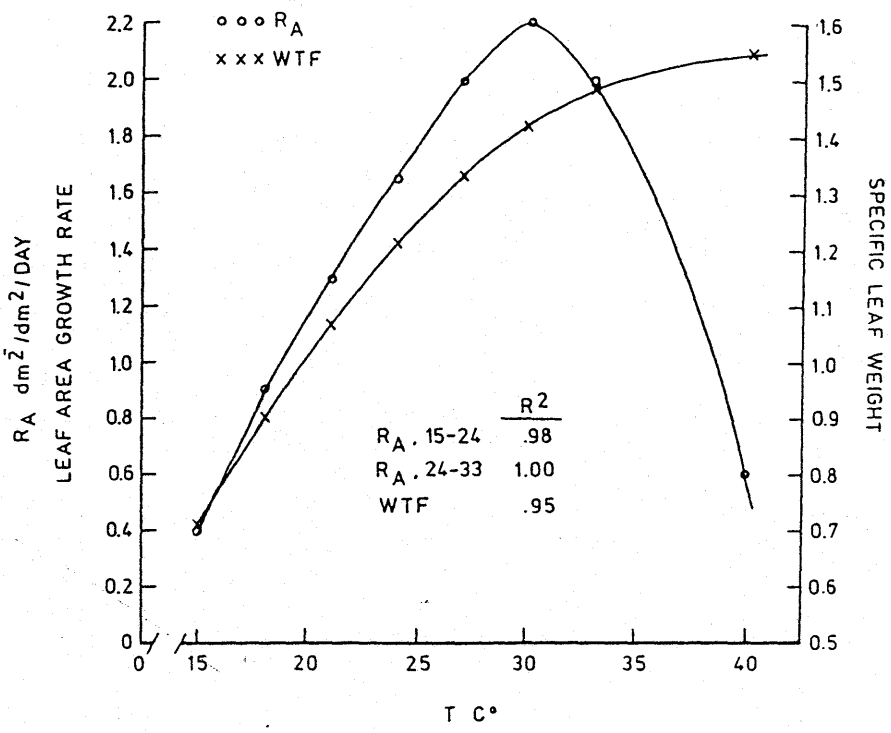


Figure 9. Leaf area growth rate and specific leaf weight vs. air temperature.

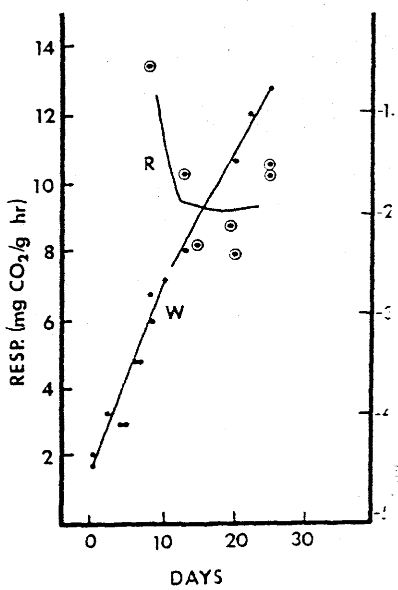
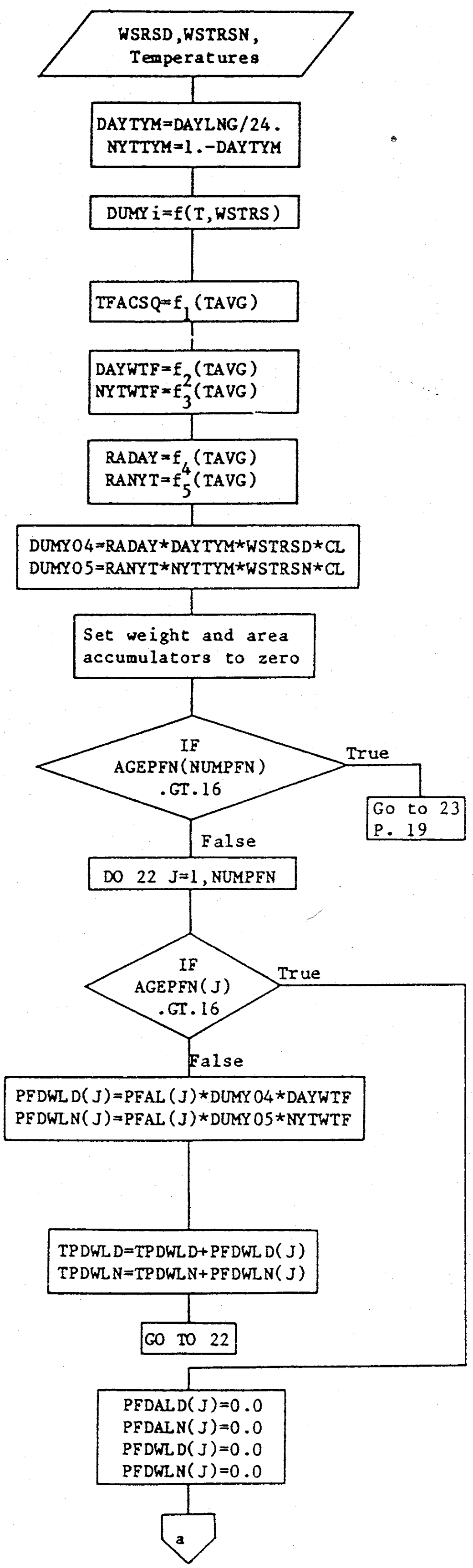


Figure 10. Respiration rate, R, an weight, W, vs. age for grown cotton squares.

[1]This type of functional notation is used in many places in the text. The functions are found in APPENDIX A locations identified in the brackets [a, b-c], where a is the page num-

SUBROUTINE GROWTH

Flowchart



NOTES

Bring in these variables.

DAYTYM and NYTTM are the fractions of the 24-hour period in day and night, respectively.

Calculate boll and square growth water as functions of temperature and water stress levels. (p. 111, line no.'s 1506-1512.)

Calculate the temperature adjustment for square growth. (p. 111, line no. 1513.)

Specific leaf weight is a temperature function. (p. 111, line no.'s 1514-1515.)

Rate of leaf area growth is a temperature function. (p. 111, line no.'s 1516-1518.)

Calculate rate of leaf expansion per cm^2 leaf area where DAYTYM and NYTTM are the fractions of daylight and night hours, respectively, with leaf water potential above-7 bars.

If the youngest mainstem node below the first fruiting branch is more than 16 days old, stop growth of leaves at all such nodes.

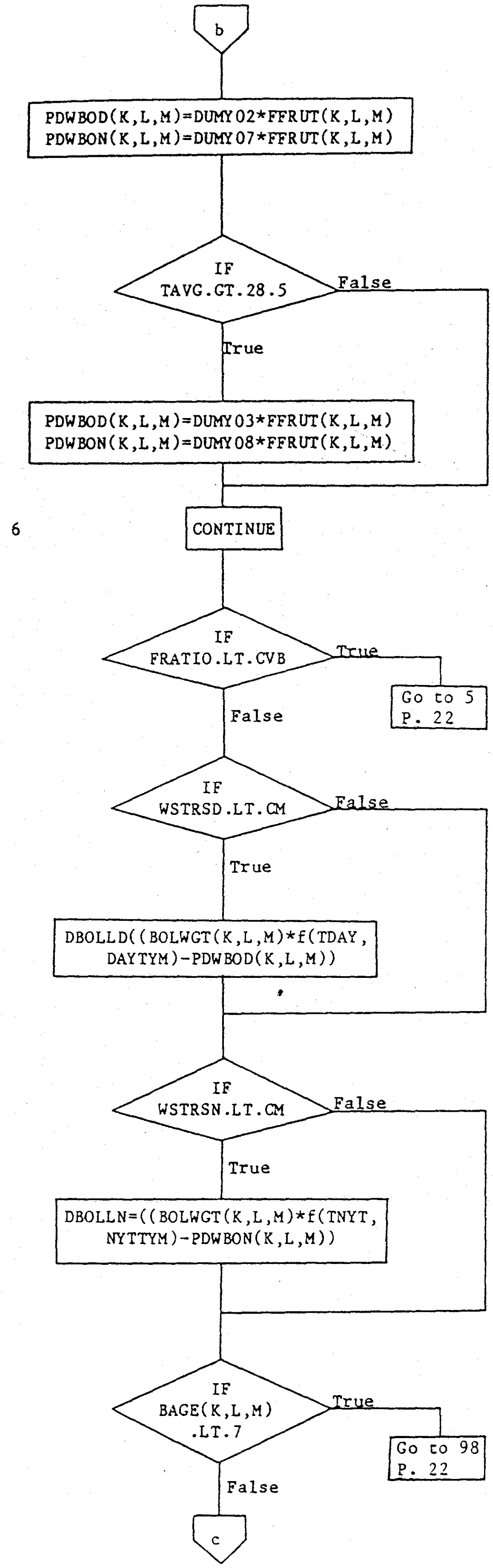
Do for all prefruiting nodes (Main-stem nodes below the first fruiting branch.)

If leaf is older than 16 days it grows no further.

Potential change in weight of the pre-fruiting leaf at node (J) then, is a function of the current area of that leaf, the temperature and the fraction of the time with leaf water potential above-7 bars.

Total the potential changes is weight of leaves at prefruiting nodes.

		NOTES
	a	
22	CONTINUE	
23	IF FCODE(1,1,1) .EQ.0 — True: Go to 25 P. 24; False: continue	Has the first fruiting site been formed yet?
	FRATIO=GBOLWT/PLANTW	
	DO 1 K=1,NVBRCH	Do for each fruiting site on each fruiting branch on each vegetative branch.
	NBRCH=NFBR(K)	
	DO 1 L=1,NBRCH	
	NNID=NNOD(K,L)	
	DO 1 M=1,NNID	
	NOWGO=FCODE(K,L,M)+1	
	GO TO (7,2,3,7,7,2,3),NOWGO	Go to (statement number etc.) depending on the value of NOWGRO.
2	CONTINUE	
	DUMY06=(AVGT,K,L,M)-0.2120865 TFACSQ=EXP(DUMY06)/1.228716514 PDWSQ(K,L,M)=f(AGE,TFACSQ) SPDWSQ=SPDWSQ+PDWSQ(K,L,M)	Potential dry matter accumulation in the square is a function of the age of the square and of temperature. Accumulate over the whole plant these potential changes in square weight. (p. 112, line no.'s 1562-1564.)
	GO TO 7	
3	CONTINUE	
	PDWBOD(K,L,M)=BOLWGT(K,L,M)*DUMY01 PDWBON(K,L,M)=BOLWGT(K,L,M)*DUMY09	Potential growth of the boll (day and night) is a function of temperature and plant water status and proportional to the weight of the boll (i.e. for the first 7 days after bloom, boll growth is exponential in time). Note: the fraction of the boll weight remaining at the site (from previous square and young boll abscission events has been updated in the previous iteration in PLTMAP). (p. 122, 2505)
	IF BAGE(K,L,M) .LT.7 — True: Go to 6 P. 20; False: continue	
	b	



NOTES

After seven days of age, a linear boll growth (day and night) expression is substituted. This linear growth rate is one function of temperature below 28.5 C

and

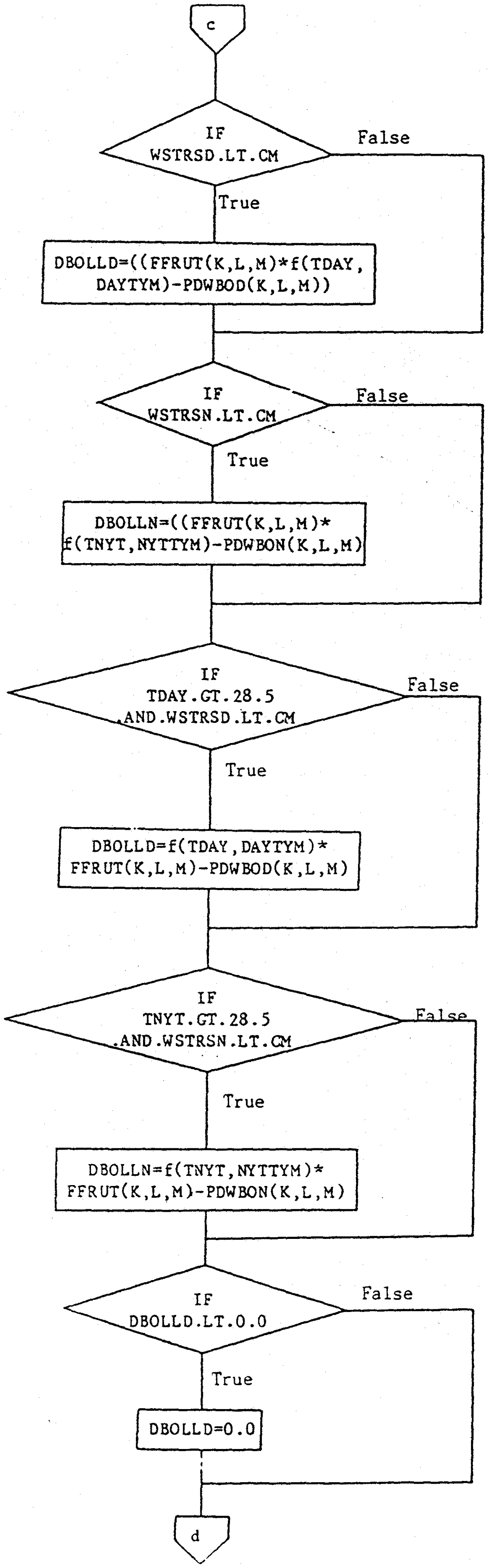
another above 28.5 C.

FRATIO (fruit ration) is the ration of green boll weight to total plant weight. If the fruit load is greater than 15% under water stress conditions, accumulate the amount boll growth that would have occurred under non-stress conditions.

Calculate the difference in the amount of boll growth that would have occurred under non-stress and stress conditions, during the daytime. (p. 112, line no.'s 1579-1580.)

Same as above, but during the nighttime. (p. 112, line no.'s 1581-1582.)

GROWTH (4)



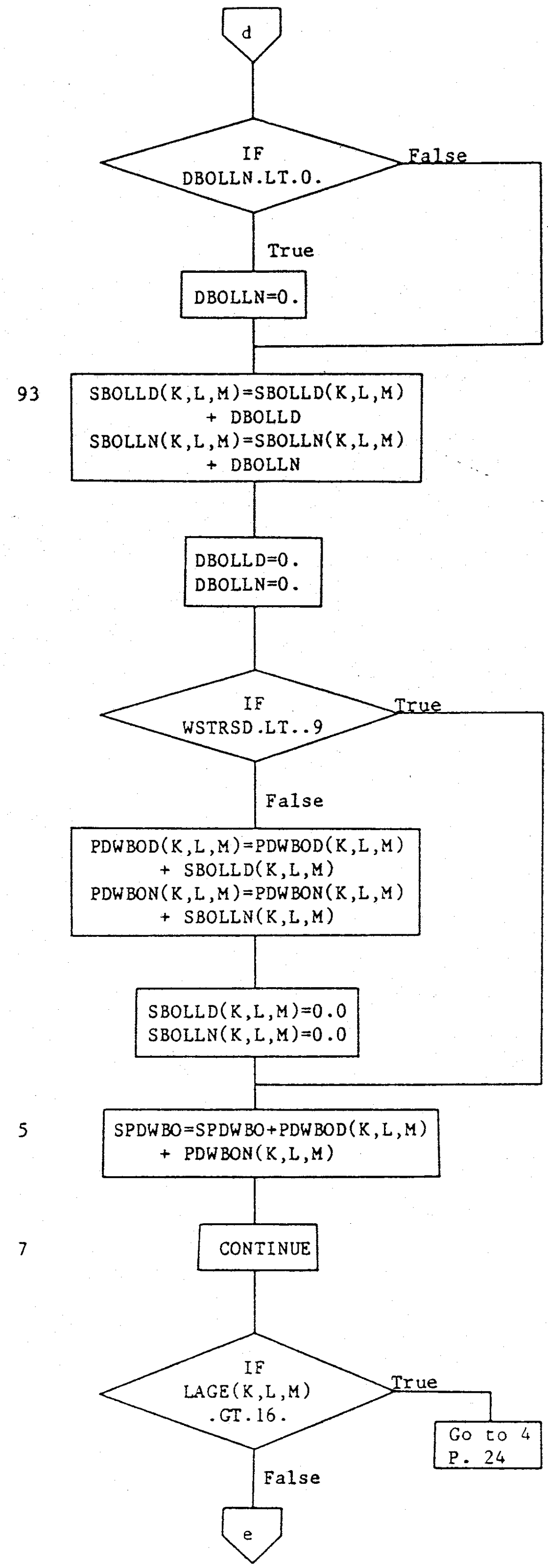
NOTES

Calculate the difference in the amount of boll growth that would have occurred under non-stress and stress conditions for boll older than 7 days, during the daytime. (p. 112, line no.'s 1584-1585.)

Same as above, but during the nighttime. (p. 112, line no.'s 1586-1587.)

Calculate the difference in the amount of boll growth that would have occurred under non-stress and stress conditions for bolls older than 7 days and the day temperature is above 28.5 C., during the daytime. (p. 112, line no.'s 1588-1589.)

Same as above, but during the nighttime. (p. 112, line no.'s 1590-1591.)



NOTES

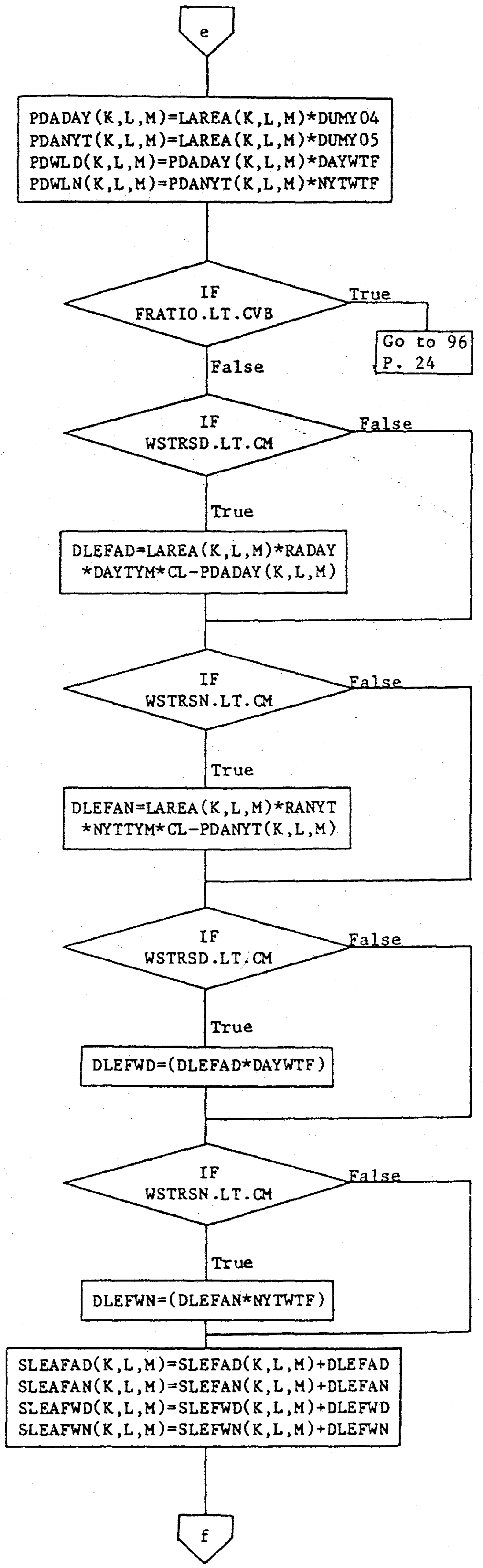
As the water stress is released due to rain fall or irrigation, make available the accumulated amount of growth that did not occur under stress conditions, during daytime.

Same as above, but during nighttime.

Accumulate the boll growth potential of all bolls in the plant, occurring during the daytime and nighttime.

If leaf is less than 16 days of age, calculate its growth.

GROWTH (6)



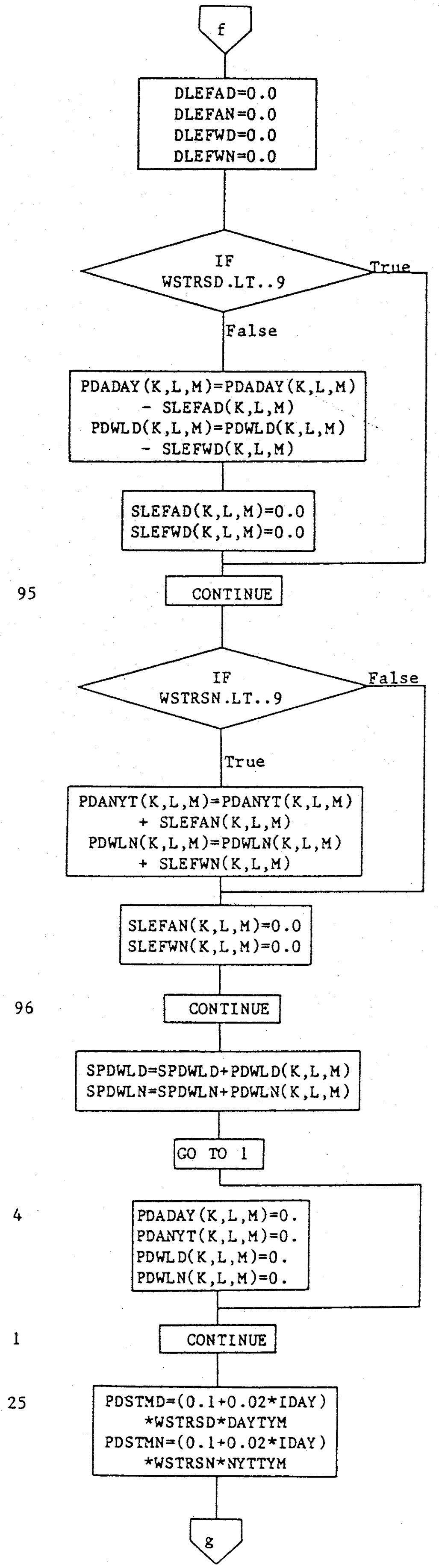
NOTES

The potential area change multiplied by a specific leaf weight factor (which is a function of temperature) gives the potential change in leaf weight.

Calculate the difference in the amount of leaf growth that would have occurred under non-stress and stress conditions, during the daytime.

Same as above, but during the nighttime.

Accumulate the amount of leaf growth that would occur under non-water stress conditions.

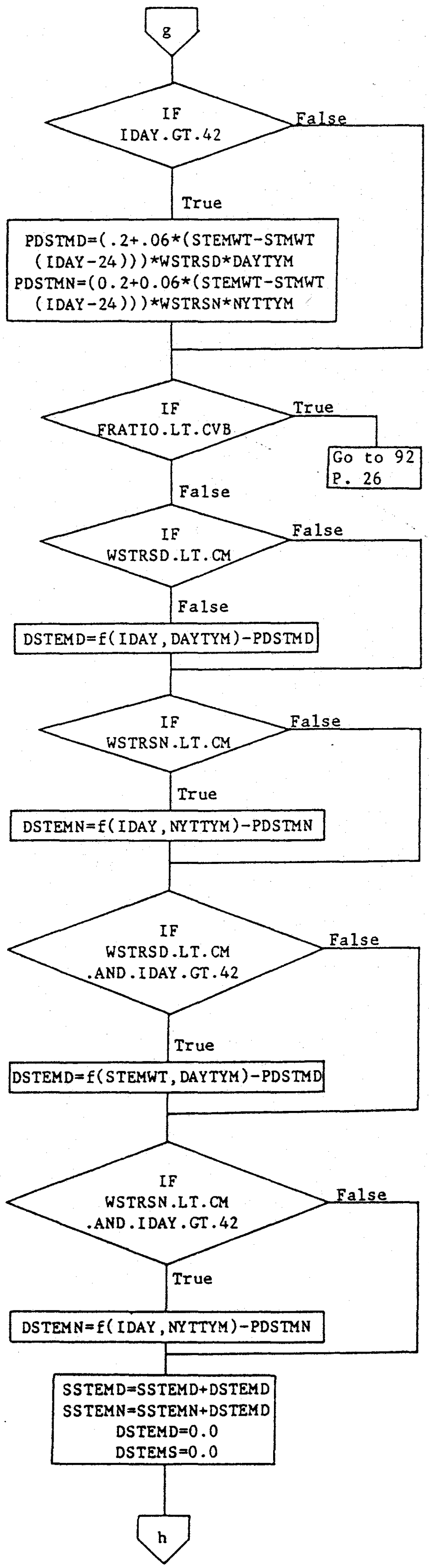


NOTES

As the water stress is released due to rain fall or irrigation, make available the accumulate amount of growth that did not occur under stress conditions, during daytime.

Same as above, but during nighttime.

Accumulate the boll growth potential of all leaves in the plant, occuring during the day and nighttime.



NOTES

After 42 days, potential stem growth is proportional to the stem weight less than 24 days old. Again the adjustment for plant turgor is made (WSTRSD & WSTRSN).

Calculate the difference in the amount of stem growth that would have occurred under non-stress and stress conditions during the daytime.

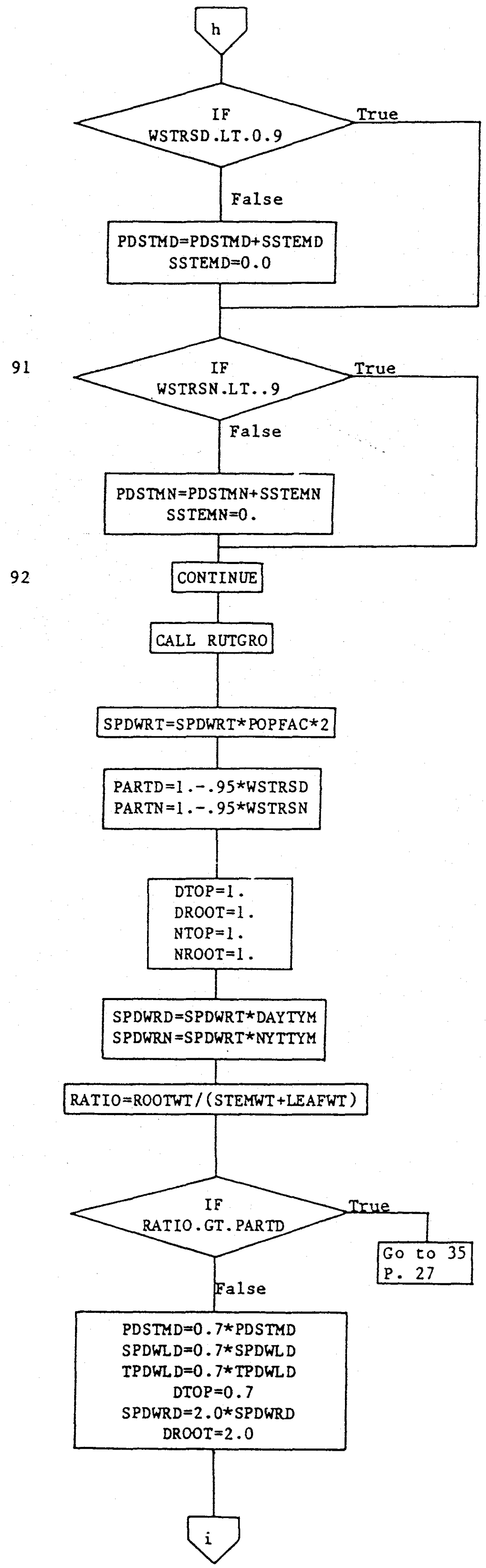
Same as above, but during the nighttime.

Same as above for stem older than 42 days during the nighttime.

Same as above, but during the nighttime.

Accumulate the amount of stem growth that would occur under non-stress conditions.

NOTES



Call RUTGRO and bring in potential root growth on a ground area basis.

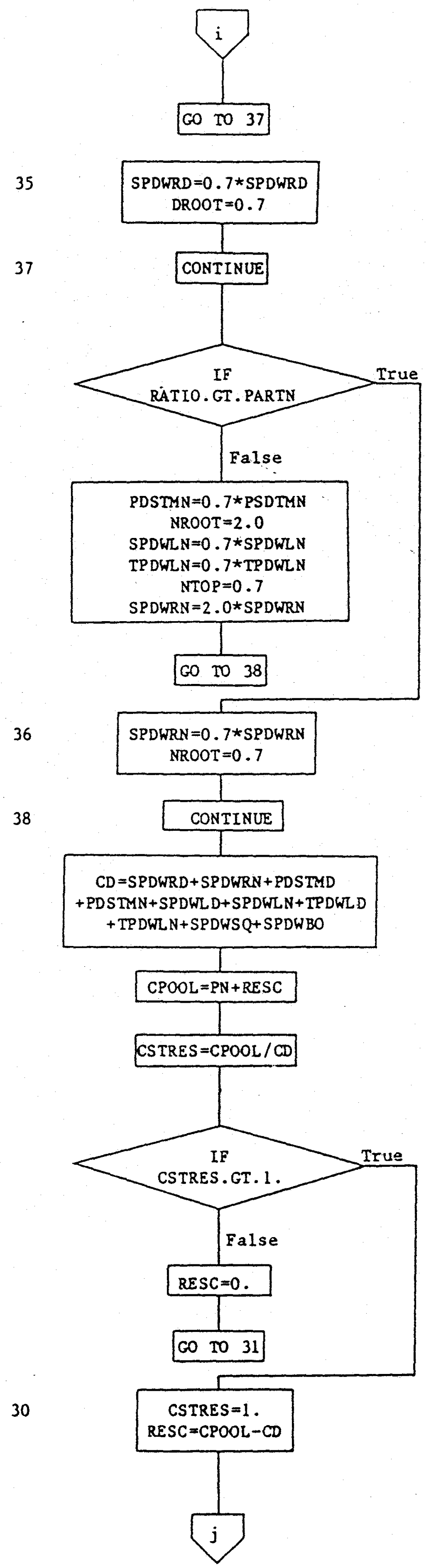
Convert potential root growth to a per plant basis.

Calculate root: top partitioning factors for daytime and nighttime growth. These are idealized or "target" root:shoot ratios which depend on the moisture stress level.

Initialize root and top day and night growth adjustment factors for no change in response to water stress.

Calculate daytime and nighttime fractions of potential root growth.

If the root:shoot ratio is greater than the ideal (PARTD) for this water stress level, cut potential root growth in half. If not, cut top growth in half and multiply potential root growth five times.



NOTES

Same logic as above for nighttime root: shoot partitioning.

Carbohydrate demand is the sum of the demands of all the organs.

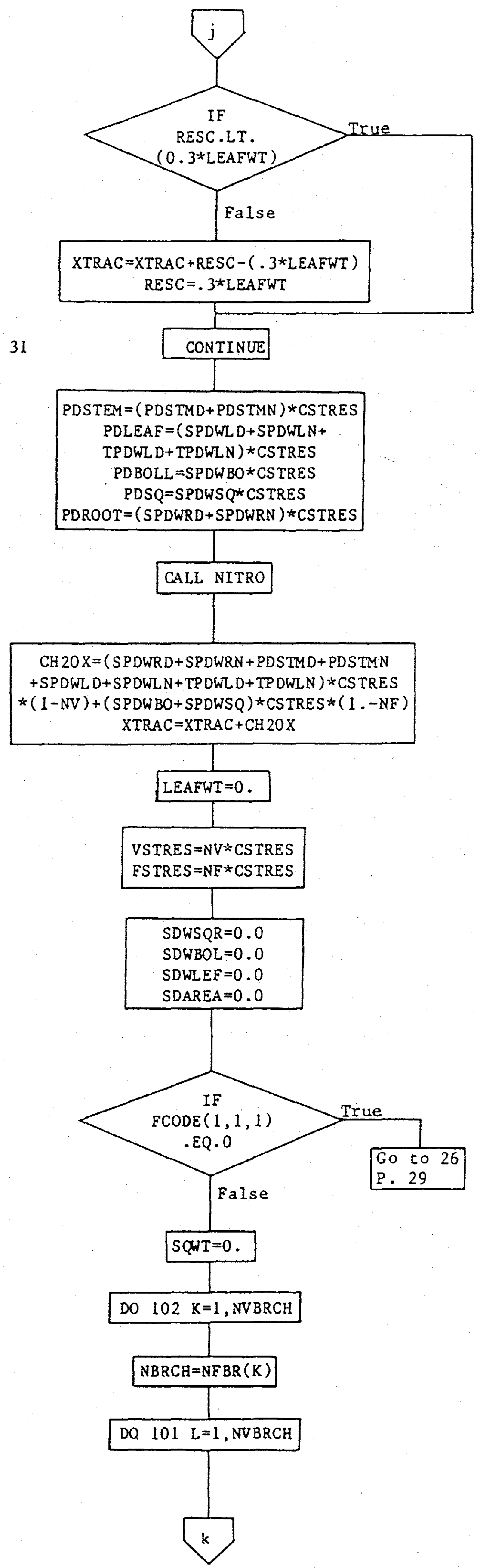
Reserves plus today's net photosynthate equals the carbohydrate pool.

Carbohydrate stress is represented by the carbohydrate supply: demand ratio.

If carbohydrate supply is less than demand, all reserves are drained.

If the supply exceeds demand, the difference is placed in reserve.

GROWTH (11)



NOTES

Reserve may be up 30% of leaf weight.

Anything beyond that is called XTRAC and added (later) permanently to the root system (thickens the root at the base of the plant.)

Reconcile potential growth with the carbohydrate supply prior to calculating nitrogen demand and nitrogen stress.

Call NITRO to bring in nitrogen supply: demand ratios for vegetative (NV) and fruit (NF) growth.

If not enough translocatable nitrogen is available in the plant for assimilation of the available carbohydrate, then the excess (CH2OX) is added to XTRAC.

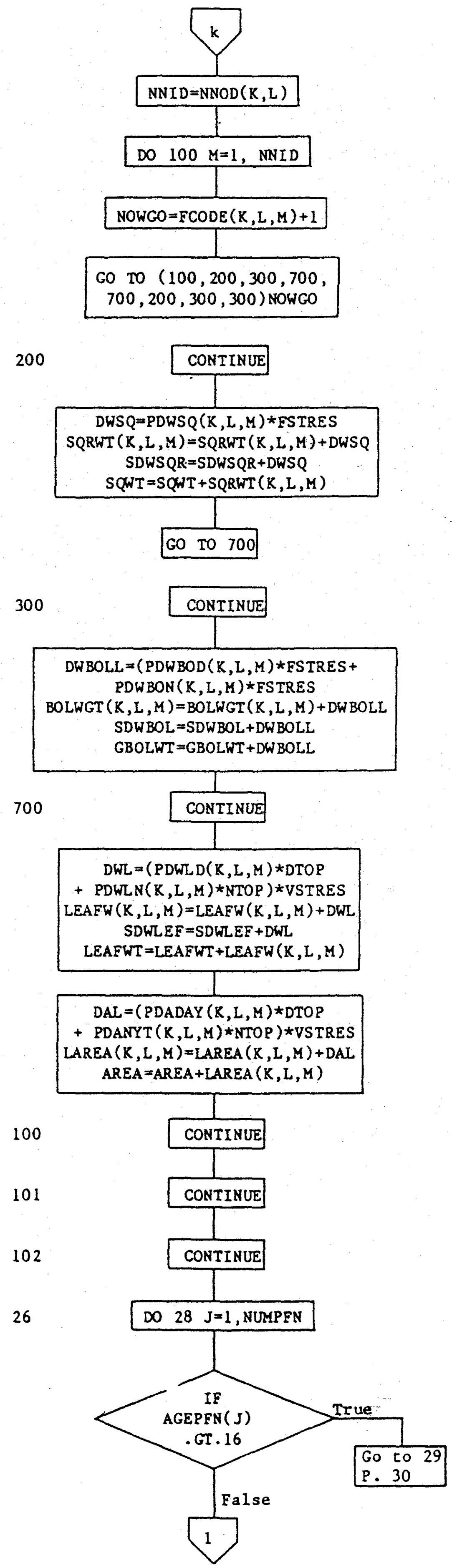
Initialize leafweight adder.

Combine nitrogen and carbohydrate stresses into single paramenters for vegetative and fruit growth.

If the first square is as yet unborn, skip this section dealing with fruit growth.

Initialize total square weight adder.

Do for all fruiting sides on the plant.



NOTES

Depending on the status of the fruit at that site. Note! 100. If an unborn square is encountered on a fruiting branch, there will be no other fruit further out on that branch, so go to the next fruiting branch on the same vegetative branch.

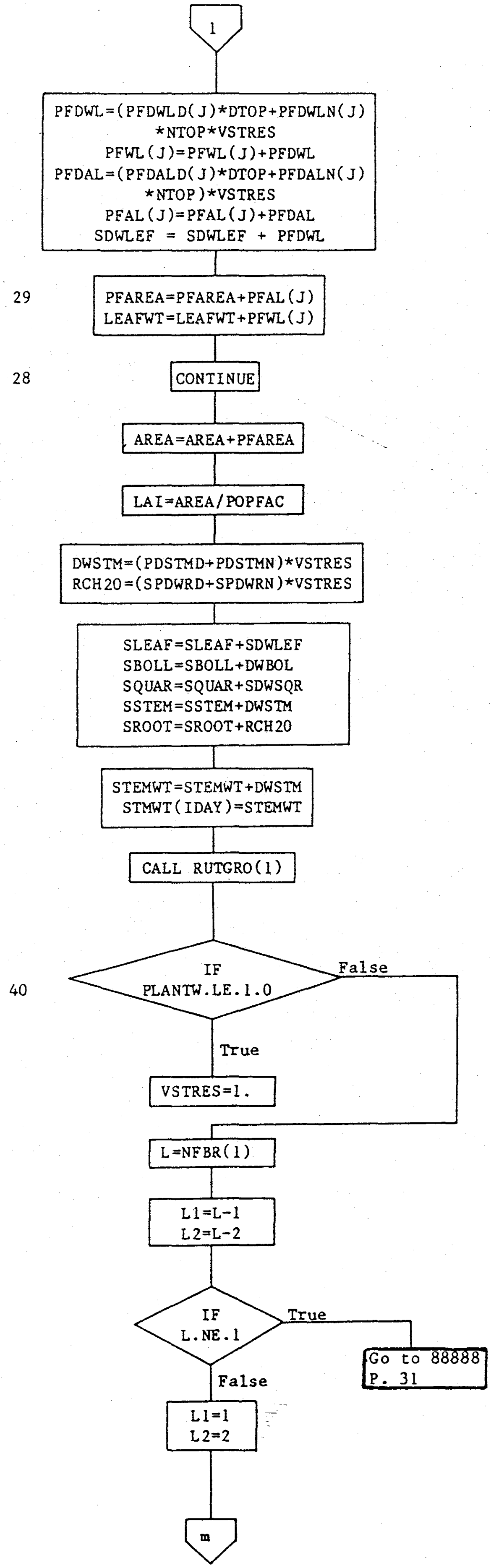
The actual change in weight of the square is the potential change in weight (which that particular square contributed to the total demand) multiplied by the combined metabolite supply:demand ratio. This weight increment is added to the square and a total plant square weight is calculated.

Logic similar to the square growth is applied to the boll growth. Note the use of FSTRES means that fruit are getting priority over vegetative organs for nitrogen. (c.f. NITRO)

The change in weight of a leaf is calculated as the sum of the day and nighttime potential changes adjusted by the day and night root:shoot partitioning coefficients respectively and the sum adjusted for metabolite supply (VSTRES). The new leaf weight is then calculated and a leafweight total for the plant is calculated. Similarly, the leaf area is expanded.

Do for each of the mainstem nodes below the first fruiting branch.

If the leaf is older than 16 days,no growth occurs.



NOTES

Calculate the changes in weight and area of these prefruiting mainstem leaves as above for the leaves at fruiting nodes, and add the growth increments to the leaves.

Add the areas and weights of these leaves to the totals for the plant.

Calculate the total area of leaves on the plant.

Calculate leaf area index.

Calculate the change in weight of stem and root tissue by adjusting potential change for carbohydrate and nitrogen supply.

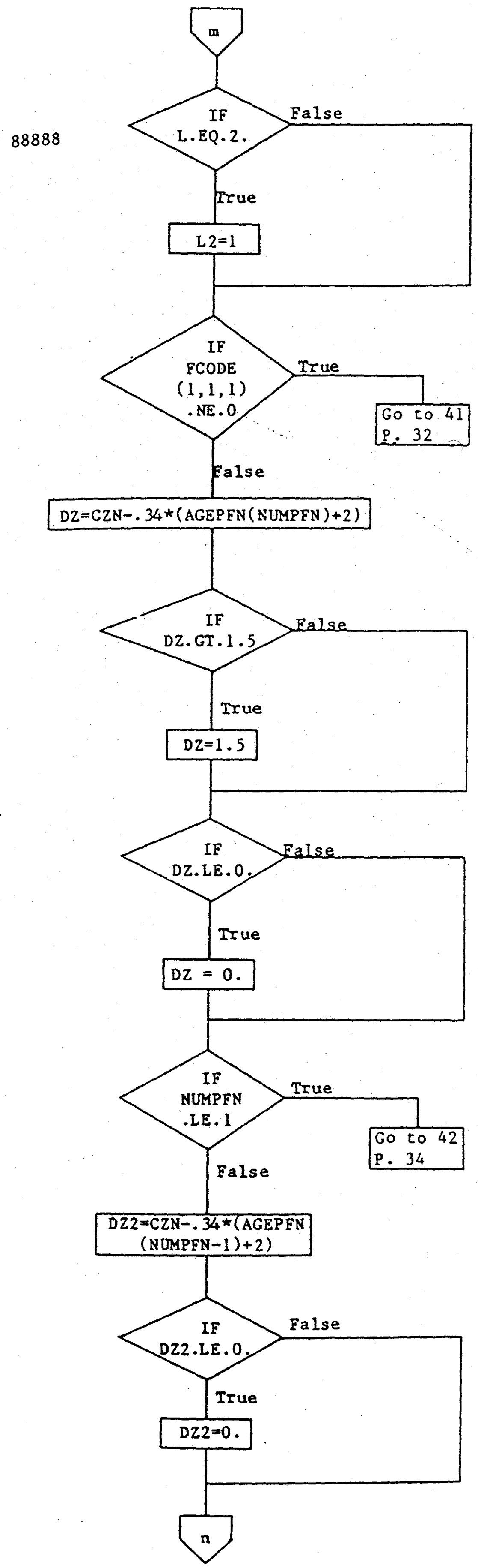
SLEAF, SBOLL, SQUAR, SSTEM, SROOTS are cumulative amounts of CH20 allocated to leafs, bolls, squares, stems, and roots respectively.

Increment the stem weight and store today's new stem weight value.

Call RUTGRO to allocate the new dry matter increment to roots.

If the plant weighs less than 1 g., set VSTRES=1 to prevent delays in small seedling growth and morphogenesis.

GROWTH (14)



NOTES

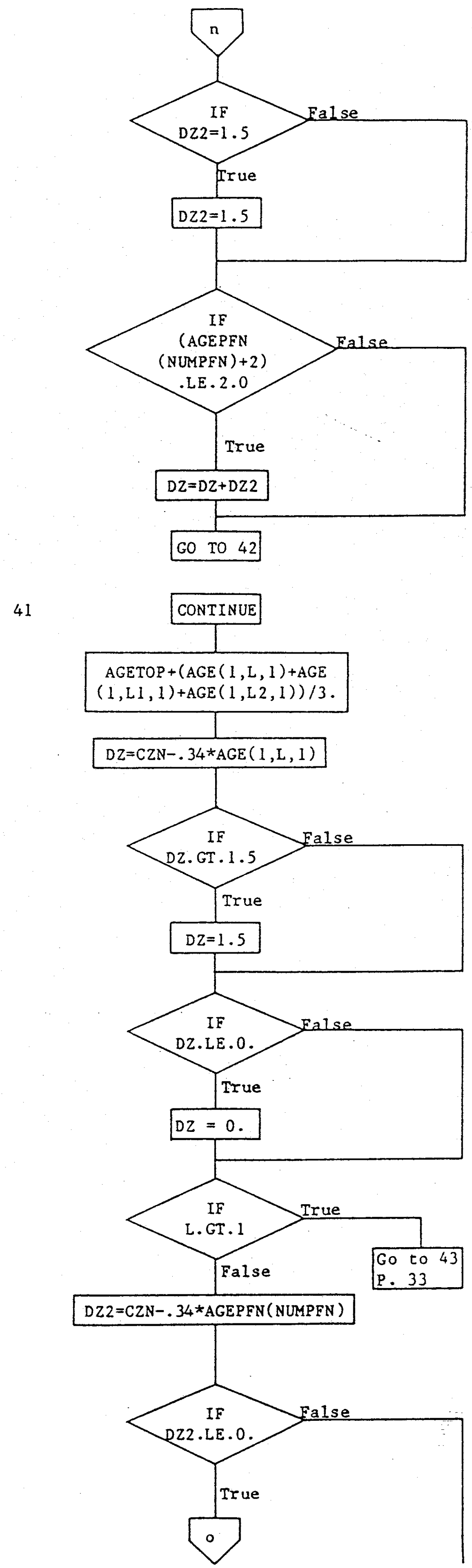
If there is a fruiting site on the plant, calculate height growth from age of fruiting branch nodes.

Calculate vertical extension as a function of the age of the top internode.

It cannot be less than 0 cm or more than 1.5 cm.

Calculate vertical extension of the second internode from the top.

It cannot be less than 0 cm or more than 1.5 cm.



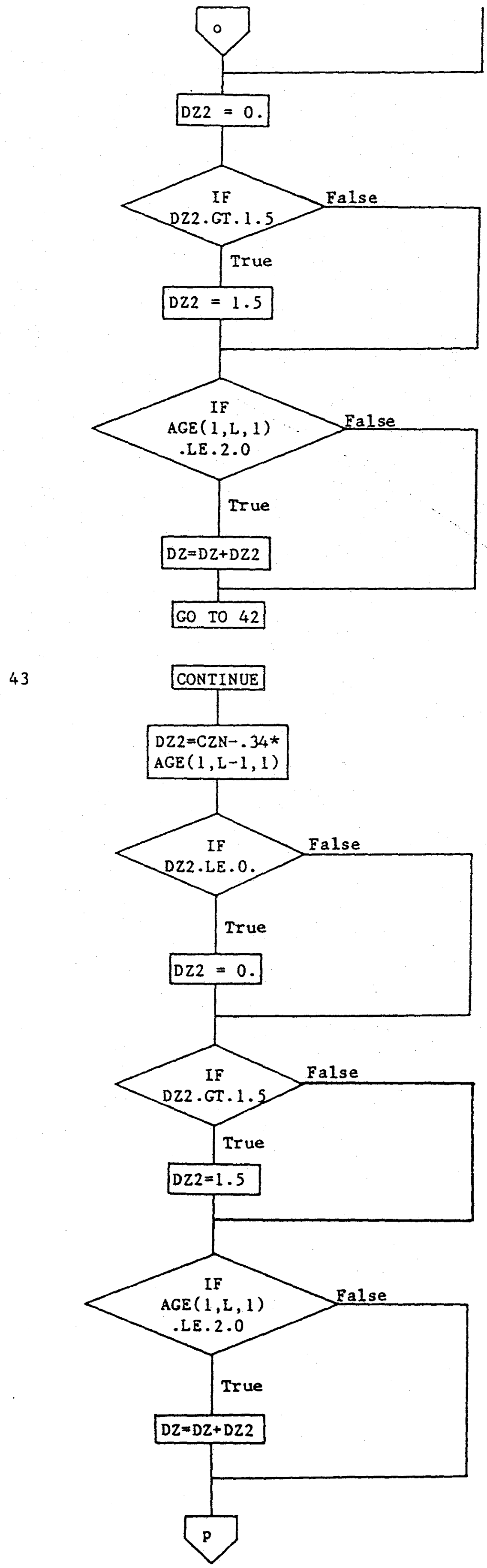
NOTES

If the age of the top node is greater than one day, then height growth occurs in the top two prefruiting internodes.

AGETOP is the average age of the top three nodes.

Calculate the growth of the top internode.

It cannot be greater than 1.5 cm/day or less than 0.



NOTES

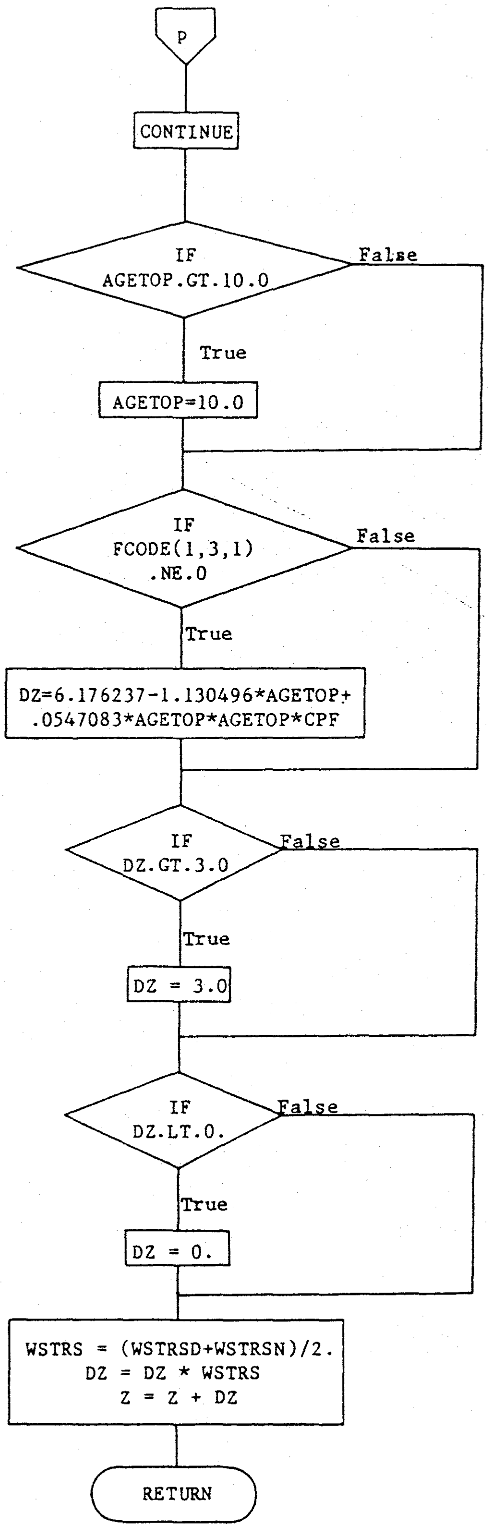
If there are two fruiting branches height growth occurs in the top two internodes.

However, if there is only one fruiting branch, part of the vertical growth occurs in the last prefruiting internode.

Again, it must be between 0 and 1.5 cm/day.

NOTES

42



If there are three fruiting branches, height growth is a function of the average age of the top three nodes and temperature.

Height growth must be between 0 and 3 cm per day.

Growth is reduced by moisture stress.

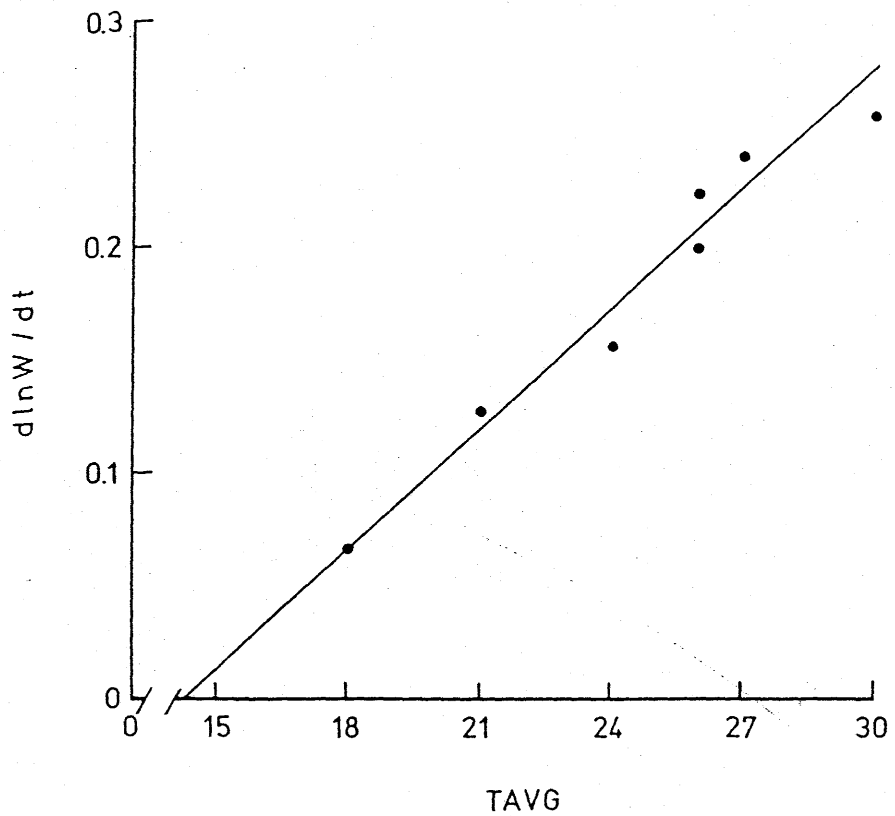


Figure 11. Young boll growth rate vs. temperature.

squares (up to seven days before anthesis). The exponents for day and night time growth increments are contained in DUMY01 and DUMY09, respectively. Here, however, the dummy variables contain adjustments for day length and water stress. Again, the dimensions of the dummy variables are g^{-1} day^{-1}.

If the boll is older than seven days, a linear growth pattern is assumed. The data base for this phase of boll growth is presented in Figure 12, from MacArthur et al., (1973). These data were collected by Hesketh under glasshouse conditions in Arizona at high CO_2 levels in order to ensure no carbohydrate limitation. The data show an increase in growth rate with age up to about 28°C and a rapid decline thereafter. The data have been fitted with two straight lines as shown in the figure. The data and the ordinate in Figure 12 have the dimensions of grams per day increase in dry weight. If the temperature is below 28.5°C the dummy variables are DUMY02 and DUMY07 for day and night growth respectively. Above 28.5°C DUMY03 and DUMY08 apply. Again, the adjustments for day or night length and water stress effects are contained in the dummy variables. The amount of growth possible at a given fruiting site depends on the fraction of a fruit still at that site. Thus, e.g.,

PDWBOD(K,L,M,) = DUMY02*FFRUT(K,L,M,). (13)

and,

DUMY02 = (.03125*TDAY - .0508)*DAYTYM*WSTRSD (14)

Next, if the green boll weight to total plant weight ratio is greater than 0.15, a record of the differences in daily potential boll growth between what would have occurred in a fully turgid plant and what would be expected in a water stressed plant is kept. These differences accumulate each day as the crop enters a drying cycle. Then, as the plant regains turgor on watering, these total differences, accumulated over time for each fruit, are added to the potential growth increments for this day. The need for this was discussed earlier by Baker et al. (1979a). Briefly, the rationale is as follows:

In writing the model, we have attempted to translate into FORTRAN the careful and thoughtful descriptions of the fruiting process in cotton presented by Mauney (1966, 1979) and by McClelland and Neely (1931), Tharp (1960) and Zaitzev (1928). In doing so, we have had to extend and sharpen existing theories in some areas a little bit. We have not contradicted them in any area that we are aware of. Although we have addressed the whole system, and it is critically important to recognize (in our case in the form of computer logic) that all the plant processes are interrelated at some level, remarks here will be confined to the production of fruiting points with some necessary references to fruit abscission.

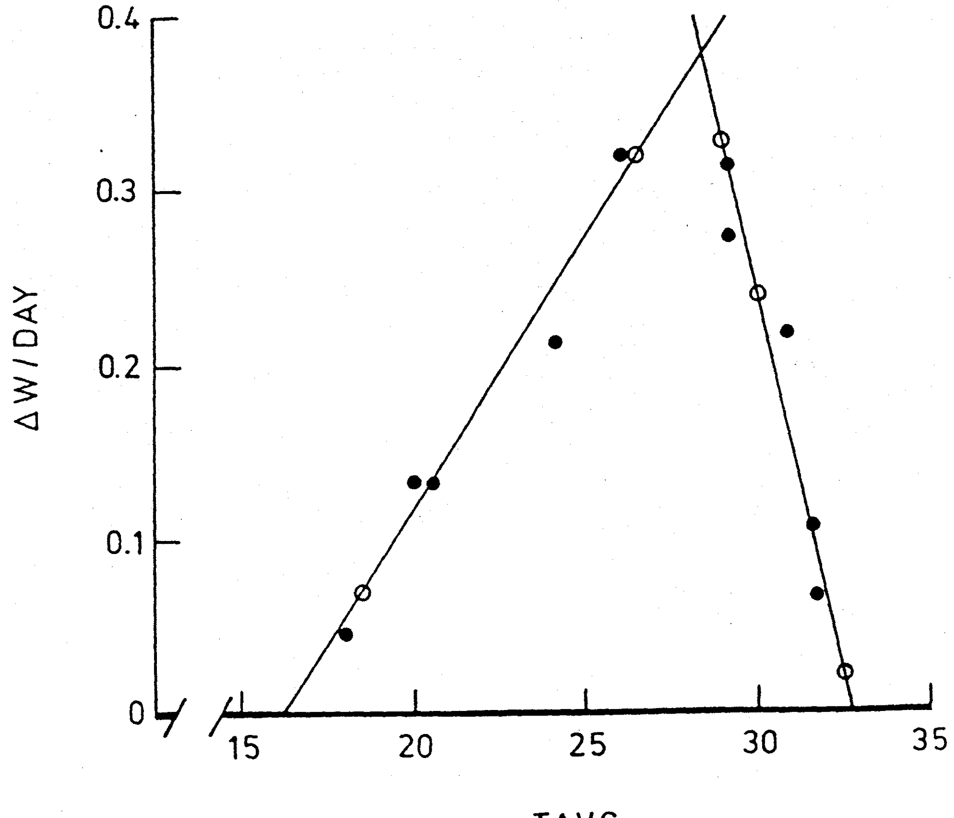


Figure 12. Boll growth rate vs. temperature. Values at 27 C and above were determined for plants in air enriched with CO_2 and with every other flower removed for some plants.

We began our work with the calculation of daily photosynthate production, respiration loss, and nitrogen uptake (Hesketh et al., 1971 and Baker et al., 1972). From that point, we were in a position to examine the classical "nutritional theory." To make it work, we had to add a bit of a new twist. We had to theorize that hormone balances in the plant shift in response to some mathematical combination of both supply and demand for metabolites. We use the supply:demand ratio. Shifts in the ratio cause lengthening or shortening of time variables such as plastochrons, and cause the abscission of a certain number of fruit. Both actions are simulated in the subroutine PLTMAP (yet to be discussed). In GOSSYM, we have written functional relations expressing the length of the morphogenetic delays and increments of fruit abortion vs. this supply:demand ratio. These are implemented in the PLTMAP subroutine, discussed below. The morphogenetic delay is referred to in Mauney's (1979) paper, and it is evidenced in the nonlinearity of morphogenetic rate vs. temperature responses.

Thus, all of the processes, photosynthesis, growth, development, and fruit abscission are highly interactive in the plant and in the model. There are far too many ramifications to mention in this discussion, but one can see very quickly that conditions favoring photosynthesis will tend to relax metabolic stresses and enhance fruiting. Higher temperatures will increase potential growth rates and respiratory losses, i.e., the demand, or the denominator of the supply:demand ratio; this, at some level, causes the plant to invoke hormonal delays in development and to abort more fruit. On the other hand, if the high temperature is accompanied by moisture stress, metabolite demand may be slowed more than photosynthesis, etc. The developmental delays and abortion all depend on the levels involved. We have calibrated each of these processes (photosynthesis, respiration, organ growth, transpiration, and the entrainment of nitrogen) in specially designed controlled environment experiments. For this, we have developed and set up a special facility (Phene et al., 1978).

Calibration of the delays and fruit abortions vs. metabolic stress (carbohydrate supply:demand ratio) in GOSSYM was done with a set of data from the rainout shelter experiments by Bruce and Römkens (1965). They had the soil conditions well documented and we were able to simulate them. We also had excellent documentation from Bruce (personal communication) on the fruiting throughout the season. They had applied water stresses of varying intensities and at various times after first bloom and during the boll development period. This was our first attempt at the simulation of a water stressed crop.

A good simulation of the well watered treatment (AAA) was obtained (Figure 13). Also, the model simulated fruiting very well, including fruiting point produc-

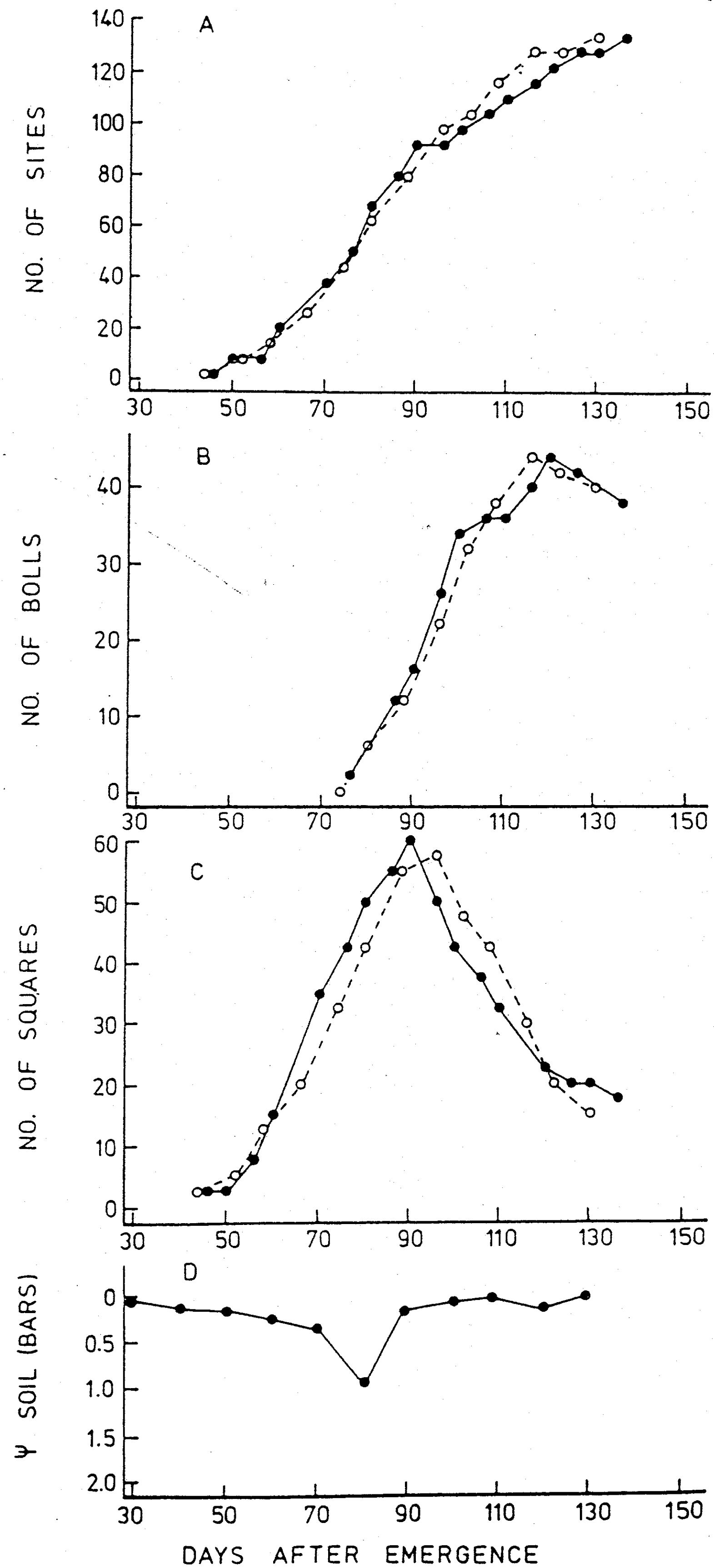


Figure 13. Simulation of treatment AAA without cell-water stress logic elongation. Soil water potentials maintained as in part D. Parts A, B, and C show numbers of sites, bolls, and squares per plant, respectively. Open circles and closed circles represent real crop and model output data, respectively.

tion and the abscission of squares and bolls, up to the maximum square load and just beyond, in each of the water stress treatments. The results of the ABB treatment are typical, and so the others will not be presented in the figures. The model correctly predicted lower maximum square loads and smaller plant heights, and numbers of fruiting points with the increased water stresses, as would be expected. However, as shown in Figure 14, the model erroneously predicted a recovery in vegetative growth, i.e. fruiting point production and a partial, but very significant, hiatus in the abscission of fruit immediately after watering and the relaxation of the moisture stress. At first these responses seemed reasonable to us; however, the real plant data showed neither of them. Further, we know that increased abscission of fruit generally occurs after relaxation of moisture stress. The literature shows this, and the data of Wadleigh (1944) in his Arkansas bulletin is a classic example.

The results with the model demonstrated a conceptual shortcoming in our description of the plant. Our options were to propose some complex water relations (per se) effect on fruiting point production and fruiting, or to look more closely at the action of the existing logic in the model. Tentatively taking the latter role, we were confident of our estimate of carbohydrate supply functions. These are relatively simple, and we had good experimental data showing a very rapid recovery of photosynthesis after watering at these water stress levels. The crop had been grown at very high levels of soil nitrogen. There appeared to be something wrong with our estimate of the metabolite demand in the system. We began to suspect that cell division and cell growth (i.e., the laying down of cellulose micelles in the cell wall) are differentially affected by cell turgor. We proposed this to John Boyer (USDA-ARS, Urbana, IL). He confirmed it (personal communication). Moreover, he has found that the biological clock which tells how long the expansion of a cell wall may continue is slowed by water stress. Looking at the estimate of carbohydrate demand in GOSSYM, the result of this is that, on irrigation, with the relaxation of water stress and with the regaining of turgor, a large additional load is placed on the metabolite supply as a larger than normal number of cells and tissues strive for growth. For a short time, this large increase in demand shifts the metabolite supply:demand ratio into what remains or may be a more acute physiological stress, even though photosynthate production and nitrogen uptake are enhanced. Abscission and delays in plant development continue or possibly increase, depending on the length of time leading into the stress.

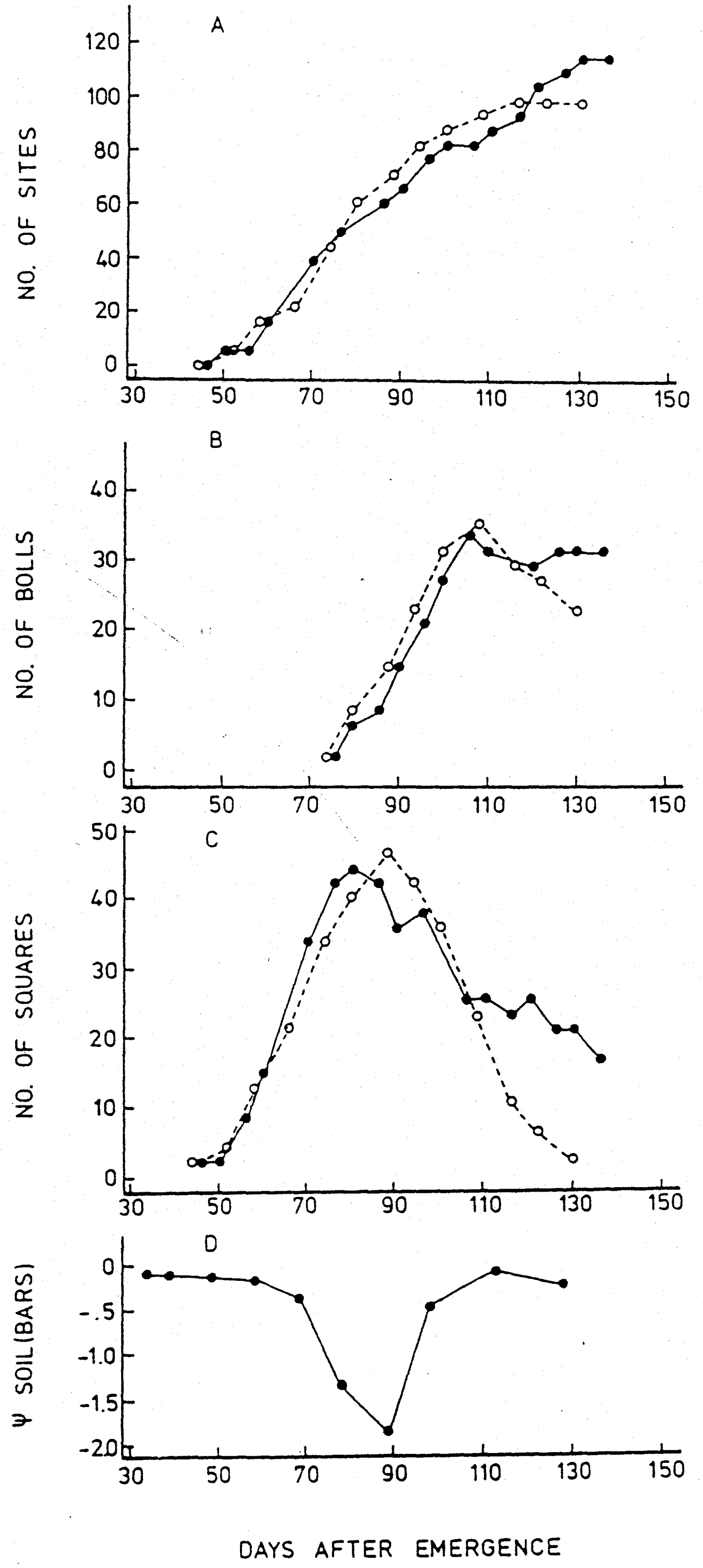


Figure 14. Simulations of treatment ABB without cell-water stress logic elongation. Soil water potentials maintained as in part D. Parts A, B, and C show numbers of sites, bolls, and squares per plant, respectively. Open circles and closed circles represent real crop and model output data, respectively.

We incorporated these ideas into GOSSYM and got a much better simulation of the entire experiment (all irrigation treatments) of Bruce and Römkens (Figures 15 and 16). This was gratifying in that we now could simulate the effects of water stress on fruiting within the framework of the nutritional theory. We believe that the significance of this lies in the fact that, at last, a rational—possibly complete—definition of the term water stress exists. Using changes in the fruiting processes, site production, and abscission as indicators, we have expressed our belief, in GOSSYM, that water stress should be thought of as a syndrome affecting photosynthesis, nutrient uptake via the transpiration stream, and growth at different levels as the stress progresses. The result is at the level of metabolite supply and demand where the connection to hormone mechanisms is made and delays in plant development and fruit abscission are induced.

Finally, while the ideas and papers of Mauney (1966, 1979) and the authors he has cited provide a basis for a coherent theory of cotton growth as interpreted in GOSSYM, we believe they represent more than that. In other work, we are finding the same stress mechanisms in the fruiting of other species including soybeans and wheat. We believe that a general theory of growth in fruiting plants is emerging.

After calculation of potential boll growth, potential leaf growth at fruiting sites is calculated. The calculations for each leaf are the same as described above for leaves at mainstem nodes below the first fruiting branch. If the plant is okra leafed, leaf area is reduced by 55% or 49% depending on row spacing. As in the case just described above for boll growth, a running difference between potential growth of a turgid leaf and a water stressed leaf is maintained, and the accumulated differences are added to the potential leaf growth values on the day the water stress is relieved.

After the potential leaf and fruit growth calculations, the nested DO's are exited and potential stem growth is calculated. Data collected in field grown cotton in 1969 are used here. The data represent growth during the first 42 days after emergence. Growing conditions were excellent during that period, and we assume that little or no shortage of either carbohydrate or nitrogen occurred. The data are summarized in Figure 17. Potential stem growth (PDSTMD) is calculated as follows:

PDSTMD = (0.1 + 0.02*IDAY) * DAYTYM * WSTRSD, (15)

where PDSTMD is potential stem growth during the daylight hours, IDAY is the day number from emergence, DAYTYM and WSTRSD are, as above, the fraction of the 24-hour period in daylight and average water stress during the daylight period. After 42 days, potential stem growth is expressed as a function of the weight of stem tissue not yet turned woody. Thus,

PDSTMD = (0.2 + 0.06*(STEMWT - STMWT*(IDAY - 24)))*DAYTYM*WSTRSD (16)

As was indicated above with reference to the effect of sink strength on morphogenesis and fruit abscission, it is essential to estimate metabolite demand properly in order to simulate the effects of physiological stress. We had found as early as the SIMCOT II (McKinion et al., 1975) work that the above logic pertaining to stem growth was necessary in order to simu-

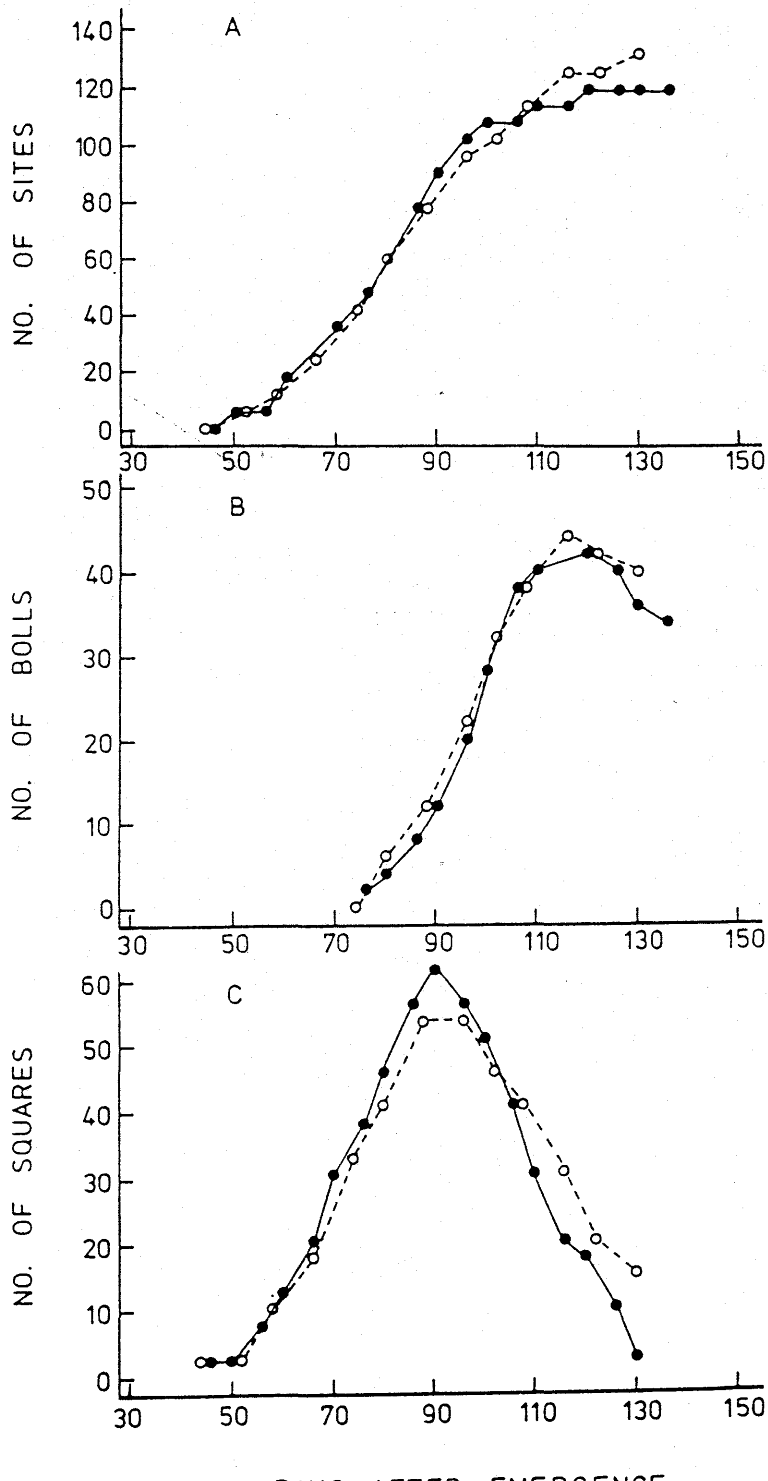


Figure 15. Simulation of treatment AAA with cell-water stress logic elongation. Soil water potentials maintained as in D. A, B, and C show numbers of sites, bolls, and squares per plant, respectively. Open circles and closed circles represent real crop model output data, respectively.

late the sigmoid growth habit in terms of plastochron length and to simulate the pattern of fruit abscission properly. Thus, the model retires all stem tissue as it passes 24 days age from growth and from the metabolite sink. Potential growth is proportional to the quantity of stem tissue younger than 24 days.

The next section contains logic to maintain a record of the difference in stem growth under water stress vs. full turgor, which is analogous to that described above for boll growth. The potential rate of root growth is calculated in the RUTGRO subroutine. This subroutine will not be discussed in detail in the present paper. However, the calculation of potential growth and actual growth of roots in each soil cell will be described. In early versions of GOSSYM, we expressed potential root growth as a function of root system turgor which was always greater than the turgor of the tops. In this way we had hoped that the model response to water stress would be to shift the root:shoot ratio toward heavier root systems. Implemented in the dynamic model, this idea of a passive shift not only failed; surprisingly, the opposite occurred, and smaller root:shoot ratios resulted under water stress. The next section of subroutine GROWTH, therefore, "brute forces" a higher root:shoot ratio under water stress. Partitioning factors for day and night, PARTD and PARTN are arbitrarily set inversely proportional to WSTRSD and WSTRSN. The root:shoot ratio, not including fruit, is then calculated. If the ratio is not greater than the appropriate partitioning factor, potential growth increments of the aboveground vegetative parts are multiplied by 0.5 and the potential growth increment of the root system is multiplied by 5.0. In this way, over a period of days, the plant "seeks" a root:shoot ratio which favors a greater root system under water stress. To date, this part of GOSSYM has not been validated separately. We can only say that it has in all cases passed the "test of reasonableness."

After the calculation of potential root growth, carbohydrate demand (CD) is totalled, as is the carbohydrate pool (CPOOL), and the ratio, CSTRES is formed. The CSTRES term, as noted earlier, serves in subroutine PLTMAP as an index of physiological stress in the plant causing shifts in hormone balances and delays in further morphogenesis and causing the abortion of fruit. This is often referred to as "physiological" shed. CSTRES is also used to estimate nitrogen requirements and to partition dry matter.

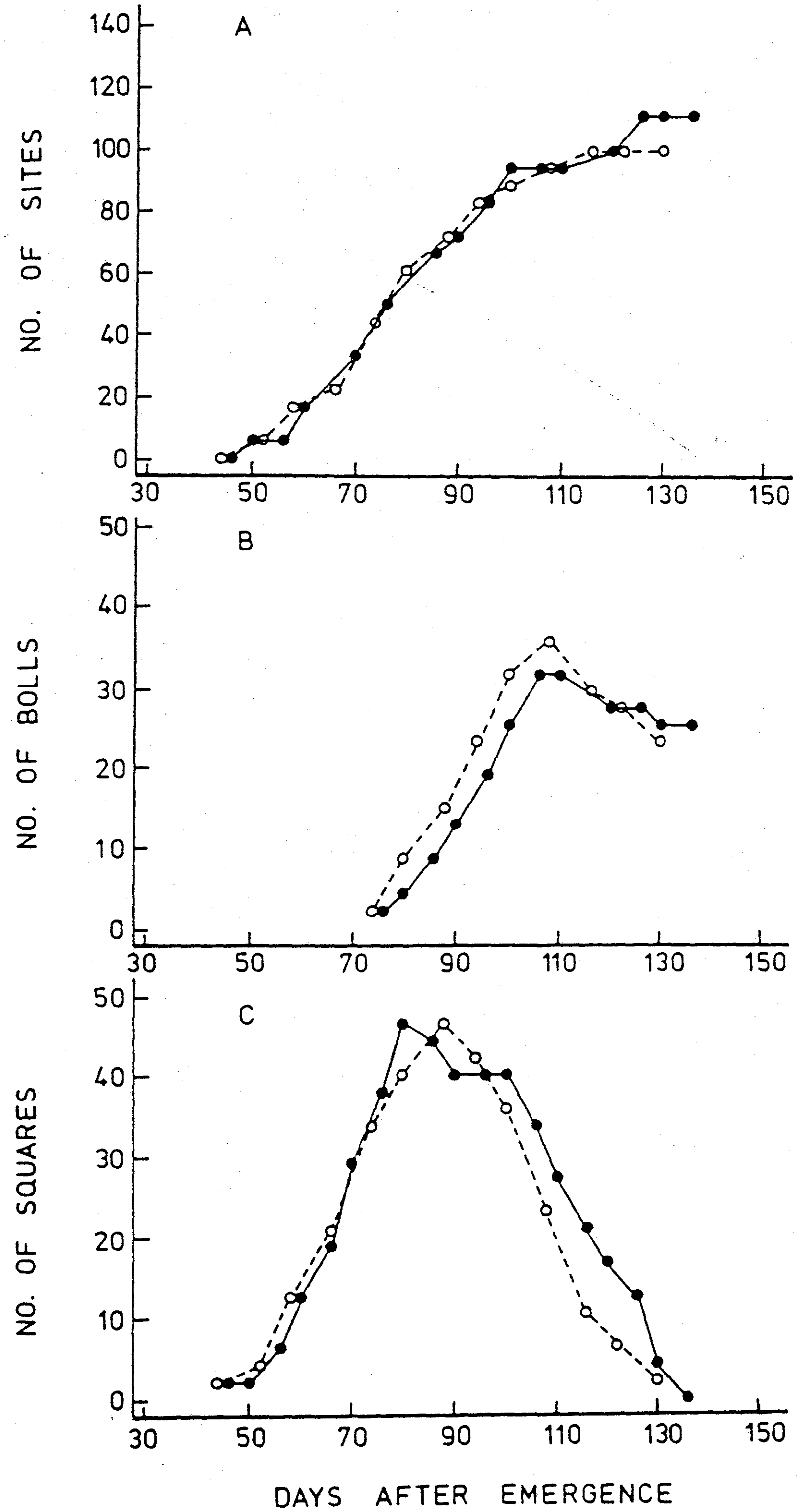


Figure 16. Simulation of treatment ABB with cell-water stress logic elongation. Soil water potentials maintained as in D. A, B, and C show numbers of sites, bolls, and squares per plant, respectively. Open circles and closed circles represent real crop and model output data, respectively.

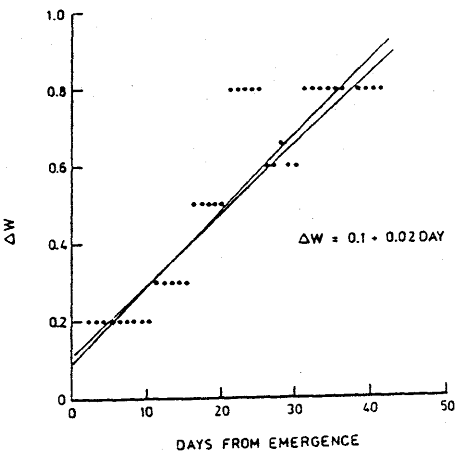


Figure 17. Daily stem growth increment vs. age.

After the formation of the ratio CSTRES, the carbohydrate pool is examined for any excess to the demands for growth. If an excess exists, it is used to fill reserves. Reserves of carbohydrate may constitute up to 0.3 of leaf dry weight. Thus, okra-leafed cotton has a smaller reserve capacity than normal leafed varieties. If there is more carbohydrate than can be put into labile reserves, the excess is stored in some unspecified location in the plant and is assumed to be unavailable for growth.

Just before calling subroutine NITRO (from GROWTH), potential organ growth increments are reduced by the CSTRES ratio to allow calculation of nitrogen requirement for growth. A nitrogen budget is maintained in NITRO. NITRO returns to GROWTH two nitrogen supply: demand ratios, one for vegetative growth (NV) and one for fruit growth (NF). Then, combined physiological stress ratios (VSTRES and FSTRES) are formed from the products of CSTRES with NV and NF.

With the combined supply:demand ratios, the model is ready to calculate the dry matter growth of each organ on the plant. These values are calculated as the simple product of the potential growth of the organ and the supply:demand ratio, VSTRES for vegetative structures and FSTRES for fruit. The RUTGRO subroutine is called a second time, here, for the allocation of dry matter to the various cells in the RHIZOS matrix.

On return to GROWTH from RUTGRO, statement 40 is executed which states that if the plant weighs less than one gram, VSTRES is redefined to be 1.0. This cutoff was found necessary to prevent delays in morphogenesis in very small plants with some weather data sets. The plant is fixing only small amounts of carbon at that time and is sensitive to the cumulative delays calculated in PLTMAP.

The last function performed in GROWTH is the incrementing of plant height. Height growth is calculated from the age or ages of the top nodes on the mainstem. In this way the indirect effects of metabolic stress and temperature (both determining rates of new mainstem node formation) are felt. Later the daily increment in height growth is adjusted for water stress effect.

Initially the height increment (DZ) is calculated as a function of the age of the top mainstem node. The data base for this process (Bruce and Römkens, 1965) is shown in Figure 18. A limit of 1.5 cm per day has been placed on the height increment for one internode, and a limit of 3 cm/day has been placed on the vertical extension rate for the plant as a whole. If there are three fruiting branches on the plant, the height increment is expressed as a function of the age of the top three nodes. Again the data of Bruce and Römkens (1965), summarized in Table 1 and Figure 19, are used. R^2 for the regression equation including temperature was 0.94 and 0.72 for the regression equation deleting temperature. However, the range of temperatures available in the data set is very narrow. We had difficulty with extrapolation, and so the form without temperature is used. Results to date have been good. In order to derive these data from Bruce and Römkens (1965) it was necessary to force correct height growth in a simulation of their AAA treatment (the wet one) and then correct the height increment data for water stress effects estimated in the simulation. The water stress values (WSTRES) are listed in Table 1.

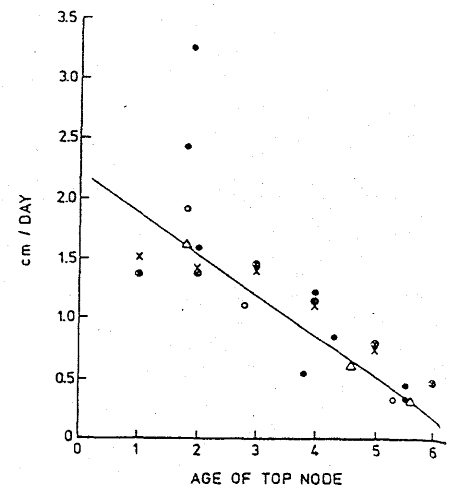


Figure 18. Daily stem height growth vs. top node age.

Table 1. Data base for height growth calculations.

AGETOP	TAVG	real * dZ/dt	model I dZ/dt	model II dZ/dt	WSTRES	DAY
12.9	22.8	0.54	0.58	0.70	0.92	30
10.2	23.4	0.85	0.57	0.34	0.94	40
5.7	20.7	1.22	1.23	1.51	0.90	50
4.0	23.4	1.59	1.84	2.53	0.91	60
3.8	23.4	2.47	1.88	2.67	0.89	70
3.6	25.3	3.25	3.46	2.82	0.77	80
3.9	25.7	3.99	3.69	2.60	0.69	90
4.3	24.3	1.92	2.32	2.33	0.86	100
5.7	22.7	1.12	1.26	1.51	0.85	110
9.7	25.9	0.60	0.64	0.35	0.83	120
12.2	23.1	0.33	0.42	0.53	0.91	130

*Data of Bruce and Römkens (1965).

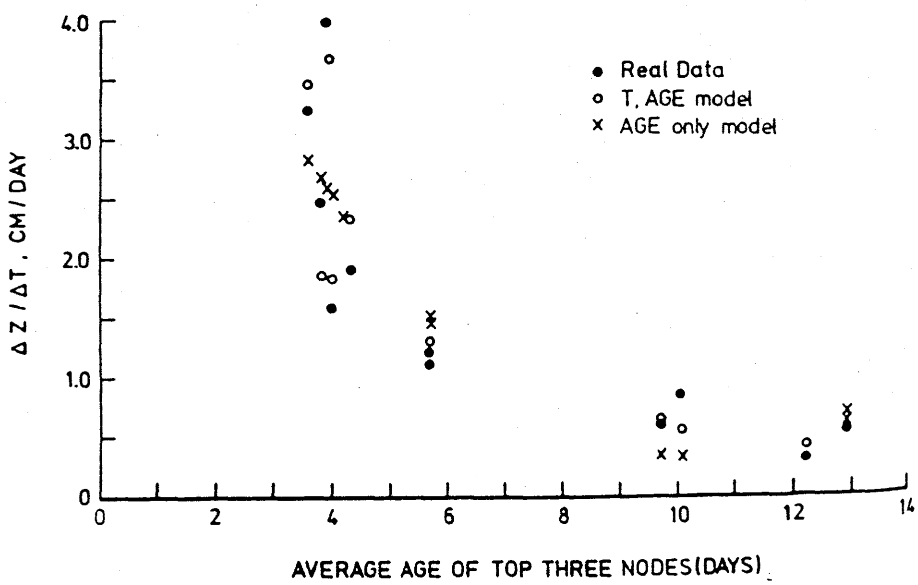


Figure 19. Daily stem height growth vs. average of the top three nodes.

RUTGRO

This subroutine calculates potential and actual dry matter in the various parts of the root system. It also calculates water stress parameters which are used in GROWTH to adjust potential growth of aboveground plant parts.

A more detailed description of this subroutine is presented by Lambert and Baker (1984) in their discussion of RHIZOS. The parts directly affecting aboveground processes will be outlined here for readability of the present discussion of GOSSYM as a whole. Flow charts are presented on pages 42-50.

The water stress parameters are calculated first and will therefore be presented first in this discussion. Boyer (1970) presents data showing an abrupt cessation in leaf growth in soybean, sunflower, and corn as leaf water potential falls below about -3 bars (full turgor). The exact cutoff varies with species and we presume it varies somewhat with conditioning. The plants approach zero enlargement asymptotically, reaching zero at or before -12 bars and we found that a -7 bar threshold works best for estimating growth in cotton. Model strategy is to assume that above -7 bars leaf water potential there is no restriction to growth of aboveground plant parts and below that threshold no growth occurs, since the asymptote is approached sharply in Boyer's data.

Our procedure, then, was to assemble a data set relating leaf water potential to environmental conditions. We had available two data sets-one of our own, collected in 1969 in the field (unpublished), in which soil suction (ψ) varied from -0.1 to -0.7 bars, and another from Jordan and Ritchie (1971) with a soil suction of -10.0 bars. These data represented hourly averages.

The Jordan and Ritchie data had continuous values of relative water content. Our own data, however, were not so well suited to the task. They had been collected in field grown cotton, enclosed in 2m x 2m airconditioned chambers in which photosynthesis and transpiration measurements were made with a closed system technique. The chambers were opened only before sunrise for leaf turgor measurements, and again at one to one-thirty p.m. In order to interpolate between the pre-sunrise turgor value and the minimum in the afternoon, we established a relationship between total change and cumulative transpiration, which was reasonably precise. We then used cumulative transpiration as an index to assign interim leaf turgor values. Turgor was expressed as relative water content (RWC). Next, in preparing these data a relationship between RWC and leaf water potential was needed.

Three data sets relating relative water content and leaf water potential were found in the literature (Klepper et al., 1971; Jordan and Ritchie, 1971; and Slatyer, 1957). These data sets are graphed in Figure 20. The line through these points was then used to obtain leaf water potential values, as needed, in both (our own and Jordan and Ritchie, 1971) data sets. Next, a stepwise regression procedure was used to develop an expression of leaf water potential (PSIL) as a function of soil water potential (PSIS), net radiation (RN) and temperature (TA), where the water potentials are in bars, temperature is in centigrade, and net radiation is in watts/m^2. This regression is as follows:

PSIL = -9.078 + 3.564*PSIS + .8538*TA - .3193*PSIS**2 + .00000936*RN**2 - .01436*TA**2 + .006762*PSIS*RN + .02857 *PSIS*TA - .0001607*PSIS*RN *TA. (17)

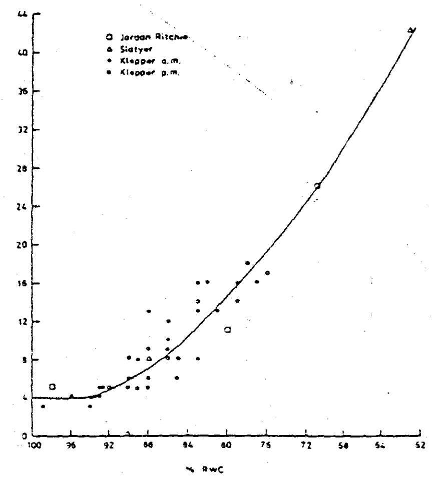


Figure 20. Leaf water potential vs. relative water content.

Table 2.

RN maximums	512, 345, 438, 470, 617, 86*
T maximums	45, 40, 34, 32, 31, 27
T minimums	27, 24, 16, 21, 22, 16
PSIS	.1, .2, .4, .5, .6, .7, .8, .9, 1.0, 1.1, 1.2, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 1.9, 2.0, 5.0, 10.0

*These net radiation maximums, temperature maximums, and temperature minimums are from the typical daily patterns used in the analysis.

The next step was to use this regression model to calculate PSIL values at 10-minute intervals for all combinations of the weather and soil water potential conditions in Table 2. Daily time courses of two such (typical) data sets are given in Figure 21 along with the net radiation and air temperature values used.

Finally, the number of minutes, t, ($\pm$ 10) in the daytime and nighttime, with PSIL above -7 bars was computed. This vector was fitted via stepwise regression to comparable vectors for daily average net radiation (RNAVG), average temperature (T), and soil suction (PSIS). Thus,

t = 1980 - 798*PSIS - 0.5*RNAVG - 71*T + 181*PSIS*PSIS + 1.2*T*T + .08*PSIS*RNAVG - 0.7*PSIS*T - 11*PSIS**3 (18)

RNAVG was assumed to be constant at night. PSIS may be soil suction averaged over the entire rooted portion of the soil profile or the maximum (absolute) value. Daytime and nighttime water stress terms WSTRSD and WSTRSN, respectively, are calculated as the fraction of time during which PSIL is above -7 bars using the average soil suction in the rooted portion of the profile. These values are then modified by averaging with similar terms calculated using the maximum value of soil suction in the root zone.

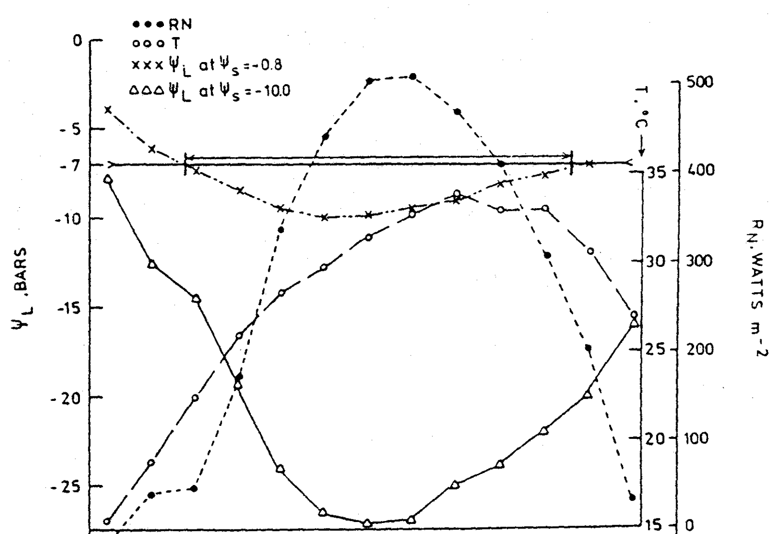
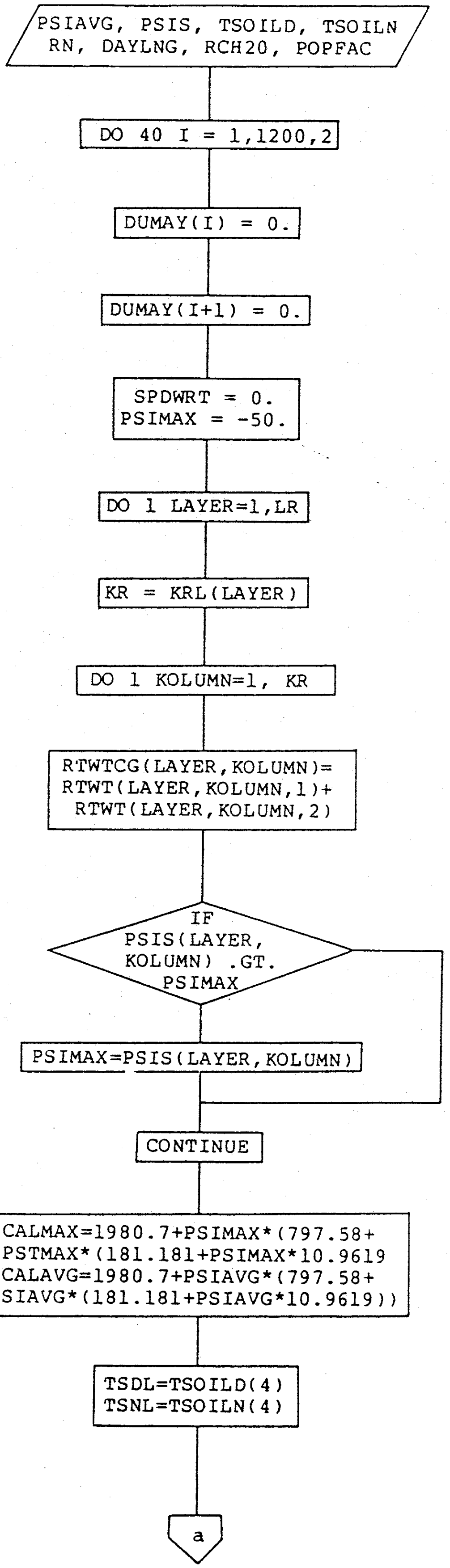


Figure 21. Typical day's time courses of net radiation (R_N), air temperature, and leaf water potentials at soil water potentials of .08 and -10.0 bars.



Bring in these variables.

Sets a dummy array to zero so that the local arrays RTWTCG, PDWRT and DWRT can be initialized to zero during each pass of the subroutine by means of the equivalence statement.

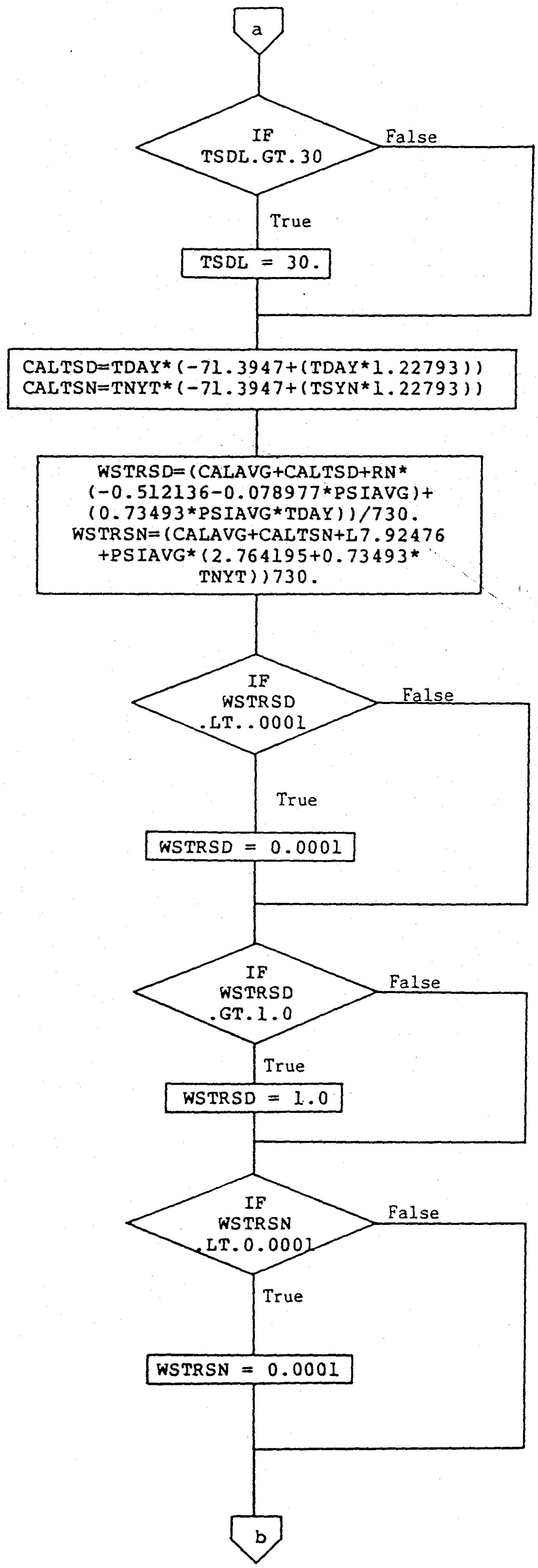
Initializes these variables.

Traverses all soil cells occupied by roots.

Roots capable of growth in any soil cell are assumed to be those in age class 1 (less than ca 3 days old) plus those in age class 2 (between ca 3 and 12 days).

By repeating this comparison over all soil cells occupied by roots, the maximum soil water potential in the root-occupied region will be found. Note that PSIS (ψ) is negative.

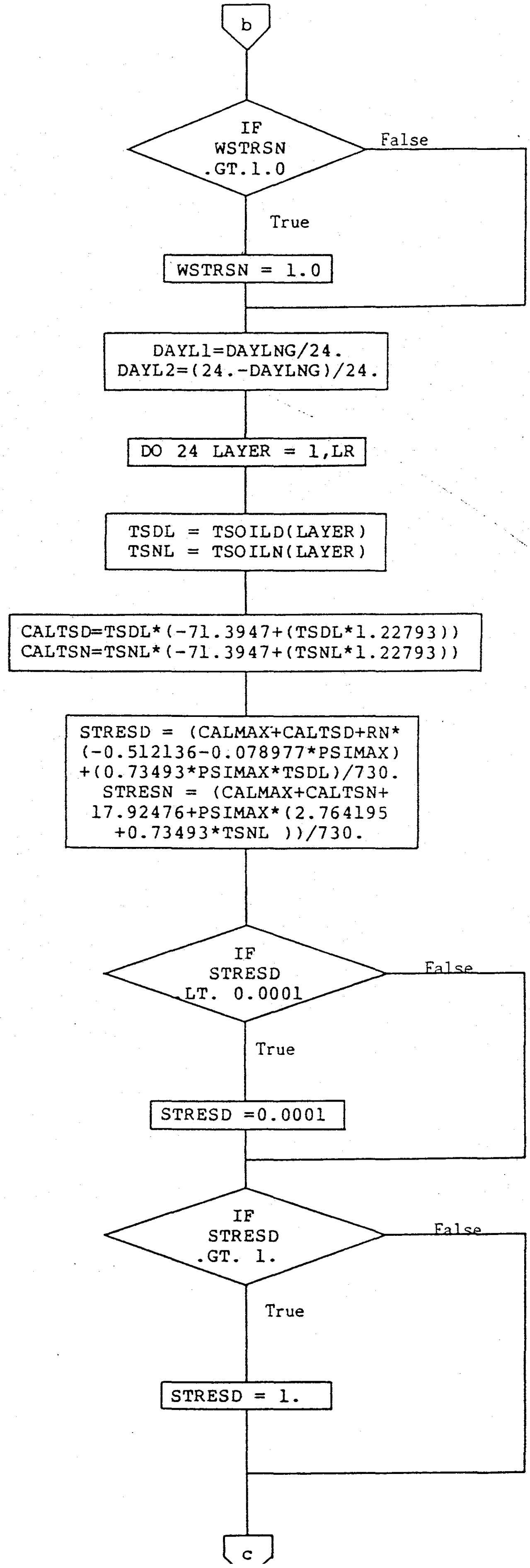
RUTGRO (2)



Limits TDSL to 30° C.

Limits .0001 .LT. WSTRSD .LT 1.

Limits .0001 .LT. WSTRSN .LT. 1.

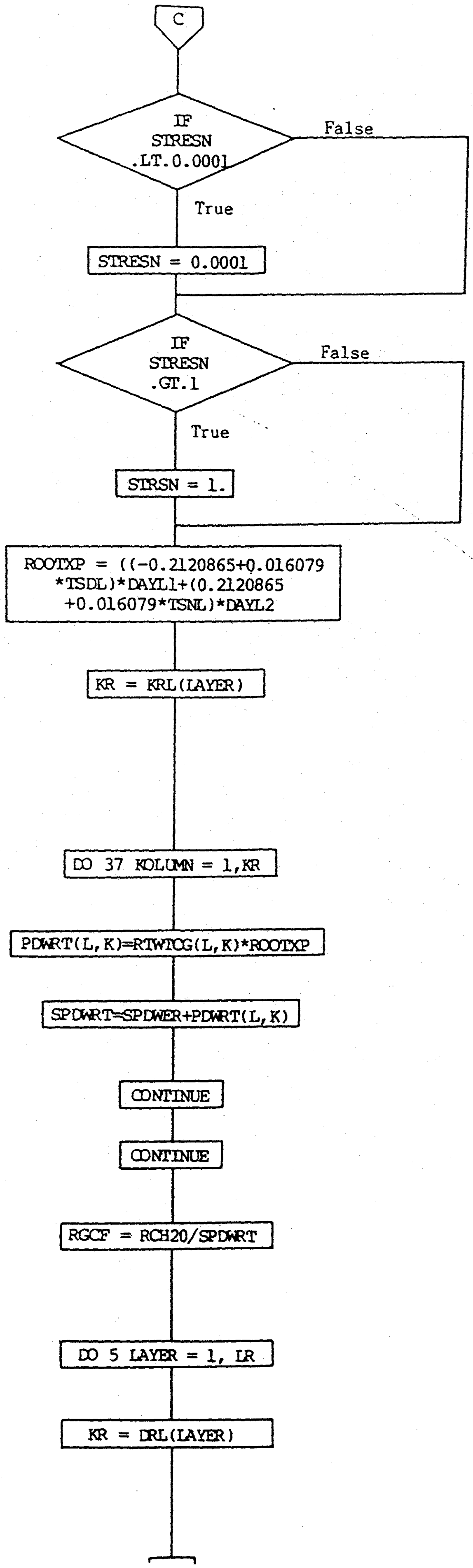


Day length as a fraction, 0-1.
Night length as a fraction, 0-1.

Traverses all layers occupied by roots.

Average temperature of the layer during daytime. Average temperature of the layer during night time.

Limits .0001 .LT. STRESD .LT. 1.



Limits .0001 .LT. STRESN .LT 1.

Specific root growth rate within soil cell, dependent on daylength, layer temperature, and water stress based on PSIMAX.

Based on unpublished data of Hesketh on boll growth in a phytron experiment. Modified for root growth based on results of this simulator. Further efforts to obtain better data are underway utilizing SPAR units.

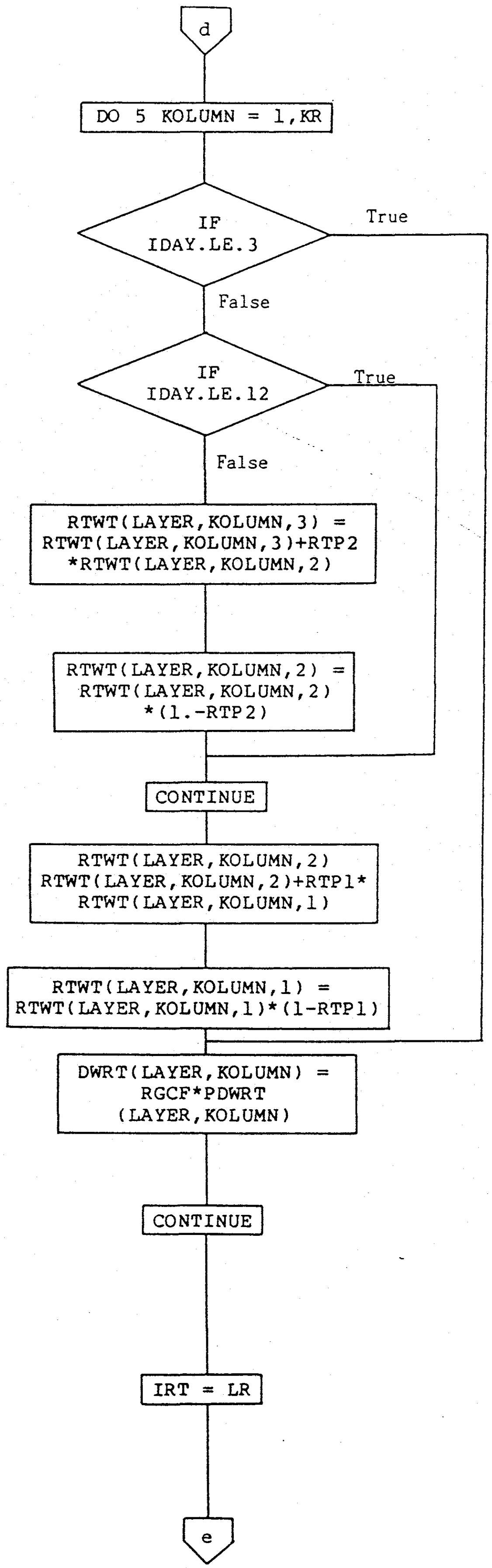
Do for all columns in the layer which are occupied by roots.

Potential root weight increment (if CH_2O is plentiful) is product of root weight capable of growth and specific rate of root growth.

Sums potential root growth over entire profile.

Root growth correction factor is the ratio of the carbohydrate available for root growth in the profile.

Covers all soil cells occupied by roots.



If the crop is three days old or less, no shifting of roots by age class is done.

If the crop is less than 12 days old, no roots are shifted from age class 2 into age class 3.

After day 12, a fraction (RTP2) of the roots in age class 2 is shifted into age class 3. RTP2 is ca 1/(12-3).

The roots added to age class 3 are here removed from age class 2.

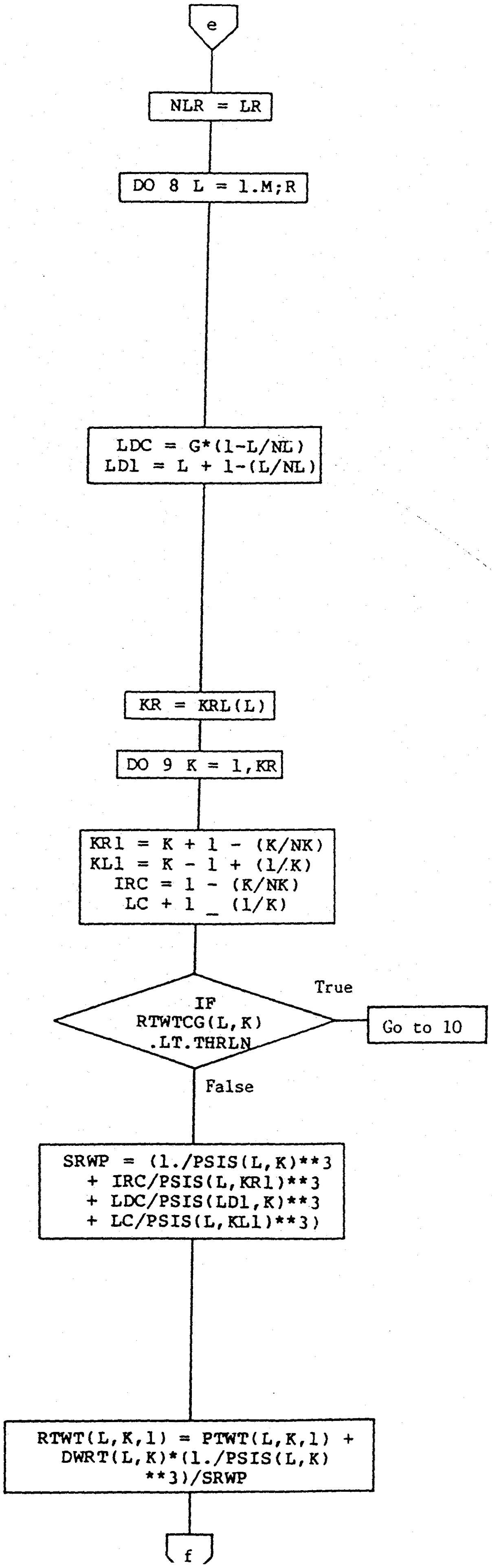
After day 3, a fraction (RTP1) of the roots in age class 1 is shifted into age class 2. RTP1 is ca 1/3.

The roots added to age class 2 are removed from age class 1.

The actual root weight increase in the soil cell. Note that DWRT = RCH2O.

The growth originating from each cell already occupied by roots has now been determined. The direction of that growth must now be determined. Growth may occur within the cell itself, to the right, to the left, or downward.

Temporary LR, for use later.



Number of layers containing roots.

Use of the variables LDC, LD1, KR1, KL1, IRC, and LC allow simplified programming SRWP and DWRT; the alternative is many IF statements to handle boundary conditions for root growth. "Layer down" coefficient for use in SRWP equations below:

= G 1 .LE. L. .LT. NL
= 0 L = NL

Number of "Layer down" (below) for use in SRWP equations below:

= L + 1 1 .LE. L .LT. NL
= L L = NL

The effect of LDC and LD1 in the SRWP and subsequent statements is to prohibit roots from growing onto the bottom of the root zone.

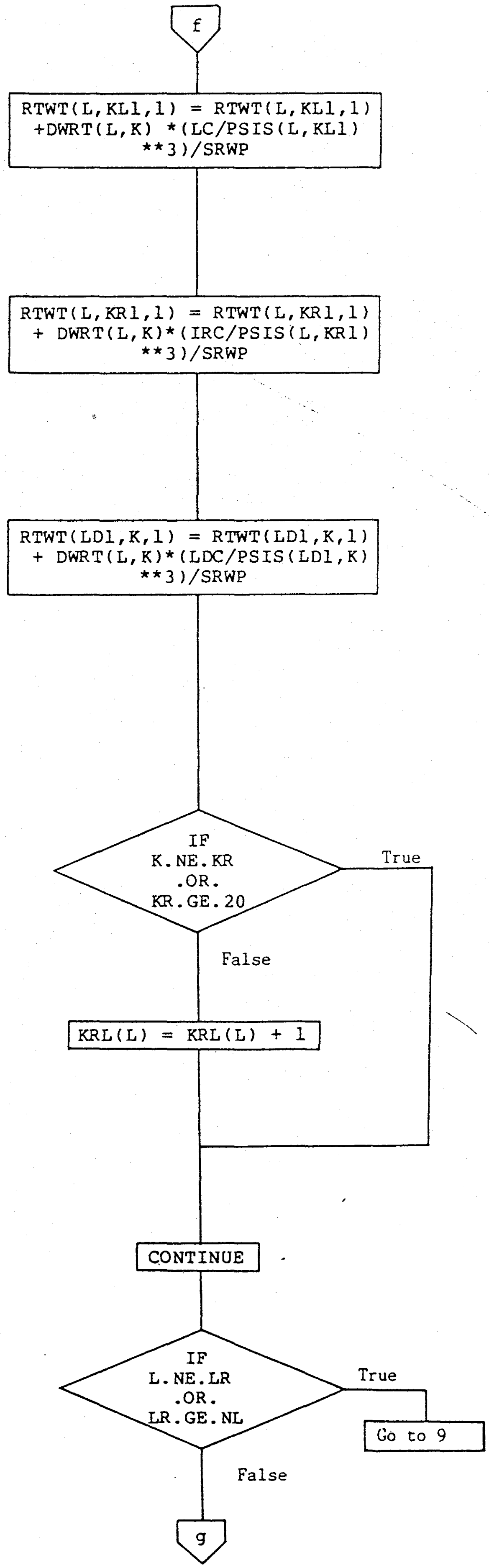
The number of columns occupied by roots in layer L.

Covers all cells occupied by roots.

If the root weight capable of growth is smaller than a threshold, roots have not traversed the soil cell and thus cannot extend into adjacent cells. Growth occurs only within the cell L,K.

Sum of weighting factors to determine relative amount of growth from the soil cell in each of the four directions: internal of the cell itself, leftward, downward, and rightward. Weighting factors based on water potential os considered cell. Approach is strictly a hypotheis. Note: that IRC, LDC and LC are either. 0 or G.

To the current young root weight in the cell L,K is added the fraction of the root growth from the cell occuring within the cell.



To the current young root weight in the cell to the left of cell L,K is added the fraction of the root growth occurring from the cell, L,K into the left hand cell. Note that if K=1, LC=0 and the boundary condition of no growth across the plant under the row is satisfied.

To the current young root weight in the cell to the right of cell L,K is added the fraction of the root growth occurring from the cell L,K into the righthand cell. Note that if K=NK, IRC=0 and the boundary condtition of not growth across the plant under the next row is satisfied.

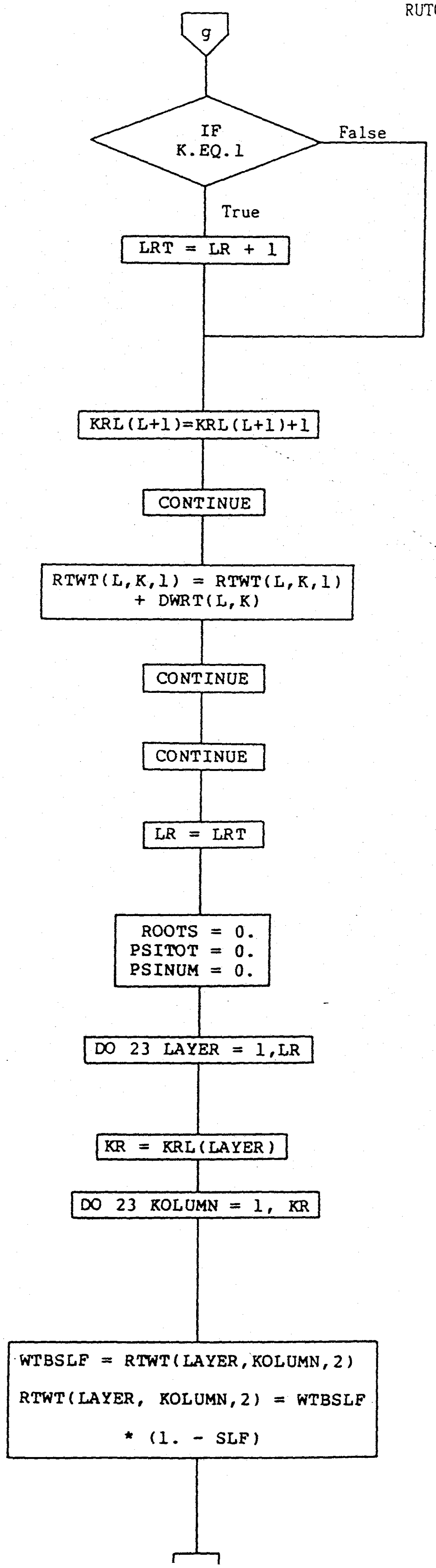
To the current young root weight in the cell below cell L,K is added the fraction of the root growth occurring from the cell L,K into the cell below. Note that LDC=0 or G to include geotrophic effects. If L=LN, LDC=0 and the boundary condition of no growth across the bottom of the root zone is satisfied.

The matrix is being traversed by layer, from left to right. If the number of columns occupied by roots equals the total number of columns in the plant, KRL cannot be increased. Further, if the cell being considered (L,K) is not the rightmost cell which contains roots in the layer, no consideration of increasing KRL is given.

Increment the number of columns occupied by roots in the layer. Note that this occurs only when growth in the rightmost cell containing roots in the layer is being considered and current root weight capable of growth exceeds the threshold value.

If the bottom layer occupied by roots is not being considered, or all layers in the slab are already occupied by roots, no consideration of increasing LR, the number of layers occupied by roots, is given.

RUTGRO (8)



Growth from the lowest layer occupied by roots downward increased the number of layers occupied by roots. Must be possible to increment LR only once within the traverse of the layer. Since left column (K=L) is generally the deepest, it is chosen for consideration in determining whether to increment LR. LRT is temporary LR; LR is not incremented until complete matrix has been traversed so that (L.NE.LR) comparison can continue accurately.

Increments number of columns occupied by roots in what will be the lowest layer occupied by roots during the next traverse of the matrix.

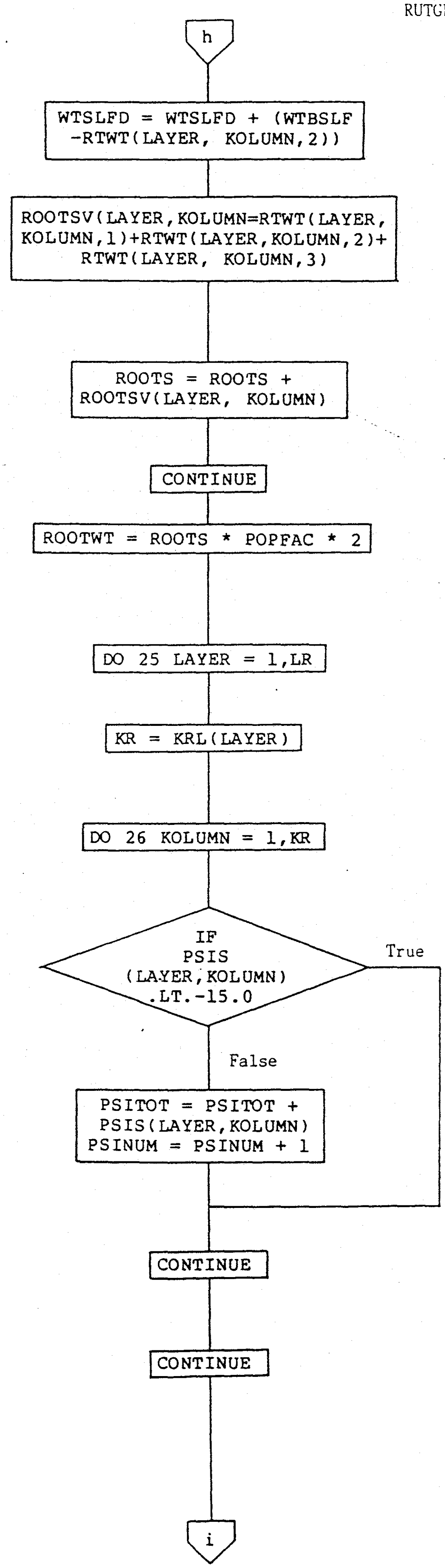
All growth occurs with soil cell L,K itself because the threshold has not been exceeded.

Sets the number of layers occupied by roots to LR or LR+1, dependent on whether a new layer has been entered by roots.

Initializes these variables.

Traverse all soil cells occupied by roots.

Root weight to be considered during sloughing. For lack of better information, hypothesis is that roots between 4 and 12 days old are sloughable. According to Huck (1976) if cotton roots live to be 12 days old they harden and live until death caused by environment or lack of energy for respiration. Root weight in age class 2 is reduced by the fraction SLF. SLF set strictly by guess.



Weight of sloughed roots is accumulated throughout the season.

Total live root weight in each soil cell due to left row is the sum of the weight in each of the three age classes. Total live root weight in the profile due to left row is the sum over all cells.

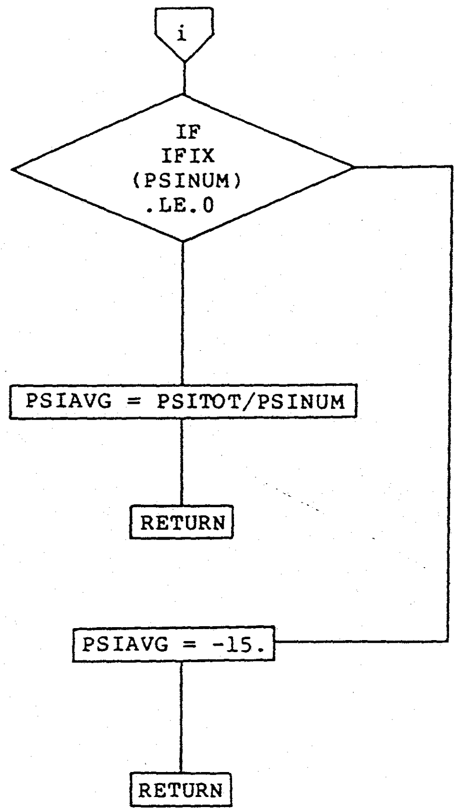
Total live root weight in the profile due to the left row is the sum over all cells.

Root weight per plant. POPFAC is the average length of row per plant. The 2 accounts for both halves of the root system.

Traverse all soil cells occupied by roots.

Average water potential in the portion of the profile occupied by roots will be calculated below. However, no cells having a water potential below -15 bars are to be considered in developing the average.

Cumulative water potential over cells occupied by roots and having a water potential greater than -15 bars. Number of cells meeting the criteria and thus included in the average.



If no cells meet the criteria, do not calculate the average water potential. IFIX allows an accurate comparison to zero, using integer arithmetic.

Average water potential is the cumulative potential divided by the number of soil cells used in the accumulation.

If no cells are above -15 bars, assume the average water potential is -15 bars.

Return to calling subroutine.

In the calculation of potential root growth in each of the cells in the RHIZOS matrix, we assume exponential growth based on the mass of roots present in the age category capable of growth. In the absence of potential root growth data at the time the model was written, we assumed that a reasonable figure might be the same as that for boll growth during the period immediately after anthesis. Thus, the ROOTXP parameter is obtained by the same function as for young bolls. Subsequent work by Whisler et al. (in process) working with GOSSYM, in which he simulated the root growth measured in SPAR units by Phene et al. (1978), showed that potential root growth is, in fact, an order of magnitude greater than potential boll growth on a weight of growing tissue basis. Other subsequent analyses by Fye et al. (1981) have shown the ROOTXP term must be multiplied by factors of five or six to simulate field crops.

After the calculation of the ROOTXP term, the model calculates a potential (PDWRT) root growth value for each cell from the root weight capable of growth (RTWTCG) where RTWTCG is the root mass, in the cell, less than ca. 12 days old, thus,

PDWRT = RTWTCG*ROOTXP (19)

Then, these cell values are summed over the whole root system to form a total (SPDWRT). RUTGRO now returns to GROWTH where an increment of carbohydrate (RCH20), actually to be alloted to the root system, is determined. Then, returning to RUTGRO, this dry matter is partitioned to each part of the root system in proportion to its contribution to total demand. RGCF is the partitioning factor.

RGCF = RCH20/SPDWRT. (20)

Finally, the root growth correction factor (RGCF) is multiplied by the potential root growth terms (PDWRT) to give an increment of dry matter accumulation (DWRT) in each cell.

NITRO

This subroutine is called from GROWTH. With GROWTH it determines the partitioning of metabolites in the plant and in the estimation of physiological stress levels. These stress levels are used subsequently in PLTMAP to estimate increases in plastochron length and to estimate amounts of fruit abscission each day. Thus, while GROWTH provides the overall model with an estimate of carbohydrate shortage and carbohydrate stress in the plant, NITRO provides an estimate of nitrogen stress. Again, as in the case of the carbohydrate stress calculations in GROWTH, the nitrogen stress is estimated in NITRO as a supply:demand ratio. Here, however, two ratios are calculated. NV, the supply:demand ratio for vegetative growth is used only in dry matter partitioning in vegetative parts. NF, the supply:demand ratio for fruit growth, is used both for dry matter partitioning to fruit and for indexing the morphogenetic delays and fruit abortion rates in PLTMAP. These calculations require that an organ-by-organ inventory of nitrogen in the plant be kept and balanced.

The supply, on the particular day, consists of the increment of nitrogen brought in through the root system (UPTAKE) plus mobilizable reserves. The requirements for full organ growth are estimated from the data obtained by Jones et al. (1974) in their review. Nitrogen in excess of the Jones et al., concentrations in vegetative tissues is considered to be reserve. Its availability status is determined by a mobilization coefficient (F2), which is usually assigned an arbitrary value of 0.5, saying simply, that only half of the nitrogen reserve is actually available on a given day.

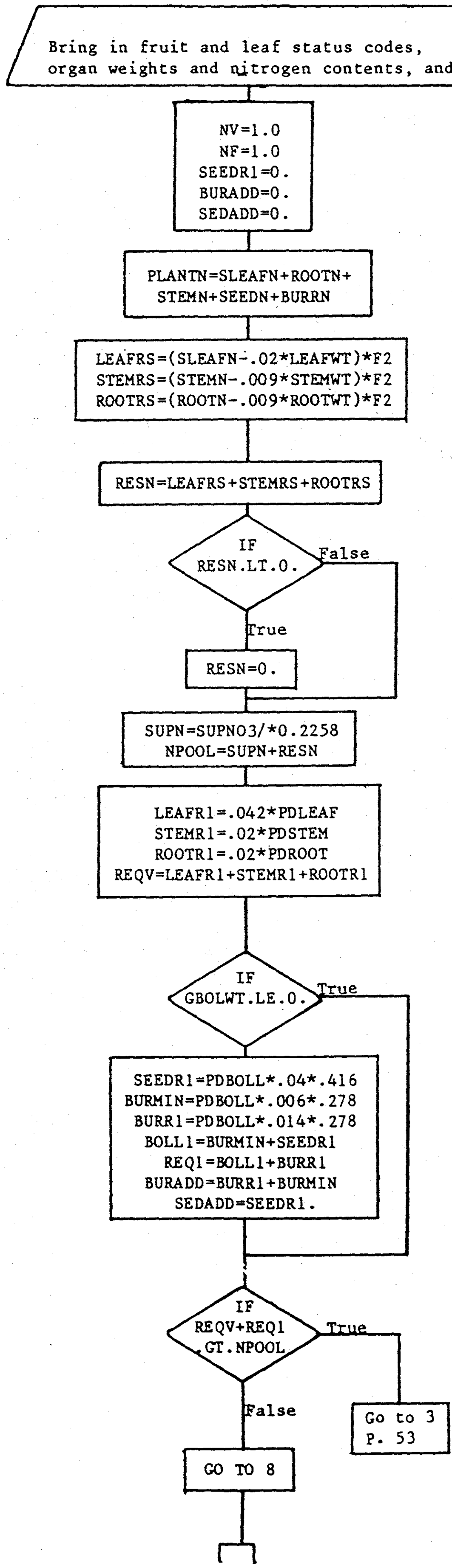
Demand is also estimated using the minimum percentages needed for full growth of the various organs (Jones, et al., 1974).

Whereas GROWTH partitioned dry matter and nitrogen to the various plant parts equally according to the contribution of each to the total carbohydrate demand, NITRO partitions nitrogen so as to fulfill fruit growth requirements first, assigning any additional nitrogen to the growth of the vegetative structure.

SUBROUTINE NITRO

Flowchart

notes



Calculate total plant nitrogen.

Calculate nitrogen reserves for today in each organ from minimum allowable concentration in that class of organ and the amount of N there now. F2 is a rate of mobilization coefficient. Its value, assigned in BLOCK DATA is 0.5.

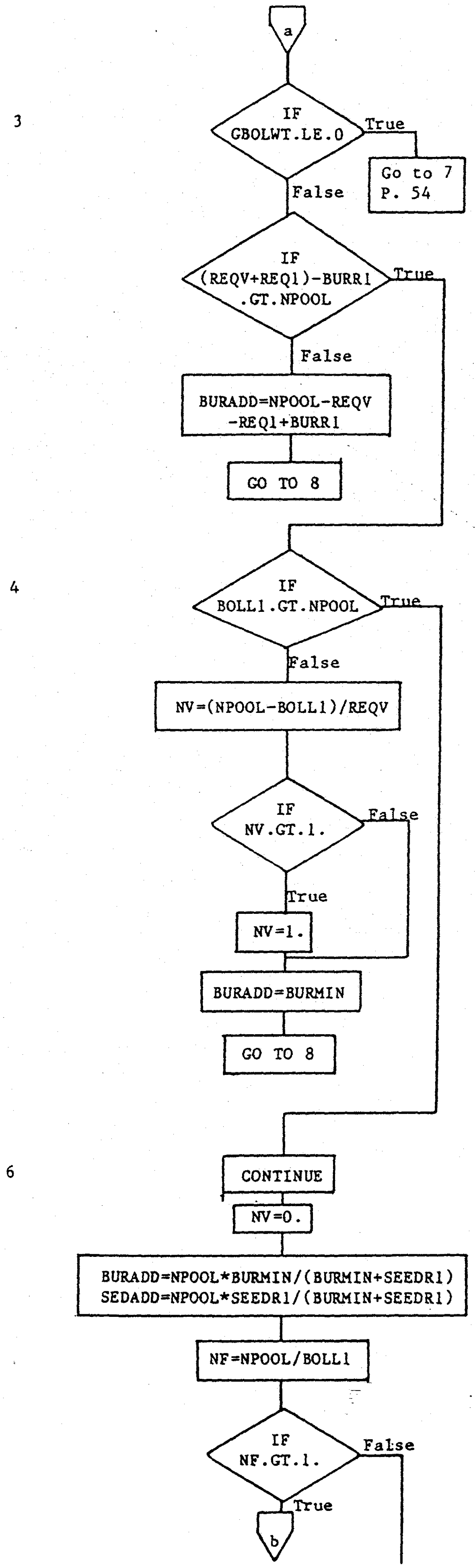
The pool available for today's growth is NPOOL.

Calculate the nitrogen required for new growth in each class of vegetative organs and in the total vegetative structure. The coefficients are the minimum N concentration associated with actively growing tissue.

If the plant has a green boll develop N requirements for boll growth.

Is there enough nitrogen for full vegetative and reproduction growth? If so, leave NF and NV equal to 1 and go on down and calculate full nitrogen additions to the organs.

1



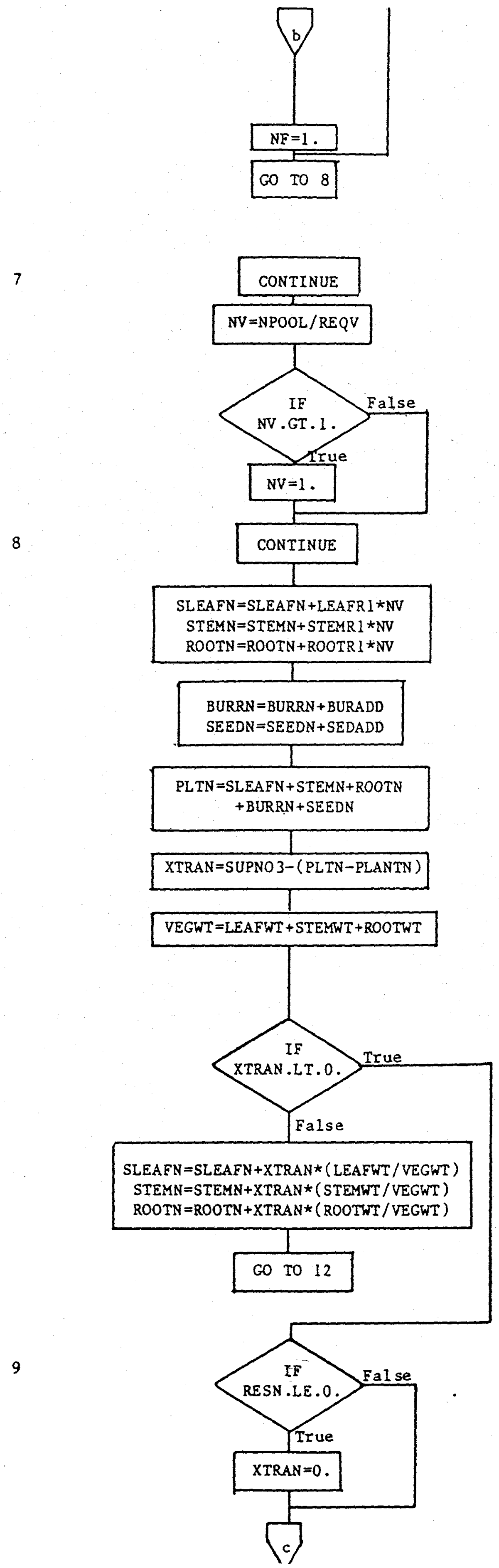
NOTES

Is there enough nitrogen for full seed and lint growth and a minimum necessary addition of N to the burrs? If so, calculate a reduced addition to the burrs and go down to calculate full vegetative growth, seed growth and the reduced concentration burr growth. (NW & NF remain =1.0.)

Is the minimum nitrogen needed for boll growth available? If no go to 6, where NV is set to 0 for no vegetative growth and reduced fruit (NF) growth.

If so, provide for a reduced vegetative growth (reduced NV) and add the minimum necessary to the burrs.

NOTES



Calculate nitrgoen to be added to each class of vegetative organs.

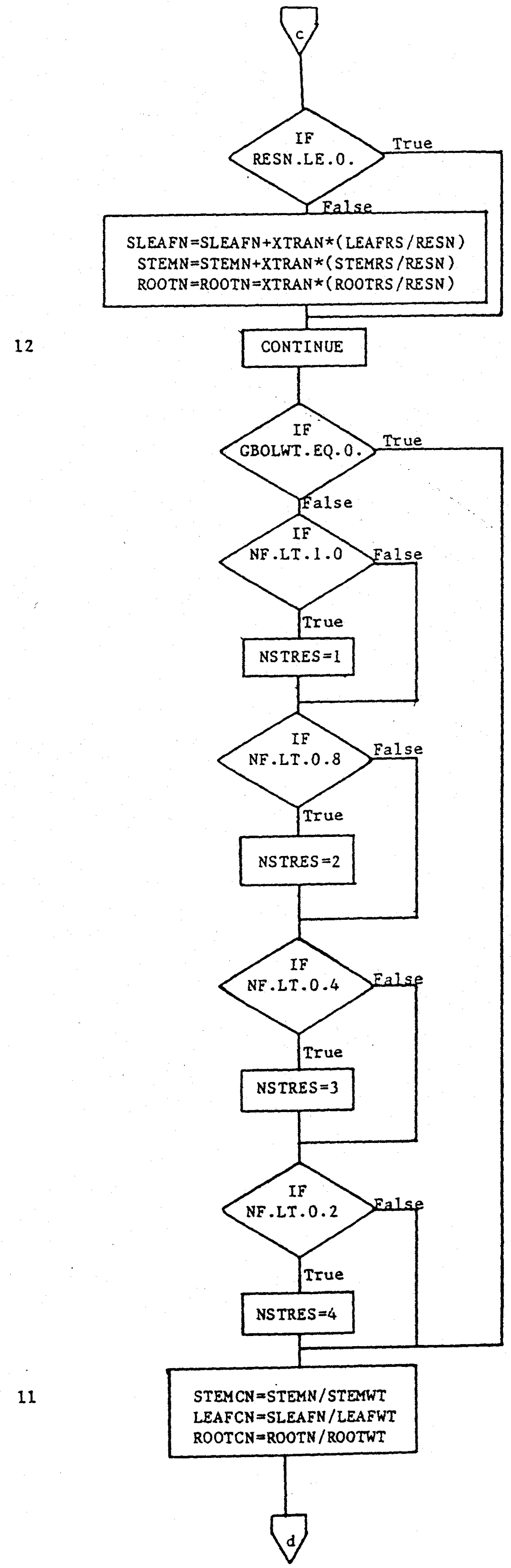
Calculate nitrogen to be added to burr and seeds.

The nitrogen to be stored in vegetative tissues is the difference between that taken up today and that allocated in structural growth. Note! this can be negative.

Calculate the dry weight of the vegetative organs.

Allocate the excess nitrogen to the various vegetative structures in proportion to their dry weight.

NITRO (4)



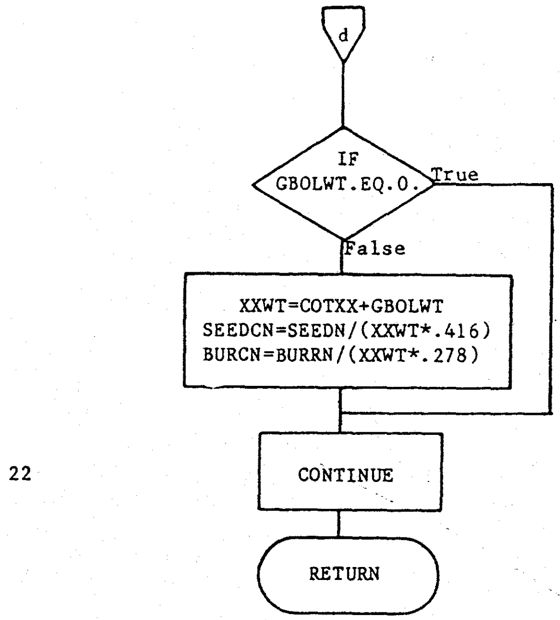
notes

Withdraw deficit nitrogen (used in growth) from reserves in the various vegetative structures.

set NSTRES level as a`f(NF)

Calculate nitrogen concentrations in vegetative parts.

NITRO (5)



NOTES

If there is a boll on the plant calculate nitrogen concentrations in the fruiting parts.

NITRO is flowcharted on pages 52 to 56. Organ weights and nitrogen contents are brought in. Also brought in (from GROWTH) are potential growth increments. The nitrogen supply:demand ratios NF and NV are initialized, and total plant nitrogen content is calculated. Then, the nitrogen reserves are calculated, for each class of organ, as the difference between current organ nitrogen content and some minimum possible concentration multiplied by the organ weight, and these differences are multiplied by a mobilization factor. The minimum concentrations are taken from Jones et al. (1974), and the mobilization factor used is 0.5. Any of the organ components of reserve could be slightly less than zero. Total plant reserve is calculated and, if less than zero, it is set equal to zero. The nitrogen pool available for the current day's growth, then, is the sum of the total reserve N plus the total nitrogen taken up by the root system that day.

Next, the nitrogen required for full growth of each of the classes of vegetative organs is calculated as the product of the potential weight gain (from GROWTH) multiplied by the minimum concentrations observed in rapidly growing organs as reported by Jones et al. (1974). These values are then summed to give a total nitrogen requirement for vegetative growth.

If a green boll exists on the plant, the nitrogen requirements for boll growth are calculated next. Here we assume that the nitrogen content of growing burs may vary somewhat without restricting overall boll growth, so, two nitrogen requirements for bur growth are calculated. The requirement for seed growth and a minimum amount of bur growth are calculated in the same manner as for the vegetative parts. Then, an additional possible increment (BURR1) to the burs is calculated. A minimum boll growth requirement is calculated (BOLL1), and a maximum is calculated as the sum (BOLL1) plus the additional possible increment to burs.

If there is enough nitrogen in the pool for full vegetative and reproductive growth, NF and NV are allowed to remain 1.0 and the model proceeds to calculate full nitrogen additions to all the organ growth increments. If, however, there is not enough nitrogen available to satisfy the demand for bur growth, but there is sufficient for at least a minimum increment to the burs and unrestricted growth of all other plant parts, a reduced addition to the burs is calculated, and full seed and vegetative growth occurs. The stress parameters still remain 1.0.

Proceeding further in assessing the nitrogen situation, if enough nitrogen is available for full boll growth, but only for a fraction of the possible vegetative growth, NV is redefined as the difference between the pool and the minimum boll requirement divided by the requirement for vegetative growth. In other words, the partitioning factor NV is simply reduced to provide the vegetative tissues whatever nitrogen is available for growth after full boll growth occurs. The amount to be added to burs, however, is set to the minimum.

If the minimum nitrogen needed for boll growth is not available, NV is set to zero, i.e., no vegetative growth occurs, and the nitrogen that is available is partitioned to the seed and burs based on the minimum bur requirement. NF is redefined as the supply:demand ratio for boll growth, and the model proceeds to use the partitioning factors NV and NF to allocate nitrogen to the plant parts by class. For example the total leaf nitrogen (SLEAFN) is incremented by the amount of nitrogen added in new growth. The addition of nitrogen to burs and seeds is made next, and the total nitrogen amount in the plant is calculated. This total now includes the current day's increment of structural nitrogen.

If the amount of nitrogen taken up by the plant exceeds the increment of nitrogen added in structural growth, the excess (XTRAN) is partitioned among the vegetative plant parts, the amount varying in proportion to their fractions of the total vegetative weight. If, in the calculation of the difference between the total nitrogen uptake and the increment in structural growth, a negative value is obtained, i.e., XTRAN is negative, a withdrawal of nitrogen from reserves in the vegetative structure, in effect, occurs.

Next, the NSTRES parameter is set depending on NF. NSTRES is simply an output variable indicating the level or intensity of nitrogen stress.

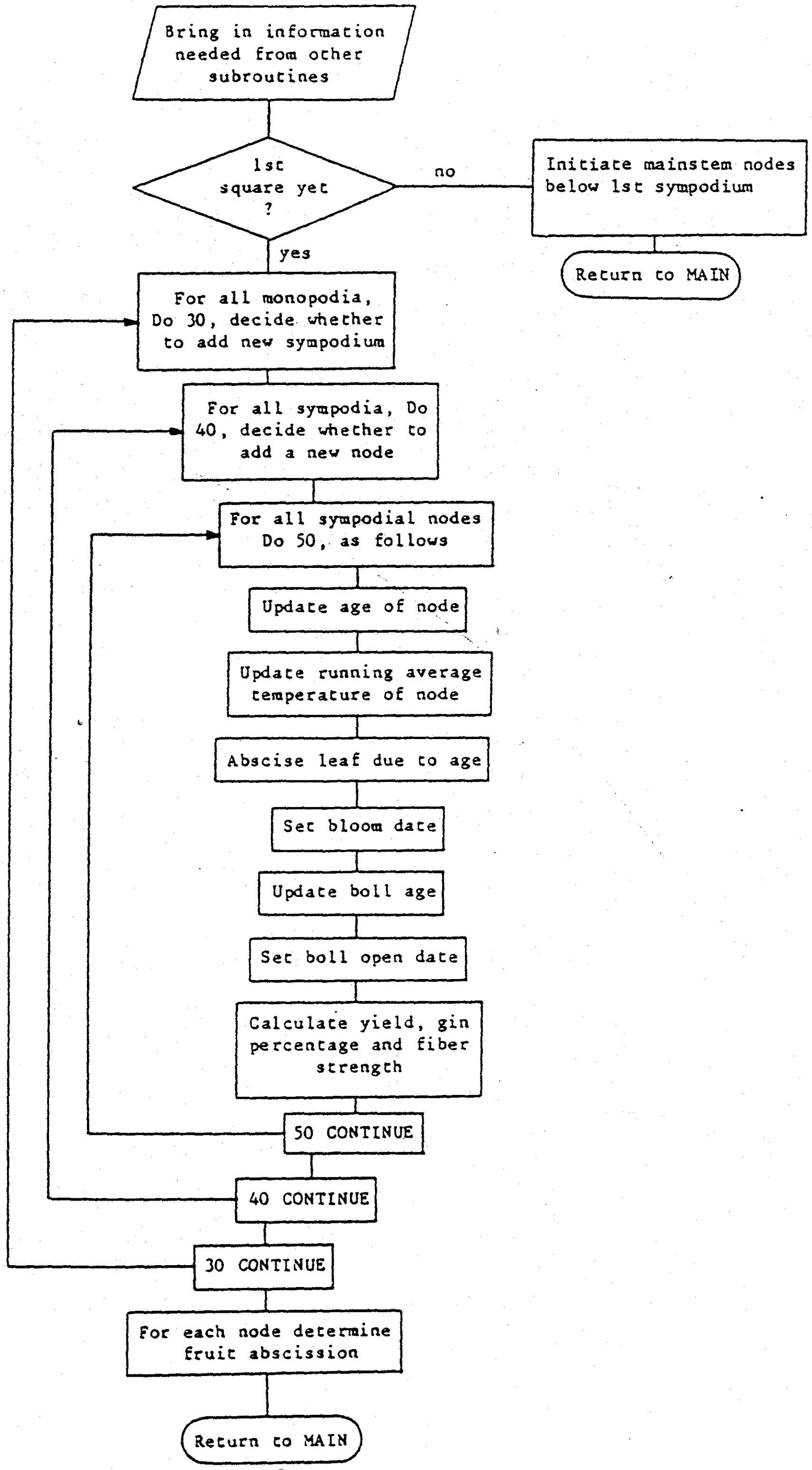
Finally, the concentrations of nitrogen in the various classes of organs in the plant are calculated, and the calculations return to GROWTH.

PLTMAP

This subroutine simulates plant morphogenesis. It handles system timing and the abortion of fruit in response to physiological stresses. It records, daily, the census of organs on the plant and their state of maturity or the time remaining before their abscission.

A simplified flow chart of PLTMAP functions is presented on the following page. The time of first square is calcu-

Simplified Flowchart of Functions Performed in PLTMAP



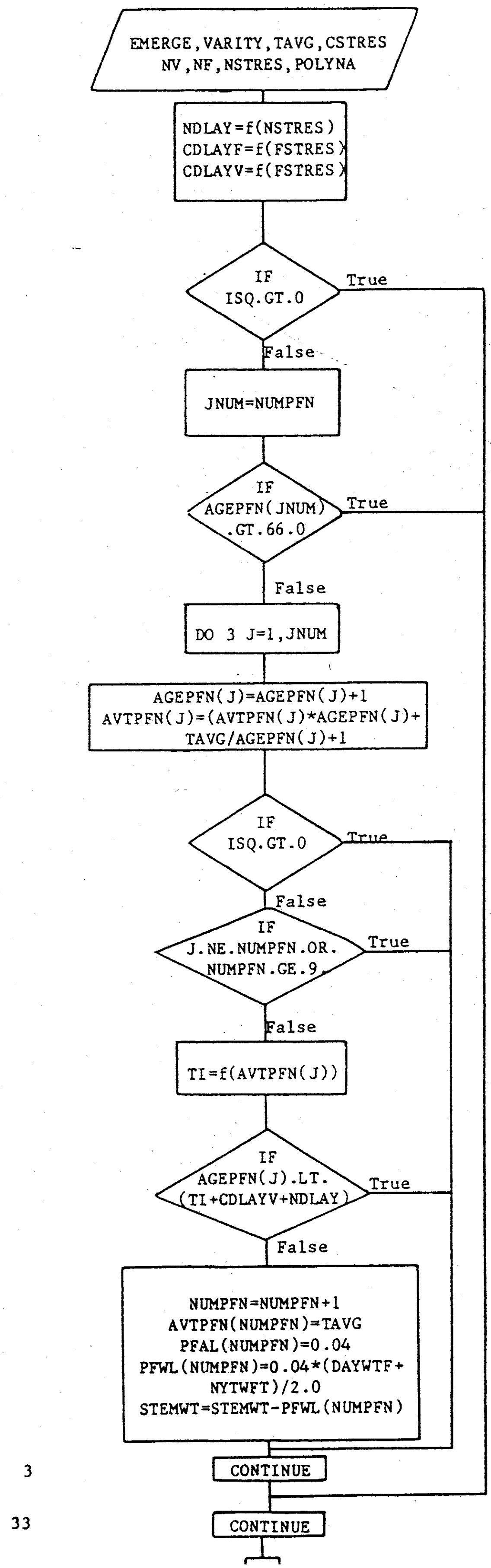
lated, and, if first square has not occurred, a new node (up to nine) may be set on the mainstem. Each node on the plant is considered in PLTMAP. New nodes and fruiting sites are initiated depending on the running average temperatures and physiological delays (in plant development); also, fruit development and maturation are determined.

After completing these functions, the nested DO's are exited and another (linear) inventory of the plant is made in which fruit abscission in response to physiological stress is carried out. After this the program returns the computer to MAIN.

PLTMAP is flowcharted in more detail in pages 58 to 78. After a number of counters are set to zero, morphogenetic delays resulting from shortages of carbohydrate and nitrogen supplies are computed. The functional relationships for the calculation of these delays are graphed in Figures 22 and 23. NSTRES, a nitrogen stress parameter is determined in the NITRO subroutine via a series of logical if statements based on the supply: demand ratio (NF) for nitrogen in fruit growth. This logic and the functional relationship in Figure 22 were developed by

SUBROUTINE PLTMAP

Flowchart



NOTES

Bring in variables, initialize adders.

Calculate delays to morphogensis due to shortages of nitrogen and carbohydrates. (p. 118, line no.'s 2149-2154.)

If the first square has not yet occured and the top node is not greater than 66 days old, contine development of the mainstem nodes below the first fruiting branch.

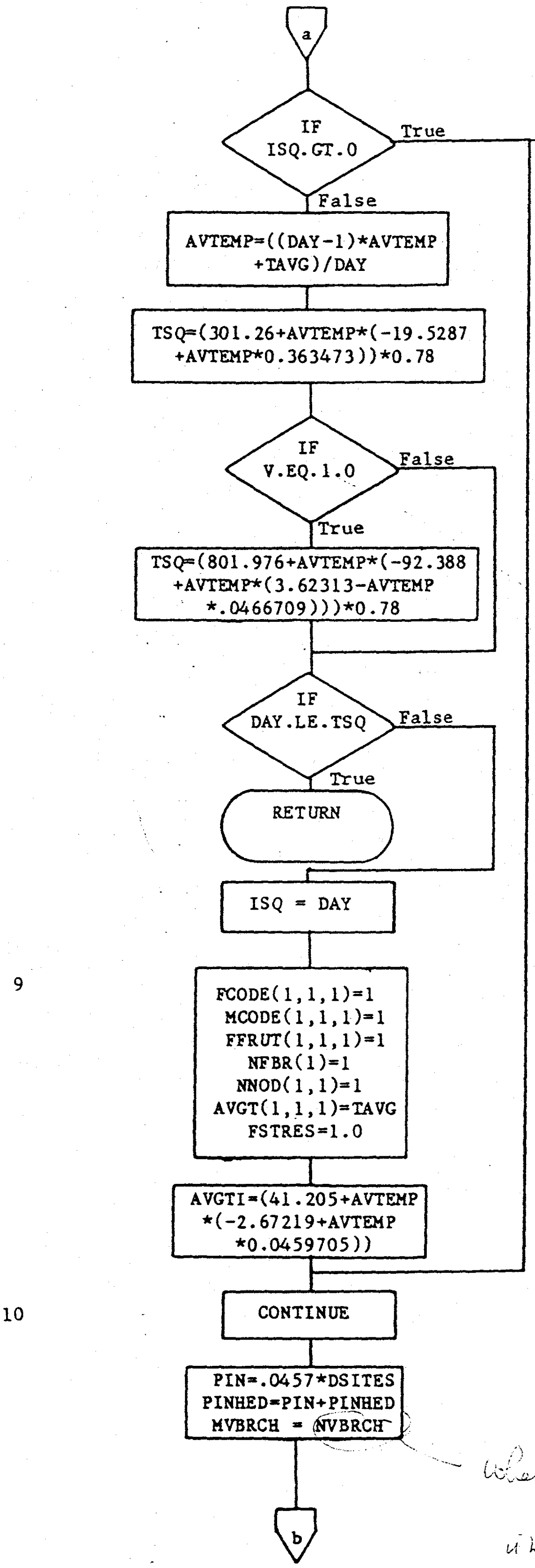
Increment the age of each node and update its running average temperature.

If there are less than 9 prefruiting mainstem nodes.

Calculate the time interval to the next node. (p. 118, line no. 2164.)

If enough time has elapsed (taking into account physiological stress induced delays.)

Add a new node, and initialize the area of the leaf at that node.



Where does this initialized?

NOTES

If the plant has not yet squared, determine if it should today.

Update the running average air temperature.

Time from emergence to first square is one function of temperature for a "High Plains" variety and another for "Delta" varieties.

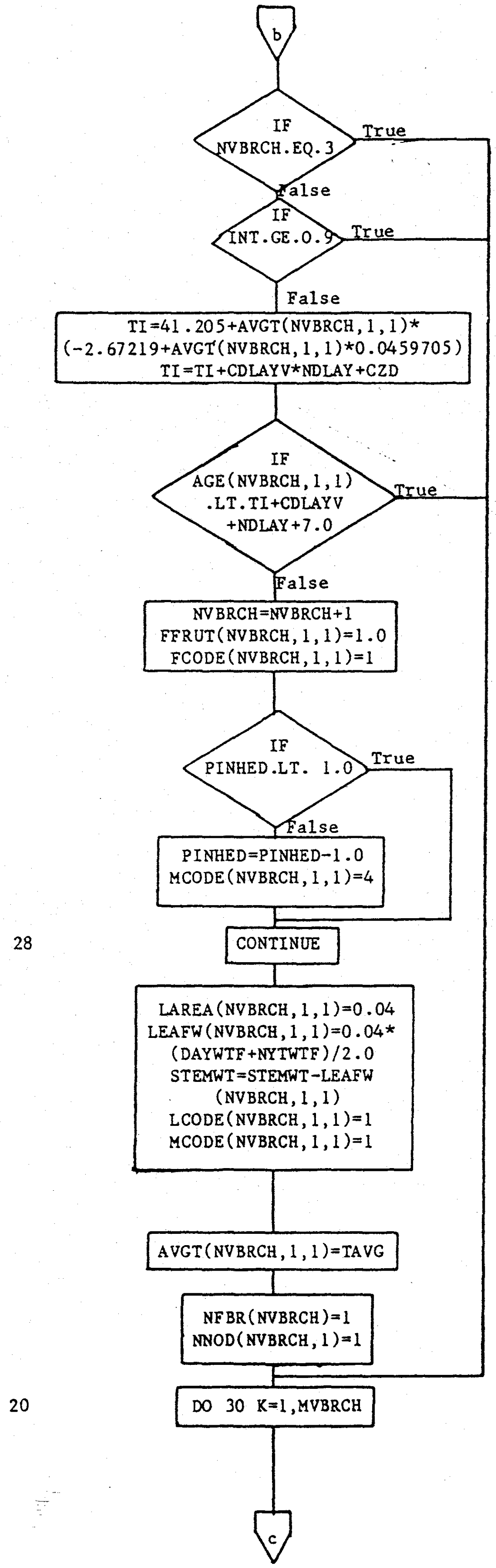
Is today the first square?

If so, set the square and,

Set the node codes, the fraction of possible fruit at the site and the running average temperature for the node.

Calculate the time interval to the next mainstem node.

Calculate pinhead square to be lost and accumulate them.



NOTES

If canopy light interception is greater than or equal to .9, don't initiate any more vegetative branches.

Compute the time interval (TI) between vegetative branches (days). Adjust TI carbohydrates and nitrogen shortages.

If the age of the most recently set vegetative branch exceeds the time interval (including physiological delays between branches), initiate a new vegetative branch.

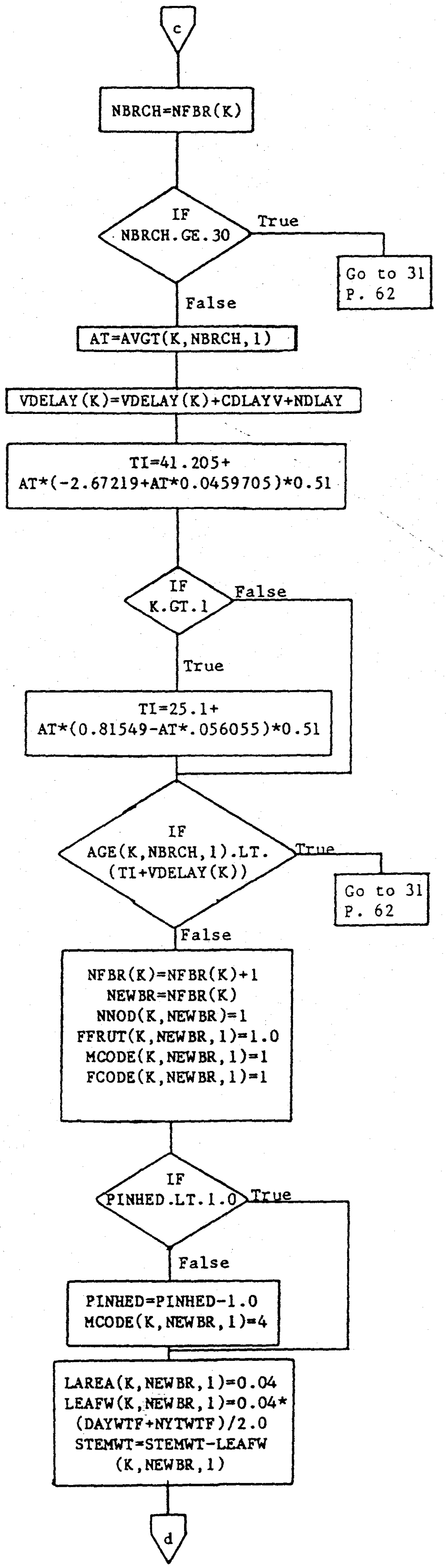
Set a new square in the new node.

If a pin head square is due to be aborted, abort this one.

Initialize the leaf area and weight at the new node. Subtract the weight from the stem weight. Set up the leaf code and fruit code for the new organs at the new node.

Initialize the running average temperature for the new node at today's average air temperature.

Do for all vegetative branches.



NOTES

If there are not yet thirty fruiting branches, compute the time interval to the next fruiting branch.

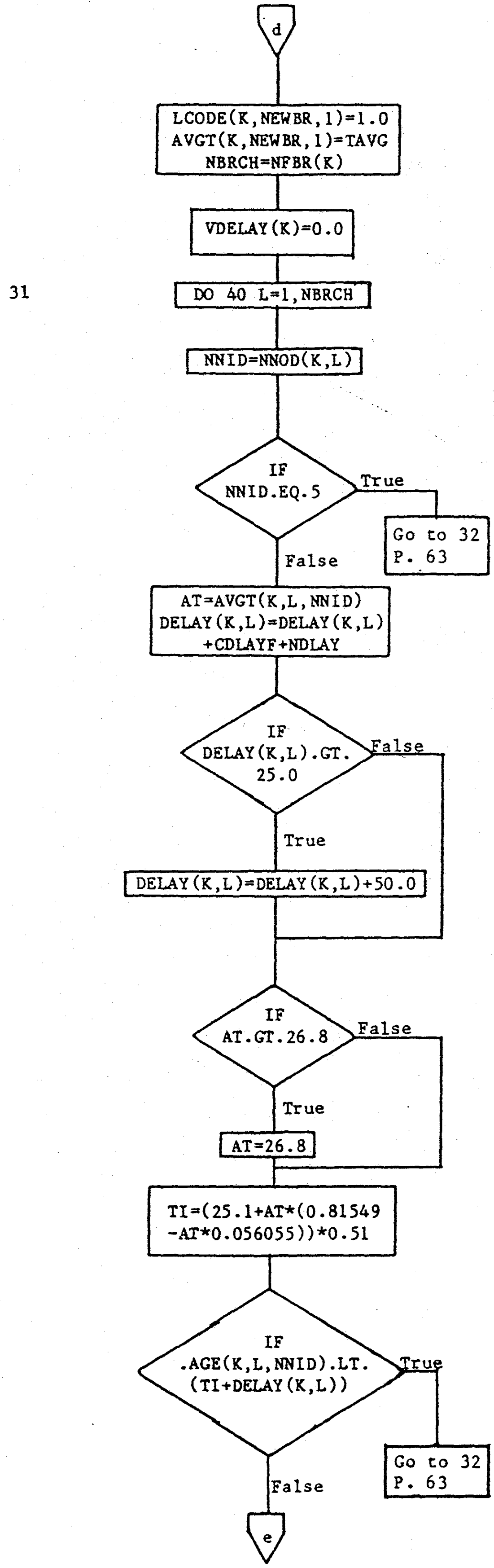
For the second and third vegetative branch, use the time interval for nodes on a fruiting branch (slower.)

If sufficient time has elapsed, start a new node and initialize the fraction of fruit present at that site.

If a pinhead square is due to be aborted, abort it and reset the pinheads to be aborted counter.

27

Initialize (as usual) the leaf area, and leaf weight for this new node and adjust the stem and total leaf weights.



NOTES

Set the leaf code for the new leaf and initialize the running average temperature for the new node.

Reset the VDELAY accumulator to 0.0

Do for each fruiting branch.

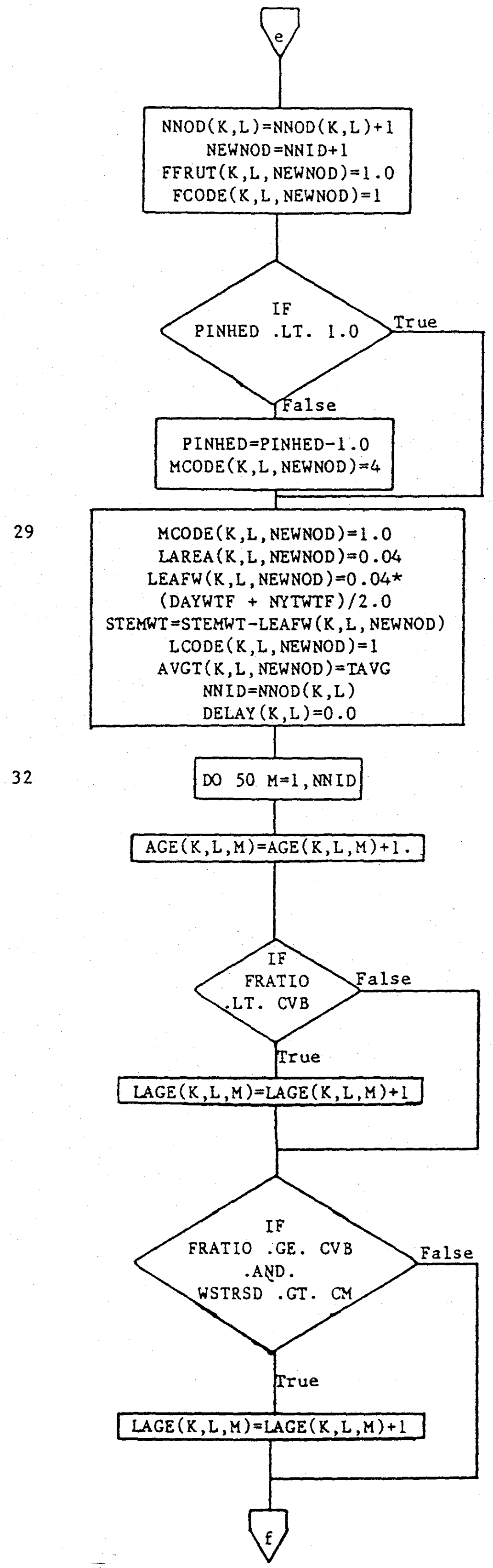
If there are 5 nodes on the fruiting branch, don't add any more.

Update the running average fruiting branch terminal node temperature and accumulate the nitrogen and carbohydrate stress induced delays in further node formation.

The time interval temperature response in new fruiting branch node formation levels off at 26.8 C.

The time interval to a new fruiting branch node is a function of temperature.

If the node is old enough (considering delays), add a new node.



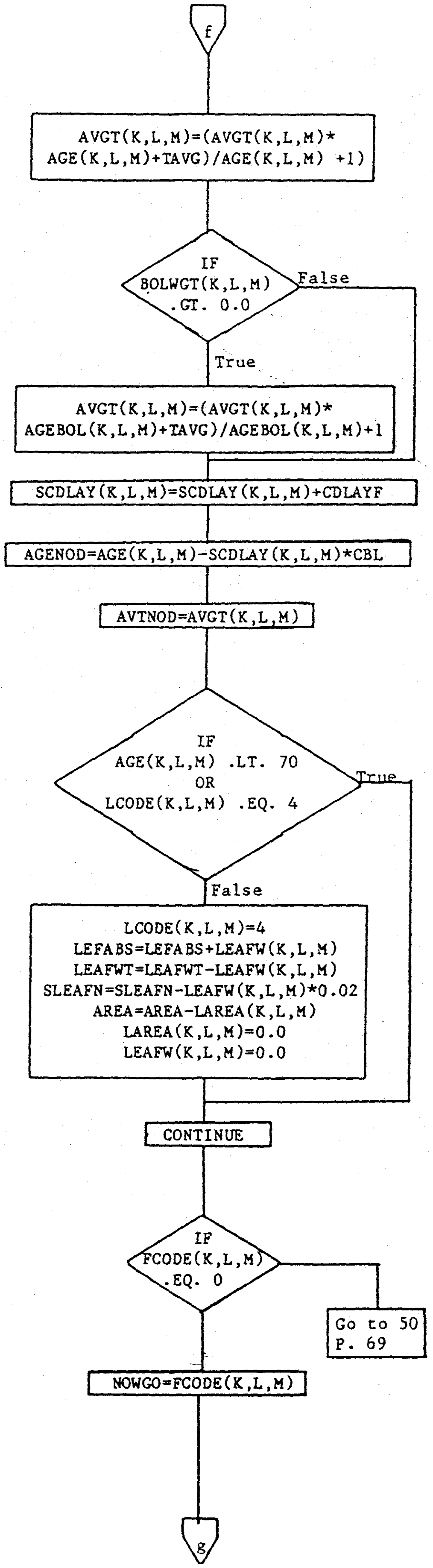
NOTES

Initialize the fraction of fruit at that site at 1.0.

If a pinhead square is due to be aborted, abort it at this site and subtract one from the pinheads to be aborted conunter.

Initialize the leaf area at this node at .36 cm, the node running average temperature and cumulative delays in further node formation on this branch to 0.

Do for each node on each fruiting branch.



NOTES

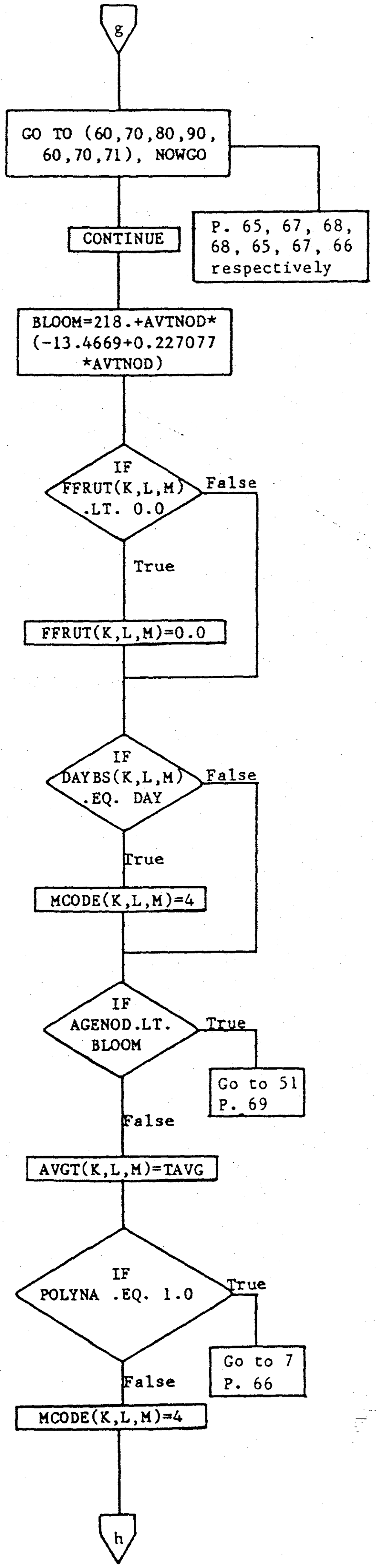
If a leaf is present at this node and it's 70 days old, abscise it.

Add the weight lost to the leaf weight lost accumulator. Subtract the leaf weight from the plant. Remove the nitrogen in the leaf (2 percent of the leaf weight) from the plant nitrogen pool. Reduce the leaf area.

If a fruit has not yet been formed at this location, skip any further consideration of this node.

NOTES

60



Depending on the status of the fruit at this node, go to statement 60,70,71, 80, or 90.

Squares are considered in the following section.

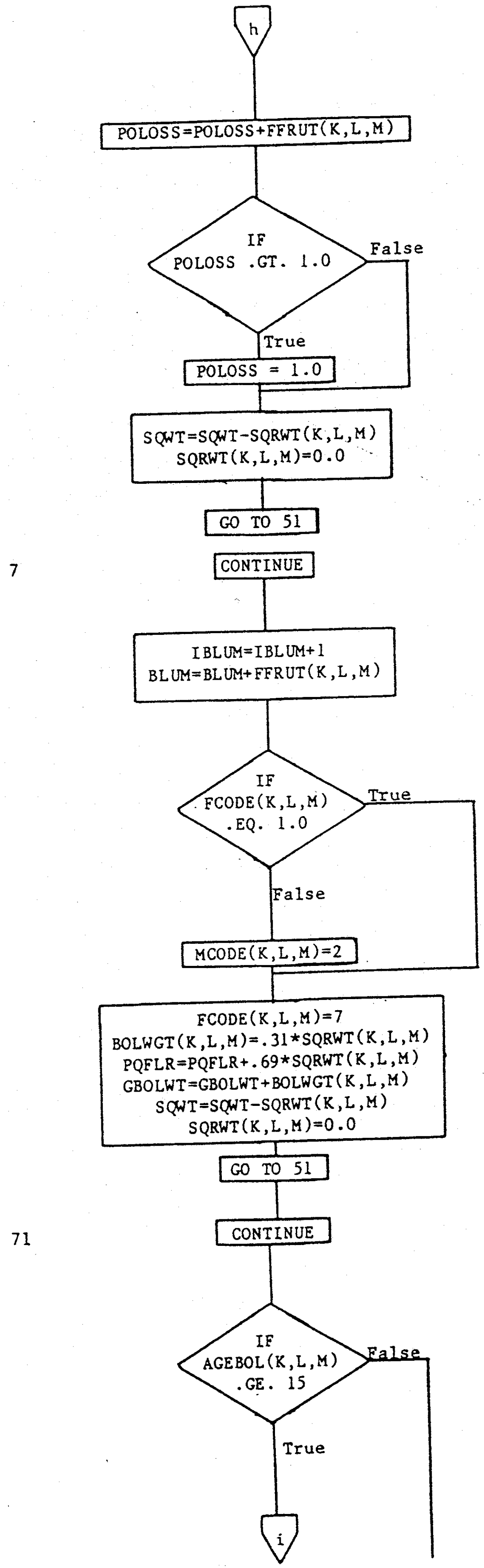
The time from initiation to bloom is a function of temperature.

The fraction of a fruit remaining at the location after losses due to abscission cannot be less than 0.

If the day of abscission of this square has arrived, abscise it. DAYABS was set below this point in the code on an earlier iteration (day). This procedure and the MCODE is only for output mapping purposes.

If the square is old enough, it is converted to a bloom.

NOTES



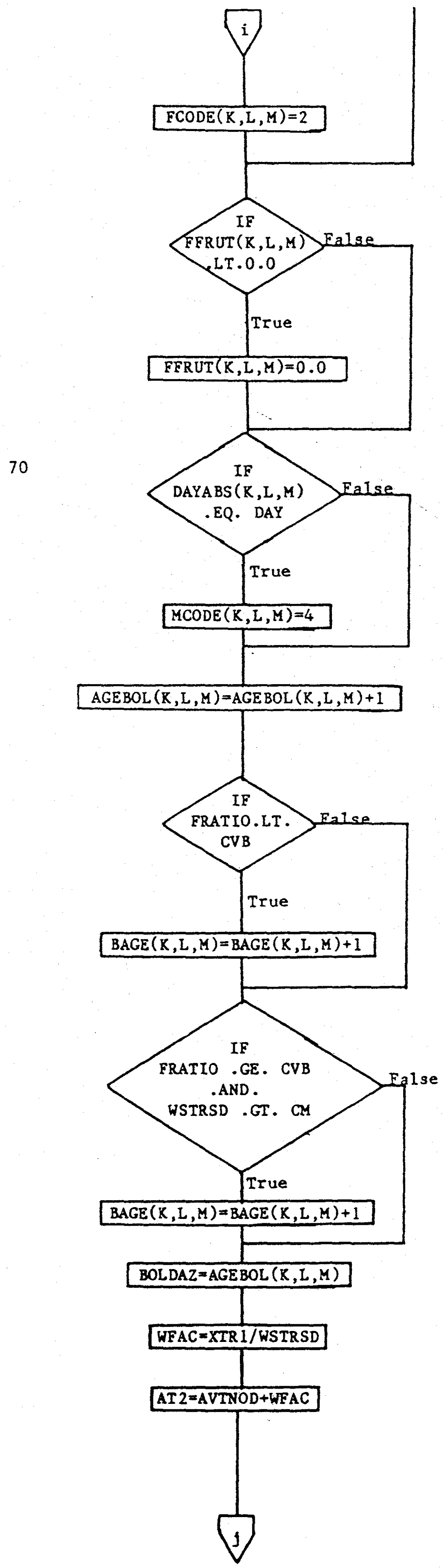
If rain interferes with the pollination (or sticks the bloom), the fruit is lost.

Count the blooms.

If a square is present, let the output map code show a green boll.

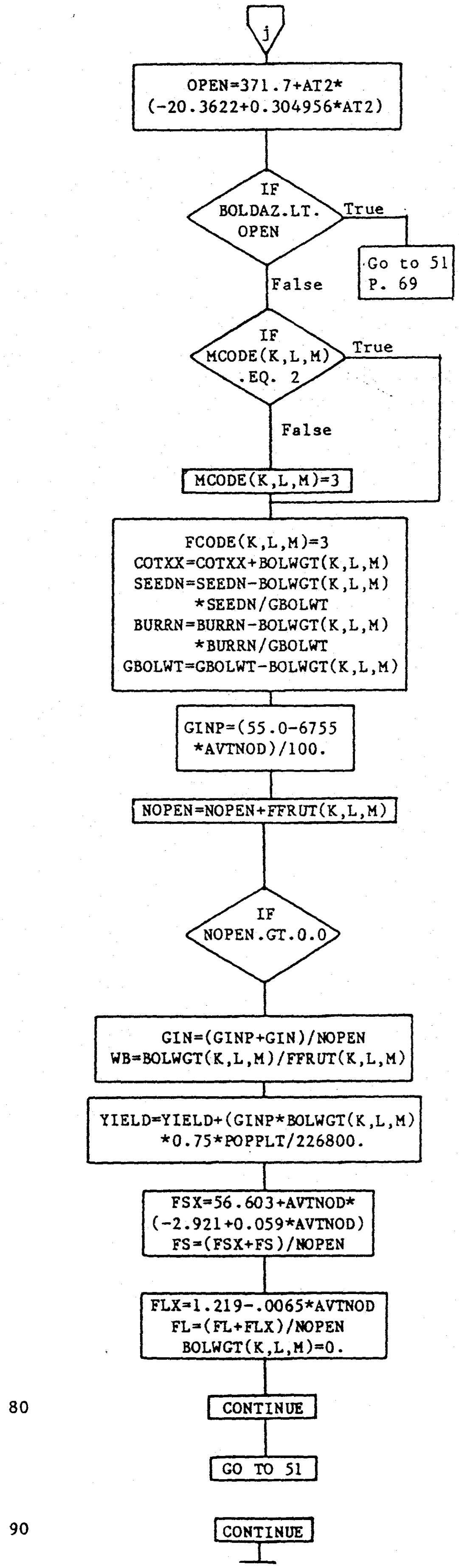
Anthesis has occured. Set the new boll weight parameters. At anthesis, subtract the weight of this square from the total plant square weight.

A young boll susceptible to abscission.



NOTES

If the boll is past the age of susceptibility, convert fruit code accordingly.



NOTES

If the boll is opening, change the output map accordingly.

Change the fruit code to show it opened. Add the boll weight to the cumulative open boll weight. Subtract the seed and burr nitrogen in this boll from the totals for the plant. Subtract the weight of this boll from the green boll weight total.

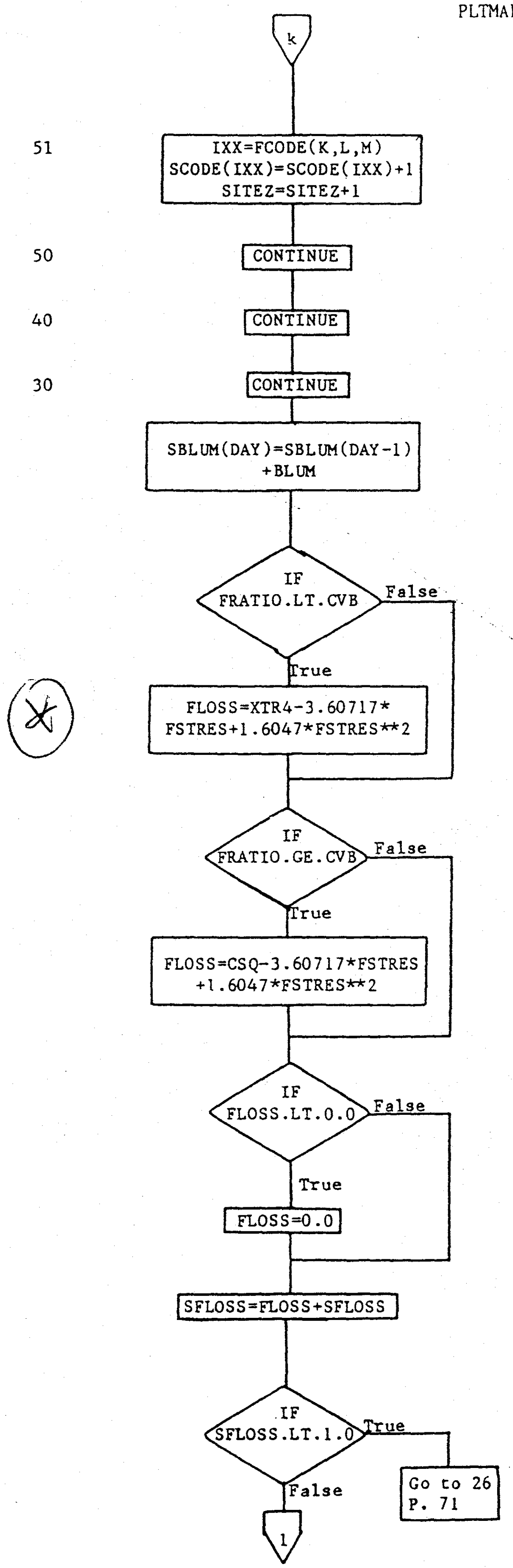
The gin percentage for the boll is a function of running average boll temperature.

Add this fruit to the number of open bolls on the plant, and calculate the average gin percentage.

Calculate per acre yield in 500 lb. bales.

Fiber strength for the boll is a function of running average boll temperature. Calculate an average fiber strength for this plant.

Calculate the fiber length of the boll as a function of the running average node temperature. Then update the average (for the whole plant) fiber-length and set the boll weight (green) at this node to zero.



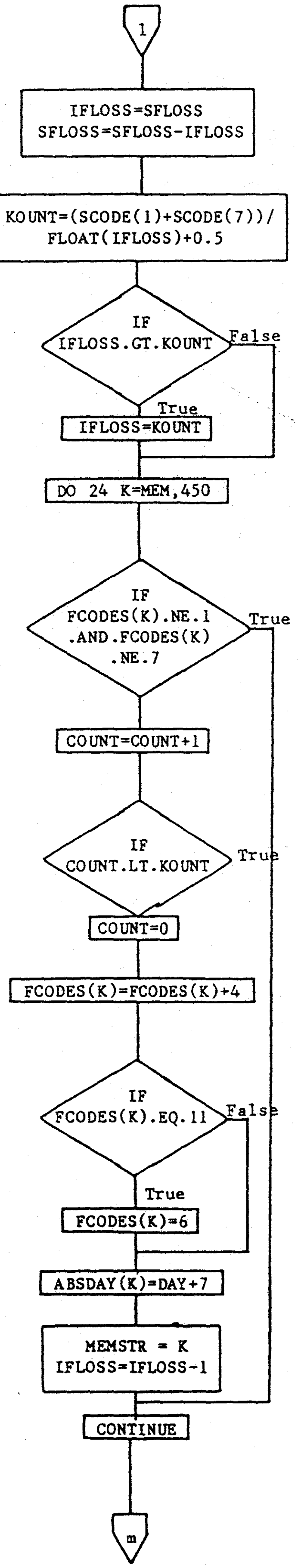
NOTES

Calculate the number of fruit to be marked for abscission today as a function of metabolite supply: demand ratio (FSTRES).

FLOSS cannot be less than zero.

Sum the fruit to be lost with those from previous days.

If a whole fruit is not available for abscission, skip the output map abscission logic.



23

240

NOTES

Get the whole number of fruit to be abscissed. Remove from the accumulator the whole numbers of fruit to be marked for abscission today.

KOUNT is the fraction of the sum of susceptible squares and bolls to be abscissed.

If the whole number of fruit to be abscissed is greater than KOUNT, it is set equal to KOUNT.

Do for the whole plant.(All fruiting branch nodes.)

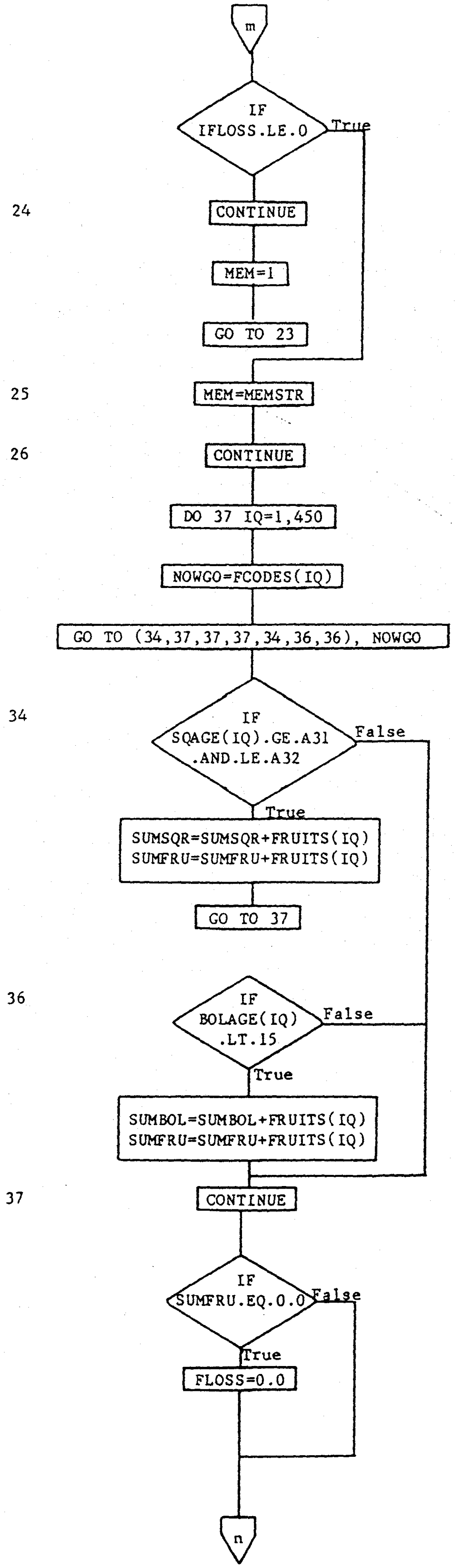
If the node doesn't contain a susceptible square or boll-skip to 240.

If the COUNT of whole susceptible fruit is less than the number needed, (KOUNT) skip to 240.

Mark the fruit for abscission.

Set the day of abscission, store the location (in the matrix) of the last fruit marked for abscission.

Subtract 1 from the integer number of the fruit to be lost.

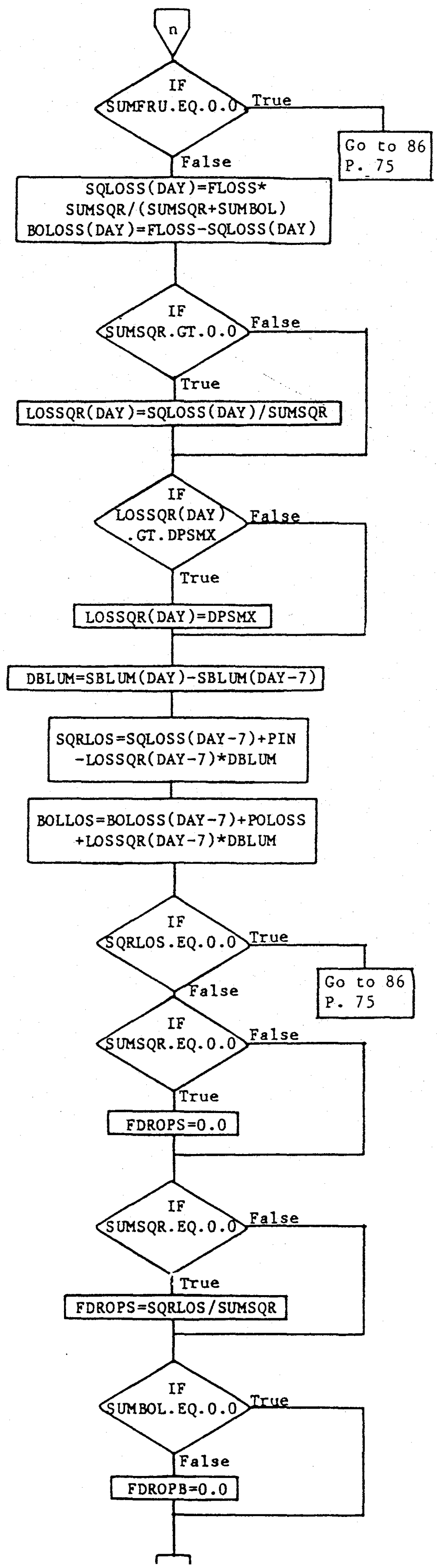


NOTES

Have enough fruit been abscissed? If so, stop and store current location. At 450, set the counter to the first fruiting point on the plant.

Begin the real (fractional) abscission of fruit. First sum up the squares and bolls which can be abscissed. These are real numbers.

If no fruit is available, none will be lost.



NOTES

The number of squares marked for loss today is the product of total fruit to be lost times the fraction of fruit which are squares. The remainder to be marked today, for loss, will be bolls.

The fraction of each susceptible square to be marked for loss today is today's number of squares divided by the total susceptible squares.

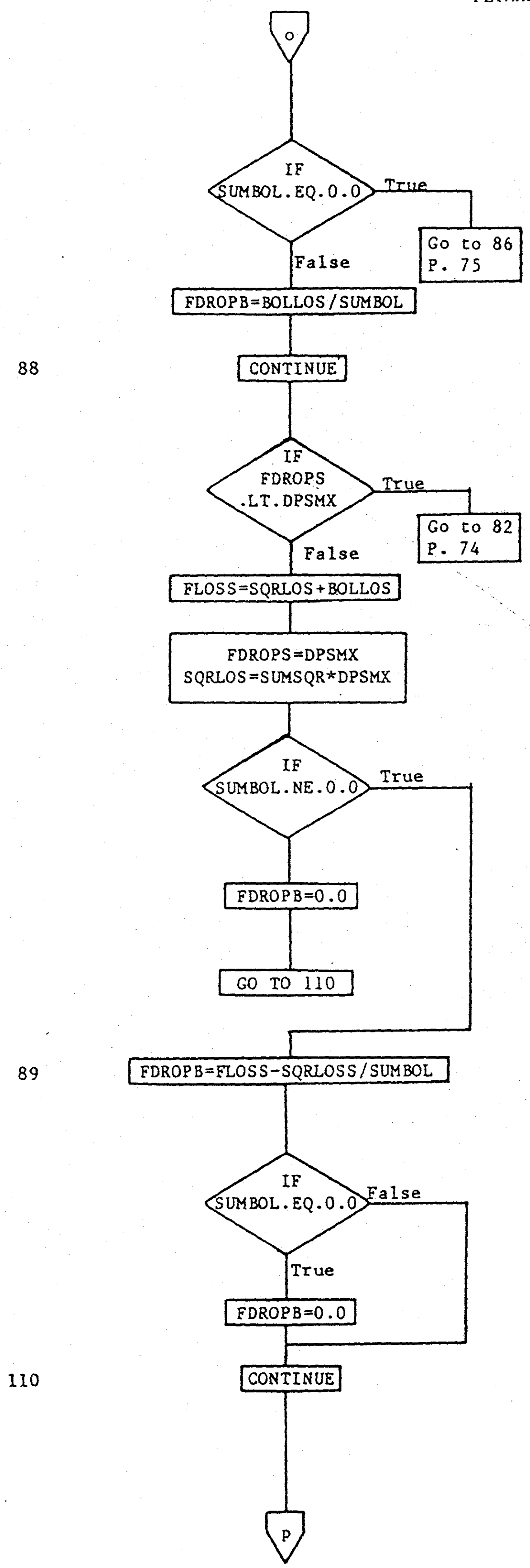
If this fraction is greater than DPSMX, it is set equal to DPSMX.

Calculate the blooms produced in the last 7 days.

Square loss today equals the number of squares marked 7 days ago plus the pinheads marked today minus the susceptible squares that have bloomed in the last 7 days.
Boll loss today equals the number of bolls marked 7 days ago plus the "stuck" (rain) blooms plus the squares marked for abscission 7 days ago which have since bloomed.

If no squares are to be lost, go to 86.

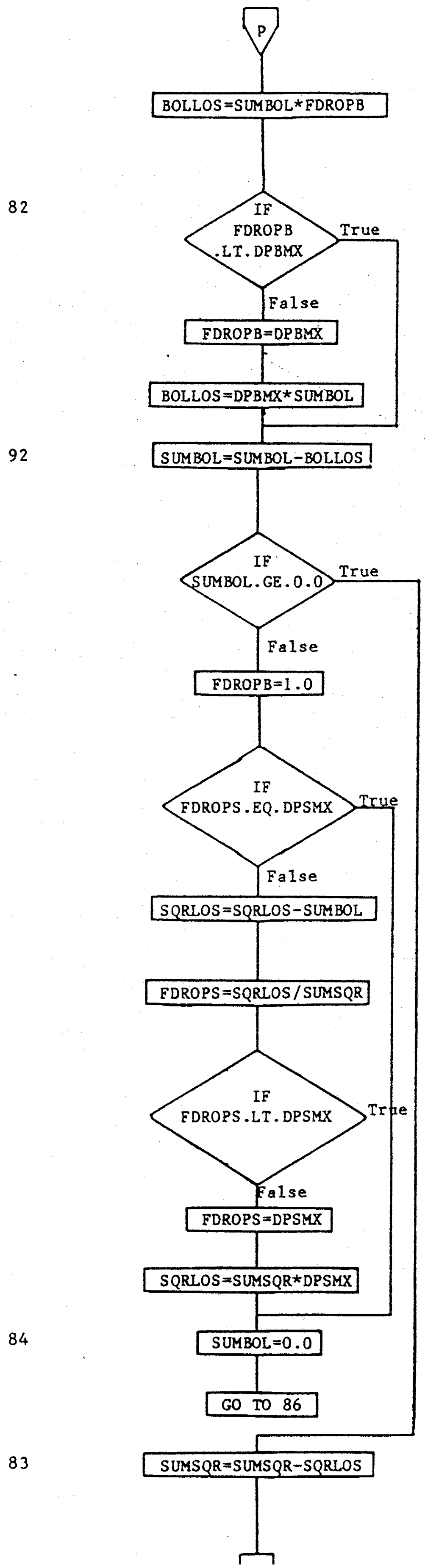
If there are no susceptible squares or bolls on the plant then, the fraction of squares or bolls to be dropped is zero. Otherwise, the fractions of existing squares and bolls to be lost are calculated.



NOTES

If the fraction of squares to be dropped from each node is greater than the maximum allowed (DPSMX) then it is equal to DPSMX and square loss is redefined as the maximum times the total number of squares on the plant.

If there are susceptible bolls on the plant, the fraction of bolls to be dropped is the difference between the total fruit loss and the loss as squares (the bolls) divided by the sum of the bolls on the plant. If there are no bolls, there will be none dropped.



NOTES

The number of bolls to be dropped is the fraction times the total number of susceptible bolls.

If the fraction of bolls to be lost exceeds the maximum allowed (DPBMX), the number of bolls lost then is equal to the total sum of bolls times this fraction.

These are subtracted from the sum.

Have more bolls been dropped than existed? If so, fix it as follows:

All the remaining bolls are dropped.

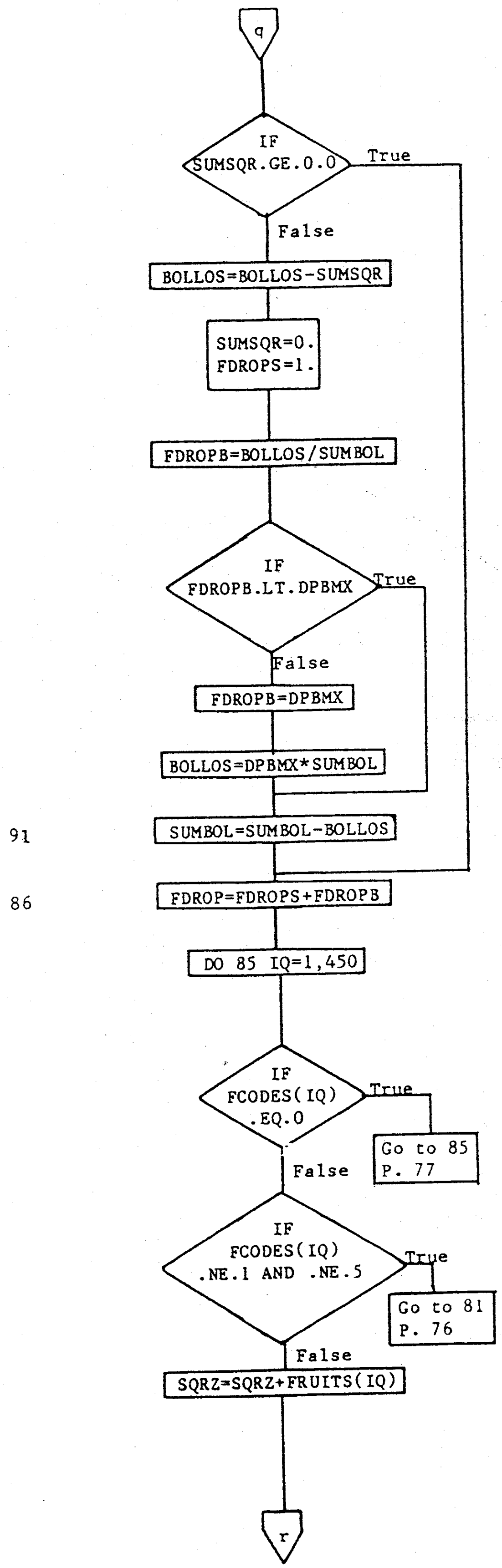
The excess boll loss will be made up as square loss here. The fraction of each square to be removed is redefined.

If FDROPS equals or exceeds DPSMX it is equal to DPSMX.

The number of squares to be lost is then DPSMX times the sum of squares susceptible.

The number of susceptible bolls on the plant is defined as 0.

The sum of susceptible squares is reduced.



NOTES

Too many squares were removed.

The excess will be removed as bolls.

All the remaining squares are removed.

The fraction of susceptible bolls to be dropped is defined again.

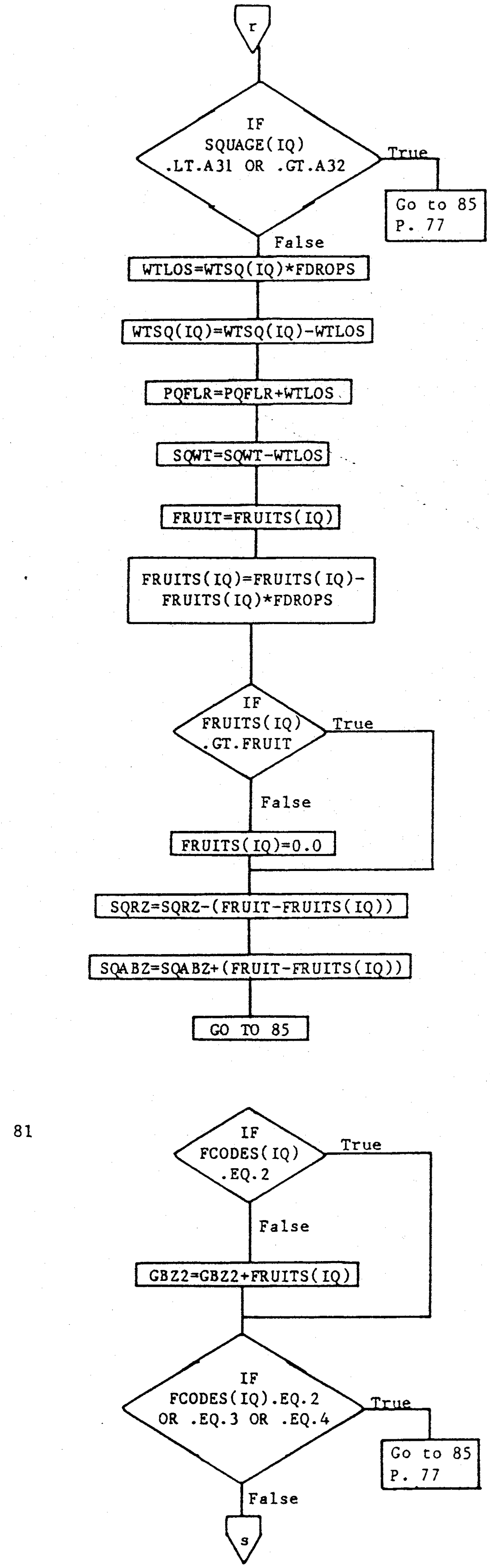
If this fraction exceeds the maximum allowed, it is set equal to the maximum and the number of bolls to be lost is calculated.

The sum of susceptible bolls remaining is reduced.

Do for each fruiting site on the plant.

If the fruit is not a square, go to 81.

Accumlate the fractions of squares at the sites.



NOTES

If the square is not in the age bracket for abscission, go to 85.

Calculate the weight of this abscissed fruit.

Remove this weight from the site.

Accumulate the weight loss.

Remove the weight of the lost squares from the total weight of squares on the plant.

Remove the fraction of fruit from the site.

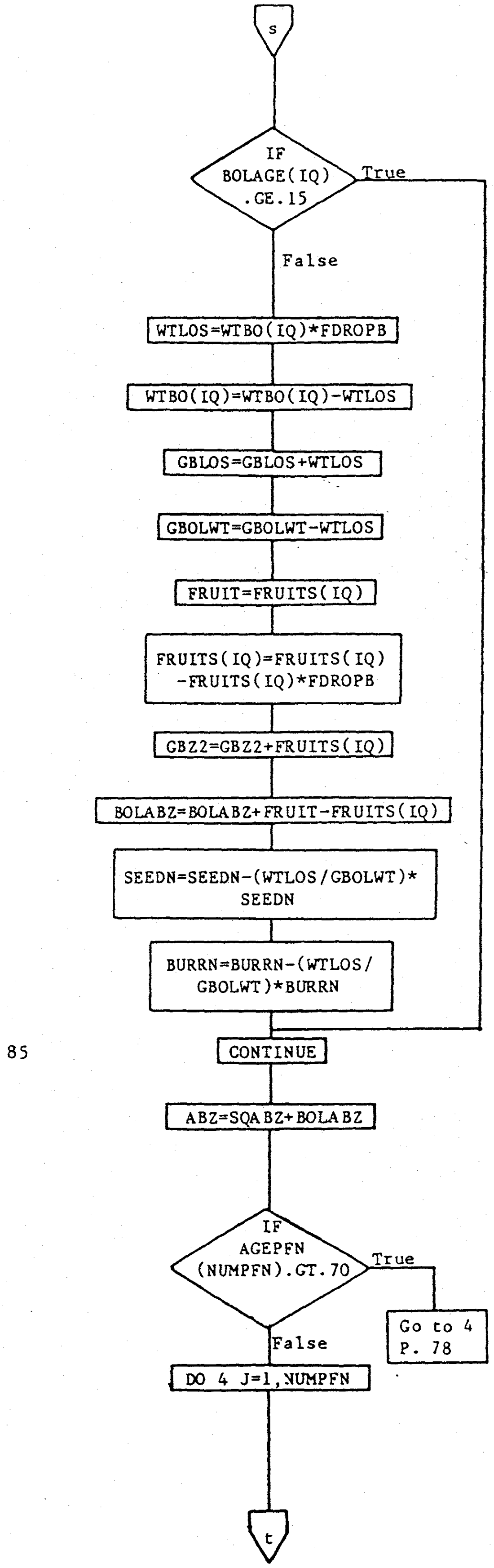
If the amount of fruit at the site goes negative, set it at 0.

Subtract the square (lost) from the sum of squares remaining.

Accumulate the abscissed squares.

Accumulate the green bolls on the plant.

Show the fruit as abscissed and the node blank.



NOTES

If the boll is older than 15 days, it is not susceptible to abscission.

Calculate the boll weight lost.

Subtract the weight loss from the site

Accumulate the weight of green bolls lost.

Decrement the green boll weight remaining.

Remove the fraction of a fruit from the site.

Accumulate the green bolls remaining.

Accumulate the abscissed boll.

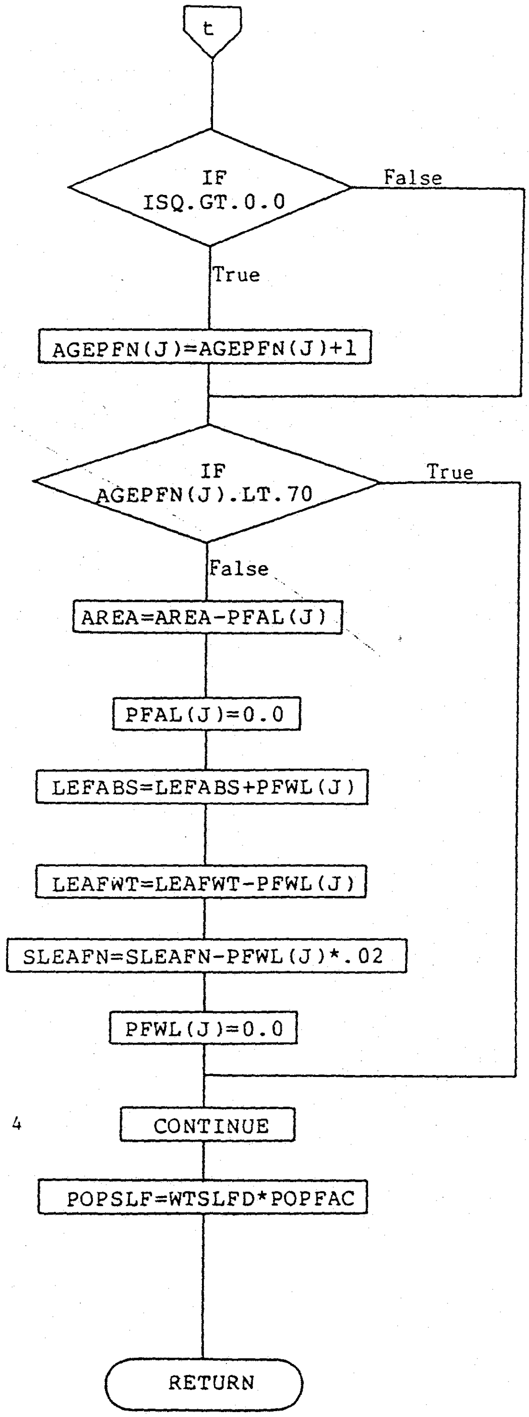
Remove the lost seed N.

Remove the lost burr N.

Calculate the total fruit lost today.

If the top node below the first fruiting branch on the mainstem is less than 70 days, consider each of the nodes below the first fruiting branch. If first square has occurred, age each node 1 day. When a node age exceeds 70 days, abscise the leaf.

PLTMAP (21)



McKinion et al. (1975) as part of the SIMCOT II model. CDLAYV and CDLAYF represent delays in node formation on vegetative branches and fruiting branches respectively. The SIMCOT II logic was abandoned entirely in the calculation of these delays from FSTRES. FSTRES is calculated in GROWTH as the product of the supply:demand ratios for carbohydrates and nitrogen for fruit growth. It should be noted that all of these delays are calculated from supply:demand ratios for fruit growth. We have tried calculating these demands in several other ways with poor results. The results suggest that some physiological change occurs in the plant at flowering which alters the physiological time between morphological events depending on the level of disparity between supply and demand for carbohydrates and amino acids in the plant. The CDLAYV and CDLAYF functions were developed empirically from simulations of the well watered treatment (AAA) in the Bruce and Römkens (1965) experiment in which high levels of nitrogen fertilization were used. We assumed that no nitrogen shortages existed in those plants. We proceeded to manually adjust the morphogenetic rates and the fruit abscission (see below for further discussion of abscission) rates until we had a perfect simulation throughout the season. The

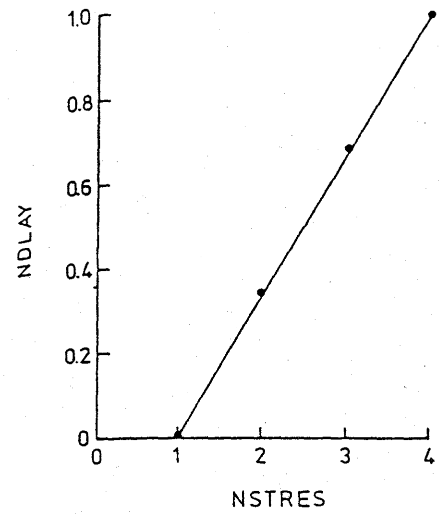


Figure 22. Morphogenetic delay vs. the nitrogen stress parameter (NSTRES).

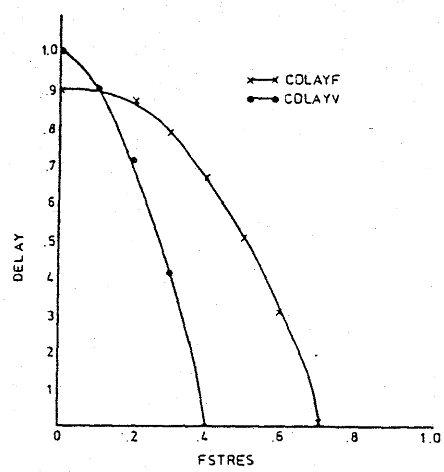


Figure 23. Morphogenetic delays vs. the FSTRES parameter.

discrepancies between morphogenetic rates predicted from the temperature functions alone and those observed by Bruce and Römkens as the fruit load developed were used to obtain the correct FSTRES values and to develop the relationships in Figure 23.

Referring to the flow chart on page 58, after calculation of the physiological delays, if the first square has not yet appeared and there are not yet nine nodes on the mainstem, the formation of further mainstem nodes proceeds. The time interval between mainstem nodes is a function of the running average air temperature since the last mainstem node appeared plus the stress induced delays for the current day. The data for this functional relationship are taken from the phytotron experiments of Hesketh et al. (1972), and they are graphed in Figure 24. We have found that the time intervals between mainstem nodes on plants grown in the field is 30% longer than in the phytotron experiments, so a multiplier (1.3) is attached to the regression equation summarizing those data. If sufficient time has elapsed since the last node was formed, a new node is formed with a leaf area initialized at 0.04 cm^2. The leaf weight is initialized using day and night weight factors (from GROWTH) and, the weight is subtracted from the stem weight.

If first square has not yet occurred, the running average air temperature since emergence is updated. The time to first square is calculated for a "High Plains" variety (CA491) or for a "Delta" variety (M8). The data for these functional relationships are graphed in Figures 25 and 26. These data are from Moraghan et al. (1968). The cotton in those phytotron experiments reached first square about 20% slower than does similar cotton in the field, so, the equations summarizing their data contain a multiplier (0.78 or 0.80 for Mississippi or Arizona conditions, respectively).

If the time of first square has not yet arrived, the computer exits the subroutine, returning to MAIN for the next day's iteration. If, however, the day of first square has arrived, the square is set and the first elements of several three dimensional arrays corresponding to monopodium number (k), sympodium number (l) and fruiting branch node number (m) are set. Finally the time interval to the formation of the next mainstem node is estimated.

Next, if a plant bug population is believed to be present, a pin head square loss is calculated. Some infestation of these insects is usually present in the mid-South, especially in the early season. We

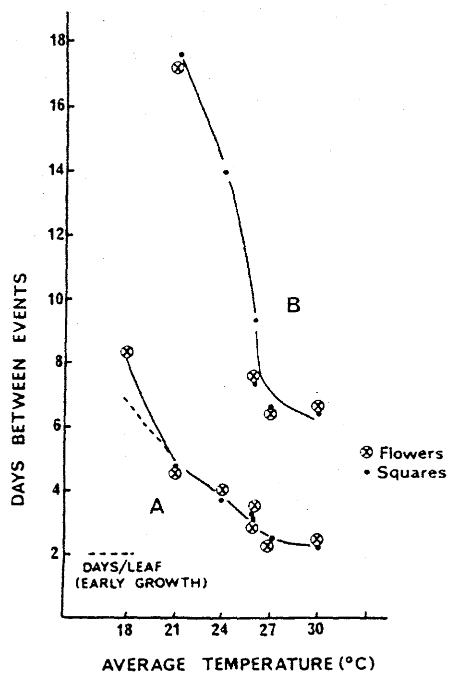


Figure 24. Time intervals between mainstem nodes and between fruiting branch nodes vs. temperature.

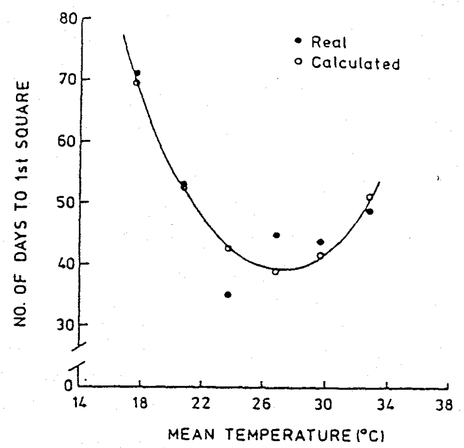


Figure 25. Time from emergence to first square in a Delta variety vs. temperature.

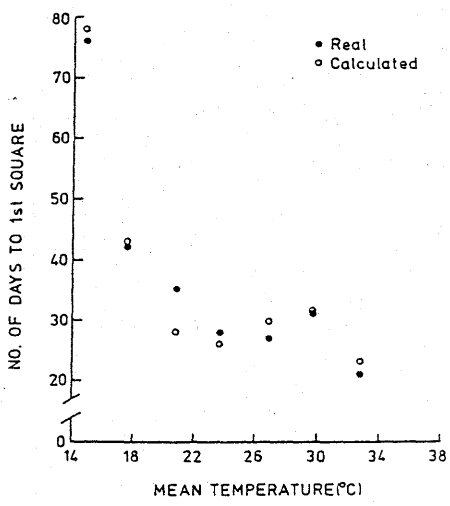


Figure 26. Time from emergence to first square in a High Plains variety vs. temperature.

found from analysis of the Bruce and Römkens (1965) data that about 4.6% of the newly formed squares will be lost to injury by these insects. Actual removal of the pin head square occurs later in the program.

Next, the possibility of initiating a new vegetative branch is considered. This is done if the number already present doesn't exceed the (cultivar dependent) limit, N1 (usually equal to three), canopy light interception does not exceed 90%, and sufficient physiological time has elapsed since the last vegetative branch was initiated. This time interval is calculated as half the time interval between initiation of mainstem node plus seven days, plus the physiological delays. If a branch is initiated, a fruiting branch node and fruiting site are initiated at the same time, and the appropriate codes are set up as before (setting first square). If sufficient squares (new sites) have been formed on the plant so that 0.0457 times the number of new sites equals 1.0, the code for the output plant map will be set to show an aborted fruit at this site. This accounts for the pinhead square losses observed in the Bruce and Römkens (1965) data. Further, if a new vegetative branch, and with it a new fruiting branch and fruiting branch node, is formed, a new leaf is initiated as before when the first square was formed.

Next, new fruiting branch and vegetative branch nodes are initiated after appropriate time intervals. Again, leaf and fruit codes are set up as appropriate and pin head squares are aborted according to the criteria described above. Initiating a new fruiting branch is considered if the vegetative branch being considered does not already have 30 fruiting branches. The time interval between fruiting branches is computed as a temperature function from the phytotron data of Hesketh et al. (1972), graphed in Figure 24. The value from the regression equation summarizing these data is multiplied by 0.51 to provide the faster fruiting potential found in the field, as compared with phytotron conditions. Physiological delays may be added to this "potential" time interval. The delay VDELAY, is a cumulative (over days) sum of the daily carbohydrate and nitrogen stress induced delays generated since the time of the initiation of the last fruiting branch on this vegetative branch. Note that the time interval for new node formation on vegetative branches (other than the mainstem) is calculated using the same function as that for fruiting branch nodes. In other words, fruiting branches are formed more slowly on the vegetative branches than on the mainstem.

Each fruiting branch is examined and if sufficient time has elapsed, a new fruiting site is formed. The data base for calculating this time interval is from Hesketh et al. (1972). It is presented in Figure 24. The regression equation summarizing these data is multiplied by 0.51 to obtain a potential time interval, and physiological delays which are cumulative over time are added to obtain the actual time interval. Again, if a new node is added, fruit and leaf codes are set up and the new leaf is assigned an area and weight as before, and the square may be immediately aborted (as a pinhead).

Finally, each node on the plant is examined and the following operations are performed: The node is aged one day, and if the weight of fruit to total plant dry weight ratio is less than 0.15, the leaf is aged one day. If, however, fruit:whole plant weight ratio is greater than 0.15, and there is a water stress in the plant (WSTRSD less than 0.75), the leaf is not aged. This is part of a mechanism which delays cessation of growth in expanding leaves during water stress (Baker et al. 1979a).

Next, the ages and number of leaves at nodes on the top ten branches of the mainstem are accumulated. Running average temperatures of the node and the boll, if present, are updated, and the running total of carbohydrate shortage induced delays in further node initiation is determined. The physiological age of the node is calculated as the chronological age minus 21% of this delay. Efforts to simulate the variation in leaf abscission rates with temperature and carbohydrate stress in field grown cotton resulted in the selection of the 21% figure. An amount of nitrogen equal to 2% of the leaf dry weight is subtracted from the total plant leaf nitrogen. Two percent is approximately the minimum leaf nitrogen concentration reported by Jones et al. (1974).

If there is no fruit at the node, the next section (down to line 50) is skipped. If a fruit is present, the following operations are performed, depending on the stage of development (implemented via a computed GO TO based on FCODE). If seven days have elapsed since the square at this site was marked for abscission, abscission occurs on the output diagram of the plant. Note, however, that this is not part of the actual simulation of fruit loss, but is simply provided for diagramatic purposes. The actual simulated fruit loss is a continuous process in which a weighted fraction of the fruit at each site is lost as shown below. This fractional fruit loss permits interfacing with insect damage models.

The data base for estimating time from square initiation to bloom as a function of temperature is presented in Figure 27. These data are taken from Hesketh and Low (1968). If sufficient time has elapsed for this square to bloom, bloom occurs. If more than half an inch of rain occurred on the current day, the variable POLYNA is set to 0. Rain is assumed to interfere with pollination and the bloom aborts. The output map code is set to 4 to reflect fruit abortion in the output, but this has no effect on the actual simulation. The actual simulation loss is implemented by adding to the accumulated pollination loss the fraction of fruit actually remaining at this particular site. If the accumulated POLOSS is greater than 1, it is set equal to 1. In other words, not more than one bloom per plant per day can be lost in this way.

If, however, this loss due to rain does not occur, the fruit remains on the plant and is counted among the blooms on the plant (IBLUM). The output map code is set to 2, and the actual simulated fruit code is set to 7 indicating a green boll. The boll weight is initialized at 31% of the square weight at that site, to allow for weight loss in the corolla. The green boll weight is added to the cumulative green boll weight for the plant as a whole. If some green boll weight has accumulated on the plant, the date (FBLOOM) is recorded. Then the total plant square weight is decremented, and the square weight for this site is set to 0.

If the site contains a boll which is pas the age of susceptibility to abscission (1 days), the FCODE is set to 2, and th fraction of a fruit remaining at the site i checked to see that it is not less than zer If seven days have elapsed since this fru was marked for abscission, the fruit abscised and the output map is change accordingly.

Next, the chronological boll age is i cremented. Then, if the ratio of fru weight to total plant weight is less th 0.15, or if it is greater than 0.15 and litt water stress exists in the plant (WSTR is greater than 0.75), the physiological a of the boll is incremented by one d Again, this is part of a mechanism whi

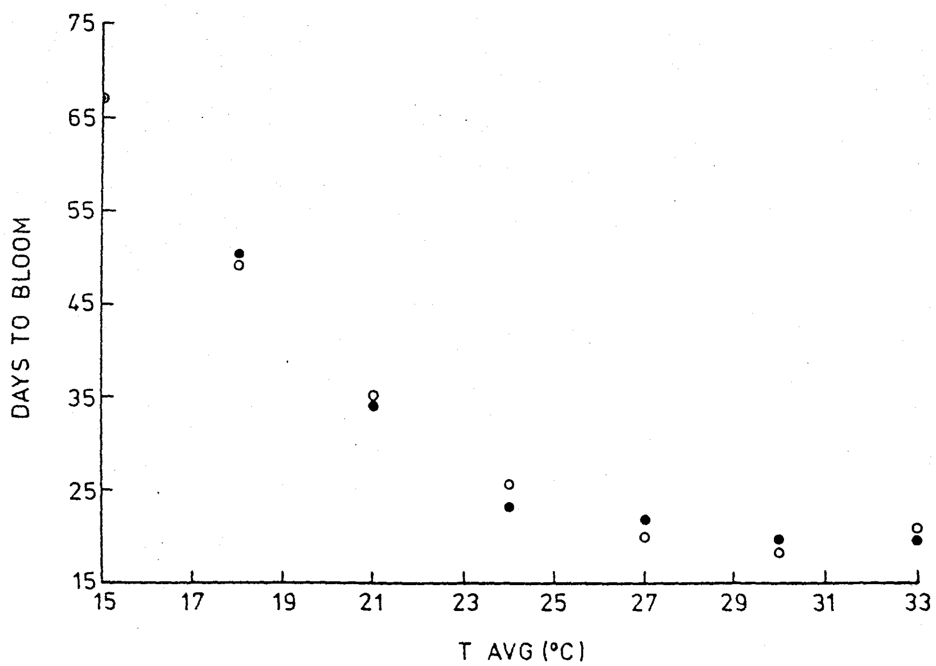


Figure 27. Days from square initiation to bloom vs. temperature.

delays cessation of organ growth during fruiting under water stress conditions. In subroutine GROWTH this physiological boll age is used to determine whether potential boll growth is in the exponential or linear phase.

Finally, the variable BOLDAZ is set equal to the chronological boll age, and a water stress factor, which reflects increased canopy temperatures during drought, is computed and added to the running average temperature. The days from bloom to open boll are then calculated using the adjusted temperature. The data base for this temperature response also was taken from Hesketh and Low (1968). It is graphed in Figure 28.

If the boll is due to open, the codes are set to 3 to reflect this. The weight of the boll is added to the open boll weight accumulator (COTXX), the weight is subtracted from the total plant green weight, and the nitrogen contained in the boll is subtracted from the total plant green boll nitrogen amount. Gin percentage, fiber length, and fiber strength are calculated from temperature functions published by Hesketh and Low (1968) (Figures 29-31). Yield is calculated as the cumulative (overall bolls opened to date) weight of lint on the plant. It is expressed in terms of 500 lb bales per acre.

The remainder of PLTMAP is devoted to the abscission of fruit within the plant. The data base for this function was developed from the plant maps obtained by Bruce and Römkens (personal communication) in their AAA (well watered) treatment, and from validation efforts by Fye et al. (1981). Cotton physiologists and agronomists have known for many years that several kinds of physiological stresses, including carbohydrate and nitrogen shortages and water stress, are associated with the "natural" abscission of squares and bolls. This area, including its hormonal aspects, has been the subject of a large part of the physiological research done over the last 30 years. Yet, very little is known about the linkages between the metabolic pathways and the hormone systems involved in abscission, and, to this day, no model exists which describes this system explicitly and mechanistically. However, the simulation models, including GOSSYM and SIMCOT II, which have been built shed some light on the nature of fruit abscission, and what is now known appears to be applicable to other plant species as well.

The model description of abscission and the development of metabolic delays in fruiting began, chronologically, with our calculation of daily photosynthate production, respiration loss, and nitrogen uptake (Hesketh et al., 1971, Baker et al., 1972) as noted above. We then moved to examine the classical "nutritional theory." We theorize that hormone balances in the plant shift in response to some mathematical combination of both supply and demand for metabolites. We use the supply:demand ratio. These shifts result in lengthening or shortening time variables, such as plastochrons, and they result in the abscission of some fruit. In GOSSYM we have written functional relations for this (described above for the delays and below for abscission).

As outlined above, a good simulation of morphogenesis and fruiting and fruit abscission was first obtained in Bruce and Römkens' well watered treatment by manually adjusting the relationships between morphogenetic delays and the physiological stress parameters and between fruit abscission and the stress parameter FSTRES. This procedure provided FSTRES values appropriate to the amount of abscission (in this case). Different relationships are used for plants with fruit dry weight:total plant dry weight ratios above and below 0.1. These relationships are graphed in Figure 32.

As was noted earlier, GOSSYM simulates the effects of water stress on fruiting within the framework of the nutritional theory. Referring again to the flow charts, after the current day's increment of fruit loss (FLOSS) is calculated, it is accumulated (SFLOSS) for the output map notation. The program, down to the CONTINUE statement 26 is concerned only with the output maps, and not with the simulation itself. Therefore, this code will not be discussed beyond the notes provided in the flow charts.

Beginning at line 26, the actual simulation of fruit abscission begins. This code permits the abscission of partial fruit at each site containing squares or bolls in the susceptible age categories. For squares, the most commonly used age category is 4 to 40 days. For bolls the age category is 1 to 15 days.

The first step is to inventory the fruiting site matrix and count or sum up the susceptible squares and bolls. Next the actual number of squares and bolls to be marked for abscission during the current day are calculated. The fraction of each suscepti-

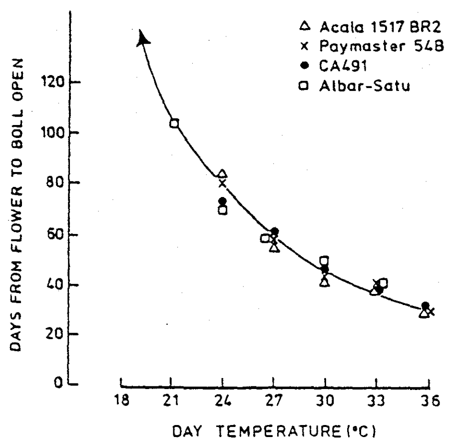


Figure 28. Days from bloom to boll open vs. temperature.

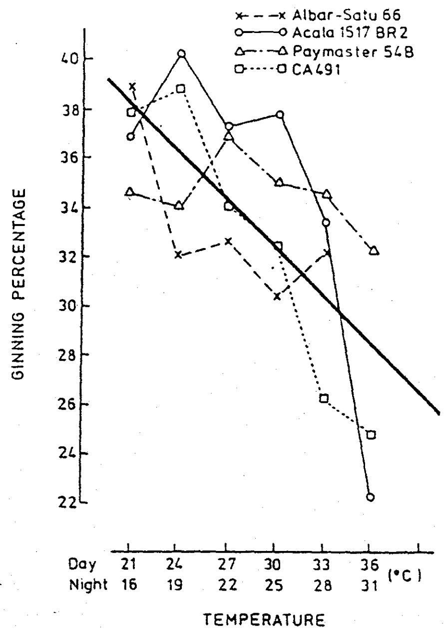


Figure 29. Effect of temperature on gin percentage in several cultivars.

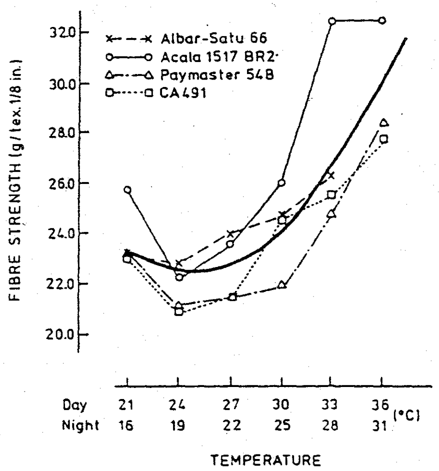


Figure 30. Effect of temperature on fiber strength in several cultivars.

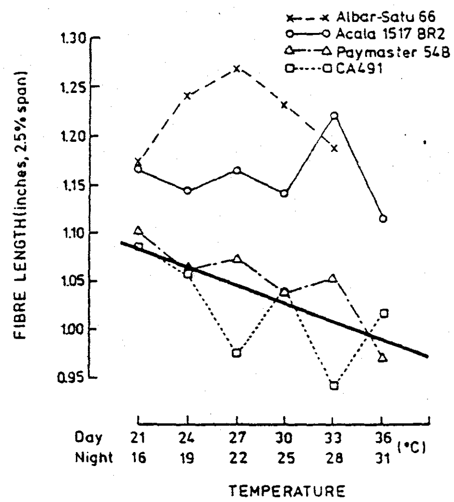


Figure 31. Effect of temperature on fiber length in several cultivars.

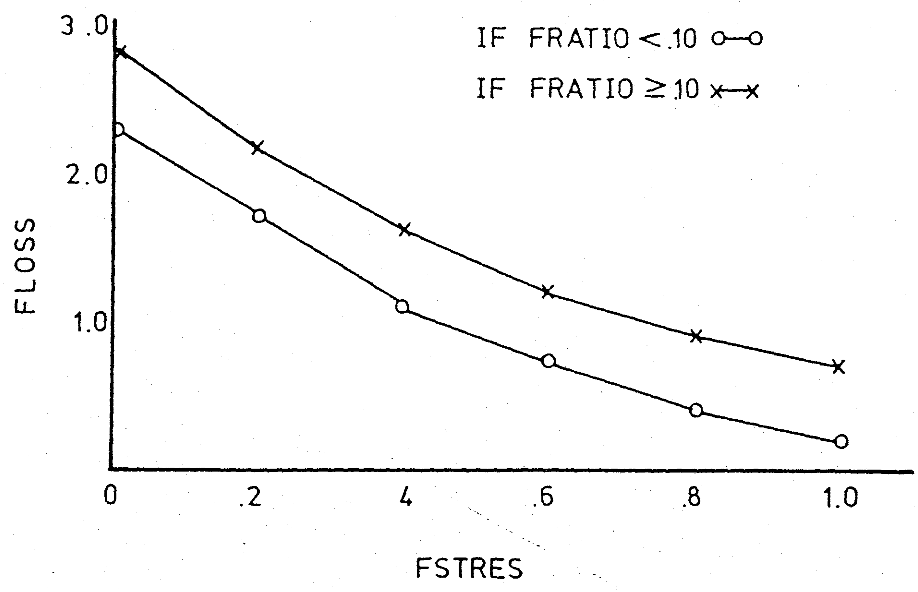


Figure 32. Numbers of fruit lost vs. FSTRES for plants with fruit dry/total plant dry weight ratios above and below 0.1.

ble square to be marked for loss is the current day's number of squares divided by the total susceptible squares. However, this fraction is limited to DPSMX (=0.5). Next, the number of blooms produced in the past seven days is calculated and those which have bloomed are shed as bolls rather than as squares. Square loss is therefore, calculated as the number of squares marked for abscission seven days ago, minus those which have become blooms, plus the pinhead squares that have been marked during the current day. Bolls to be lost today equals the number of bolls marked for abscission seven days ago, plus the blooms whose petals have been stuck by rain, plus the marked squares which have become bolls in the past seven days. The fraction of existing susceptible bolls to be dropped is not allowed to exceed the limit DPBMX (=0.5).

If the program attempts to drop more bolls than exist, the fraction of susceptible bolls to be lost is set to 1.0, and the square loss is recomputed to make up the difference to provide the same total fruit loss. Similarly, if the program attempts to drop more squares than exist at this time, the boll loss is redefined so that the excess square loss is made up as boll loss. Again, the fractional limits are preserved.

Beginning with line 86 the actual removal of the fruit from the plant is done. If the fruit code is not 0, 1, or 5, the fruit is a square. If it is between 4 and 40 days old it is susceptible, and a fraction (FDROPS) of it will be dropped. Fruit numbers and weights are removed from the appropriate registers, and added to registers representing cumulative losses.

Similarly, green boll numbers are summed, and if the boll age is less than 15 days, a fraction (FDROPB) is dropped. Again, this involves removing the fruit numbers and weights from the appropriate registers, and adding the losses to other registers to keep records of cumulative boll losses. In the case of boll losses, a record is also kept of tissue nitrogen losses.

Finally, PLTMAP records the aging and senescence of leaves on the mainstem below the first fruiting branch. The program begins aging them on the day of first square and it abscises them 70 days later.

Typical Output

A sample of typical output is presented in part on pages 83 through 92. It is a copy of the output for day numbers 1, 50, 100 and 150 in a simulation of the ABB crop of Bruce and Römkens (1965). It consists of the values of a number of state variables which are useful in model verification, validation, and trouble shooting. The output also includes diagrams representing the above the below-ground physical structure of the plant as well as the distribution of nitrogen and water in the root zone. Further detail on the output of information on the below-ground system is presented in Lambert and Baker. (1984). Output can be requested every nth day of the simulation from emergence to harvest by setting n equal to the desired value in the keyboard inputs (c.f. Appendix A).

Lines 2, 3 of the output list cultural input (from the input card deck) data as follows: plant population per acre, latitude of the site, Julian day of emergence, length of the season, row spacing in cm., fertilizer application rates at planting and sidedress in lb N per acre, days between sidedress applications and an unused variety selector (0.00).

Line 4 is an instruction from the computer to the user operating interactively from a terminal to type in a run identifier. Line 5 is the run identifier. Line 6 is an instruction from the computer to type in the NOITR value, which selects the number of iterations per half day to be used in solving the Darcy flow equations in RHIZOS. Line 7 shows the NOITR (5). Line 8 is an instruction from the computer to type in the plant map output frequency. In the present run 50 days between maps was selected. Lines 11 and 12 are an instruction from the computer requesting the maps needed in the output. In line 13 all possible maps were selected.

Lines 14 and 16 are requests from the computer for certain system constants. The values used in this run were as follows: XTR1 is used in PLTMAP to form a correction factor for air temperature as a function of water stress. XTR2 and XTR3 are coefficients in the equation defining physiological stress induced delays in morphogenesis. XTR4 is one of the coefficients in the equation relating fruit loss to physiological stress. A1, A21, and A22 are coefficients in the equation relating delays in morphogenesis to physiological stress. A31 and A32 are parameters defining the minimum and maximum ages, respectively, of susceptibility in square abortion. CZD is a coefficient in the equation relating time interval between vegetative branches to temperature. CZN is a coefficient in the equations relating change in plant height to age of the top nodes on the mainstem. CSQ is a coefficient in the equation relating square absicission to physiological stress after the fruit ratio exceeds 0.2. CBL is a parameter which changes the rate of physiological aging of a node in response to physiological stress. CL is a parameter which adjusts leaf growth. CM is a water stress threshold below which growth that would have occurred under non-stress conditions is accumulated and added to the carbohydrate sink on rewatering. CPF is used to adjust the rate of mainstem height growth. CVB is an FRATIO threshold above which leaves and bolls may not be aged under water stress. DPSMX and DPBMX are parameters limiting square and boll abscission rates.

Line 18 is printed every day that a fertilizer application is made. Line 19 shows the volumetric nitrate content of cell 1, 1 of the RHIZOS matrix. Line 20 is a label for state variables in line 21. TNNO3 and TNNH4 represent the total nitrate and ammonia nitrogen in the profile on that day. Line 24 is a label for the state variables in line 25. DEADWT and XTRAC are cumulative amounts of dry matter sloughed by the root system and permanently stored respectively.

Next on this page are maps of the volumetric nitrate content and volumetric water content of the soil as of the end of this day. The top of the next page contains maps of soil suction and root dry matter.

Lines 155-207 contain crop phenology output, including days from emergence, numbers of fruiting sites, squares, green bolls, open bolls, the number of fruit abscised today, the number of mainstem nodes with fruiting branches, plant height, leaf area index, the combined physiological stress, and the average soil water potential in the rooted portion of the soil matrix. In this section notes are printed when the fertilizer applications are made, or when first square or bloom occurs.

Lines 208-225 presents the values of state variables, some of which are used in validation efforts and some of which are used in trouble shooting (e.g. confirming the materials balances). This information is presented with the numerical values on lines following headers with appropriate labels. Lines 208-209 list the sum of daily increments in net photosynthate production, today's net photosynthate increment, the increments of water evaporation from the soil and from the plant, incident and net radiation daily totals, and the air temperatures. Lines 210-211 present tissue nitrogen amounts and concentrations. Lines 212-213 provide the information needed to verify the nitrogen budget. Lines 214-215 present the supply: demand ratios for nitrogen in fruit and vegetative growth, the carbohydrate supply:demand ratio, the combined nitrogen-carbohydrate supply demand ratio for vegetative growth, the canopy light interception value, and the root:shoot dry matter partitioning factors. Lines 216-217 present potential dry weight changes and current dry weights in the various classes of organs on the plant. Lines 218-219 present the number of mainstem nodes below the first fruiting branch, stress induced morphogenetic delays, the numbers of fruit, and the weights of the leaves and roots to be abscised or sloughed off today. Lines 220-221 contain miscellaneous information, notably the water stress parameters, WSTRSD and WSTRSN, used in GROWTH. Lines 222-223 present a number of accumulations used in verifying the water balance. The plant height and weights of the plant parts are listed in lines 224-225. These are used, along with SPN, to verify the dry matter balance, and in some validation efforts.

The plant map, lines 227-232, shows three fruiting branches each with one node. The fruit has abscised from the first fruiting branch, but squares remain on the other two. The nitrate distribution map (lines 234-264) shows that some fertilizer has been added, and that some of it has moved as a result of evapotranspiration.

The maps in lines 265-296 and 329-360 show the water extraction pattern. The root distribution map (lines 297-328) depicts (compared to the same map on day one) root growth. It shows the impact of low soil moisture content on root elongation in the top two soil layers.

```
 1 GOSSYM OUTPUT
 2   20498.00      34.00     129.00     170.00     101.60
 3      75.00      75.00      28.00       0.00
 4  ENTER RUN IDENTIFICATION
 5  BRUCE AND ROMKEM'S DATA TREATMENT ABB
 6  ENTER NOITR -  I1 FORMAT
 7   5
 8  ENTER FREQUENCY INTEGER.  I2 FORMAT.
 9  50
10   FREQUENCY OF 50 DAYS.
11  ENTER 1 UNDER THE FIRST LETTER OF EACH PLOT YOU WISH TO SEE.
12  TOPS ROOTS PSIS VH2OC DIFF VNO3C
13  1    1     1    1     0    1
14  XTR1 XTR2 XTR3 XTR4 A1   A21  A22  A31  A32
15  1.70-0.42-4.20 2.20 0.89 0.20-2.00 2.0040.00
16  CZD  CZN  CSQ  CBL  CL   CM   CPF  CVB  DPSMXDPBMX
17  2.00 2.10 2.70 0.10 3.70 0.70 1.10 0.10 0.50 0.50
18   FERTILIZER SUBROUTINE CALLED  ##################
19  VNO3C(1,1) =      0.0476
20    DAY      DATE     CSTRES   NSTRES   WSTRSD   WSTRSN    TNNO3   TNNH4
21     1       5- 9-74 0.159       1      0.983    1.000     95.20   54.54
22   TH2O     CUMRAN   CAPUP    CUMES    CUMEP    CUMSOK   H2OBAL    LAI
23  265.85     0.00     0.00     1.09     0.00     0.00   266.94    0.05
24   HEIGHT   WEIGHT   LEAFWT   STEMWT   ROOTWT   SQARWT   GBOLWT    DEADWT   XTRAC
25    1.51    0.663    0.242    0.219    0.201    0.000     0.000    0.000    0.000
26
27
28      VOLUMETRIC NITRATE CONTENT OF SOIL                           DAY   1
29      AT THE END OF MAIN
30
31      UNITS -  MG/N PER CM**3                                     LEGEND
32
33                        1 1 1 1 1 1 1 1 1 1 2
34      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                   <=   0.0000
35
36                                                  0.0000 < 0 <=   0.0100
37   1  4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
38   2  4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4     0.0100 < 1 <=   0.0200
39   3  4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
40   4  4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4     0.0200 < 2 <=   0.0300
41   5
42   6                                              0.0300 < 3 <=   0.0400
43   7
44   8                                              0.0400 < 4 <=   0.0500
45   9
46  10                                              0.0500 < 5 <=   0.060
47  11
48  12                                              0.0600 < 6 <=   0.070
49  13
50  14                                              0.0700 < 7 <=   0.080
51  15
52  16                                              0.0800 < 8 <=   0.090
53  17
54  18                                              0.0900 < 9 <=   0.100
55  19
56  20                                              0.1000 < *
57
58      TOTAL =      95.1965   MG N
59
60      VOLUMETRIC WATER CONTENT OF SOIL                             DAY   1
61      AT THE END OF MAIN
62
63      UNITS - CM**3/CM**3 SOIL                                    LEGEND
64
65                        1 1 1 1 1 1 1 1 1 1 2
66      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                   <=   0.0000
67
68                                                  0.0000 < 0 <=   0.050
69   1  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
70   2  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.0500 < 1 <=   0.100
71   3  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
72   4  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.1000 < 2 <=   0.150
73   5  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
74   6  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.1500 < 3 <=   0.20
75   7  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
76   8  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.2000 < 4 <=   0.25
77   9  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
78  10  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.2500 < 5 <=   0.30
79  11  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
80  12  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.3000 < 6 <=   0.35
81  13  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
82  14  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.3500 < 7 <=   0.40
83  15  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
84  16  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.4000 < 8 <=   0.45
85  17  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
86  18  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.4500 < 9 <=   0.50
87  19  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
88  20  5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5     0.5000 < *
89
90      TOTAL =     265.8531   MM WATER
91
```

```
      ROOTS IN EACH CELL, TOTAL                                     DAY    1
          AT THE END OF RUTGRO

      UNITS - G/CM**3 SOIL                                          LEGEND

                          1 1 1 1 1 1 1 1 1 1 2
      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                            <=   0.0000

                                                              0.0000 < 0 <=   0.0001
   1  2 1 0
   2  2 0                                                     0.0001 < 1 <=   0.0005
   3  2 0
   4  0                                                       0.0005 < 2 <=   0.0050
   5
   6                                                          0.0050 < 3 <=   0.0100
   7
   8                                                          0.0100 < 4 <=   0.0150
   9
  10                                                          0.0150 < 5 <=   0.0200
  11
  12                                                          0.0200 < 6 <=   0.0250
  13
  14                                                          0.0250 < 7 <=   0.0300
  15
  16                                                          0.0300 < 8 <=   0.0350
  17
  18                                                          0.0350 < 9 <=   0.0400
  19
  20                                                          0.0400 < *

      TOTAL =       0.0051  GM. DRY WEIGHT

      PSIS FOR EACH LAYER AND COLUMN                                DAY    1
      AT THE END OF MAIN

      UNITS - CM**3/CM**3 SOIL                                      LEGEND

                          1 1 1 1 1 1 1 1 1 1 2
      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                         <= -15.0000

                                                            -15.0000 < 0 <= -10.0000
   1  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
   2  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                -10.0000 < 1 <=  -6.0000
   3  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
   4  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -6.0000 < 2 <=  -3.0000
   5  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
   6  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -3.0000 < 3 <=  -1.5000
   7  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
   8  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -1.5000 < 4 <=  -1.0000
   9  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
  10  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -1.0000 < 5 <=  -0.6000
  11  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
  12  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -0.6000 < 6 <=  -0.4000
  13  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
  14  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -0.4000 < 7 <=  -0.2000
  15  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
  16  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -0.2000 < 8 <=  -0.1000
  17  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
  18  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                 -0.1000 < 9 <=   0.0000
  19  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
  20  9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9                  0.0000 < *

      TOTAL =     265.8531   MM WATER
```

DAY	SITES	SQRZ	GBZ	OBZ	ABZ	MAINODES	HEIGHT	LAI	FSTRES	PSIAVG
1	0	0.00	0.00	0.00	0.00	0	1.51	0.05	0.16	-0.05
2	0	0.00	0.00	0.00	0.00	0	2.59	0.05	0.30	-0.07
3	0	0.00	0.00	0.00	0.00	0	3.33	0.05	0.35	-0.10
4	0	0.00	0.00	0.00	0.00	0	3.73	0.06	0.35	-0.14
5	0	0.00	0.00	0.00	0.00	0	3.79	0.07	0.32	-0.25
6	0	0.00	0.00	0.00	0.00	0	3.79	0.08	0.23	-0.45
7	0	0.00	0.00	0.00	0.00	0	3.79	0.09	0.26	-1.22
8	0	0.00	0.00	0.00	0.00	0	3.79	0.09	0.28	-1.61
9	0	0.00	0.00	0.00	0.00	0	3.79	0.09	0.32	-1.27
10	0	0.00	0.00	0.00	0.00	0	3.79	0.10	0.20	-0.13
11	0	0.00	0.00	0.00	0.00	0	3.79	0.10	0.37	-0.15
12	0	0.00	0.00	0.00	0.00	0	5.21	0.11	0.11	-0.15
13	0	0.00	0.00	0.00	0.00	0	6.24	0.12	0.21	-0.17
14	0	0.00	0.00	0.00	0.00	0	6.97	0.13	0.17	-0.18
15	0	0.00	0.00	0.00	0.00	0	7.37	0.14	0.15	-0.19
16	0	0.00	0.00	0.00	0.00	0	7.43	0.15	0.41	-1.39
17	0	0.00	0.00	0.00	0.00	0	7.43	0.16	0.17	-1.17
18	0	0.00	0.00	0.00	0.00	0	7.43	0.16	0.67	-1.06
19	0	0.00	0.00	0.00	0.00	0	7.43	0.16	1.00	-0.87
20	0	0.00	0.00	0.00	0.00	0	7.43	0.16	1.00	-0.81
21	0	0.00	0.00	0.00	0.00	0	7.43	0.16	1.00	-0.72
22	0	0.00	0.00	0.00	0.00	0	8.60	0.16	1.00	-0.58
23	0	0.00	0.00	0.00	0.00	0	9.54	0.16	1.00	-0.55
24	0	0.00	0.00	0.00	0.00	0	10.18	0.16	1.00	-0.50
25	0	0.00	0.00	0.00	0.00	0	10.54	0.17	1.00	-0.49
26	0	0.00	0.00	0.00	0.00	0	10.59	0.17	0.96	-0.49
27	0	0.00	0.00	0.00	0.00	0	10.59	0.17	0.62	-0.44

The same output information is repeated every 50 days until the end of the season. The plant map at day 100 (lines 435-460) shows the green boll load. It also shows two vegetative branches which the model assumes are attached to the fourth and fifth mainstem nodes.

By day 150 (lines 659-689) the plant map output shows open bolls at the locations marked with $. The season ended on day 170, and yield of seed cotton was printed (line 841).

For validation purposes, the software includes the capability to print-plot seasonal time courses of real and predicted numbers of squares, bolls, fruiting sites, mainstem nodes, and plant height. Such plots have been copied for the ABB run, and are presented in Figures 33-34.

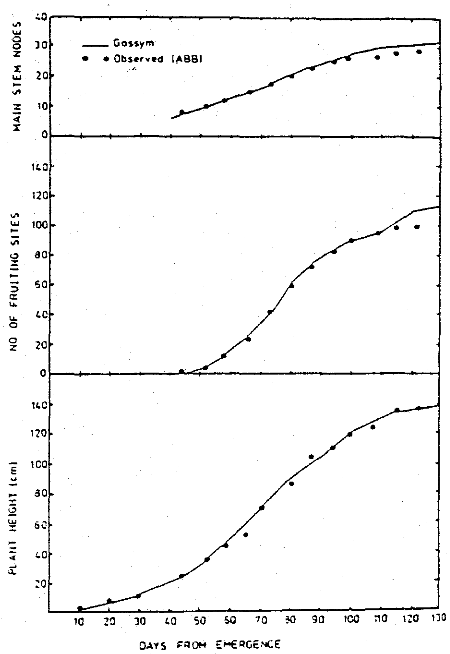
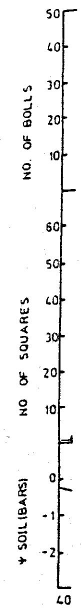


Figure 33. Simulated and observed seasonal time courses of mainstem, fruiting site, and plant height development.



Figur

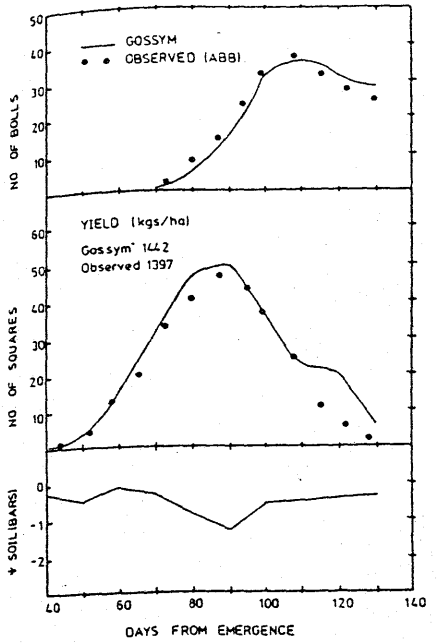


Figure 34. Simulated and observed numbers of bolls, squares, and simulated soil water potential.

```
 FERTILIZER SUBROUTINE CALLED  ##################
   28    0    0.00   0.00   0.00   0.00   0      11.84  0.18  0.67   -0.43
   29    0    0.00   0.00   0.00   0.00   0      12.82  0.18  0.63   -0.41
   30    0    0.00   0.00   0.00   0.00   0      13.50  0.18  0.69   -0.41
   31    0    0.00   0.00   0.00   0.00   0      13.84  0.18  0.96   -0.42
   32    0    0.00   0.00   0.00   0.00   0      13.89  0.19  0.92   -0.39
   33    0    0.00   0.00   0.00   0.00   0      15.18  0.19  0.72   -0.39
   34    0    0.00   0.00   0.00   0.00   0      16.17  0.20  0.67   -0.43
   35    0    0.00   0.00   0.00   0.00   0      16.84  0.20  0.60   -0.48
   36    0    0.00   0.00   0.00   0.00   0      17.18  0.21  0.74   -0.56
   37    0    0.00   0.00   0.00   0.00   0      17.23  0.21  0.83   -0.65
   38    0    0.00   0.00-  0.00   0.00   0      18.32  0.22  0.81   -0.28
   39    0    0.00   0.00   0.00   0.00   0      19.37  0.22  0.77   -0.28
   40    0    0.00   0.00   0.00   0.00   0      20.10  0.22  0.35   -0.28
************ FIRST SQUARE ON DAY   41  ************
   41    1    1.00   0.00   0.00   0.00   1      20.49  0.22  1.00   -0.29
   42    1    0.95   0.00   0.00   0.05   1      22.35  0.23  0.51   -0.30
   43    1    0.95   0.00   0.00   0.00   1      23.83  0.23  0.27   -0.29
   44    1    0.95   0.00   0.00   0.00   1      24.86  0.23  1.00   -0.33
   45    1    0.95   0.00   0.00   0.00   1      25.54  0.24  1.00   -0.36
   46    2    1.95   0.00   0.00   0.00   2      25.92  0.25  1.00   -0.38
   47    2    1.91   0.00   0.00   0.05   2      27.33  0.26  1.00   -0.41
   48    2    1.91   0.00   0.00   0.00   2      28.67  0.27  1.00   -0.42
   49    3    3.91   0.00   0.00   0.00   3      29.65  0.28  1.00   -0.43

 SPN       PN       ES       EP       RI       RN       TAVG     TDAY     TNYT
 26.49     1.73     0.27     1.03   719.00   488.34    20.97    23.19    17.64
STEMCN    STEMN   LEAFCN   SLEAFN   ROOTCN    ROOTN    BURCN     BURRN   SEEDCN
 0.010    0.083    0.023    0.097    0.011    0.021    0.000     0.000    0.000
 SEEDN   TOTNUP     PLTN   PLANTN    NPOOL    XTRAN     RESN    SUPNO3    VEGWT
 0.000    0.000    0.210    0.191    0.019   -0.008    0.008     0.011   14.271
  NF       NV       CD      CPOOL   CSTRES   VSTRES      INT     DTOP    DROOT
 1.000    0.933    0.777    2.979    1.000    0.000     0.31     0.70     2.00
SLEAF     SSTEM    SROOT    SBOLL    SQUAR   SDWLEF    DWSTM    SDWBOL   SDWSQR
  4.07     8.53     2.14     0.00     0.05     0.20     0.35     0.00     0.02
NUMPFN    NDLAY   CDLAYV   CDLAYF    FLOSS    GBLOS   LEFABS    PQFLR   WTSLFD
   6       0.00     0.00     0.00     0.00     0.00     0.00     0.02     0.01
  DAY      DATE   CSTRES   NSTRES   WSTRSD   WSTRSN    TNNO3    TNNH4
  50    6-27-74   1.000      1      0.738    0.977   201.99    24.53
 TH2O    CUMRAN    CAPUP    CUMES    CUMEP   CUMSOK   H2OBAL      LAI
235.31     0.00     0.55    18.65    12.57     0.00   265.98     0.29
HEIGHT   WEIGHT   LEAFWT   STEMWT   ROOTWT   SQARWT   GBOLWT    DEADWT    XTRAC
 31.63   26.845    4.572    8.430    2.046    0.032    0.000     0.308   10.477


            I-X
          X-I
            I-O                         I-X
            I                           I
            I                           I
            I                           I


      VOLUMETRIC NITRATE CONTENT OF SOIL                        DAY  50
      AT THE END OF MAIN

      UNITS -   MG/N PER CM**3                                   LEGEND

                          1 1 1 1 1 1 1 1 1 1 2
      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                <=    0.0000

                                                    0.0000  < 0 <=   0.0100
  1   7 8 * * * * * * * * * * * * * * * 9 8 7
  2   4 9 * 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4       0.0100  < 1 <=   0.0200
  3   4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 4 4 5 3
  4   3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 2       0.0200  < 2 <=   0.0300
  5
  6                                                 0.0300  < 3 <=   0.0400
  7
  8                                                 0.0400  < 4 <=   0.0500
  9
 10                                                 0.0500  < 5 <=   0.0600
 11
 12                                                 0.0600  < 6 <=   0.0700
 13
 14                                                 0.0700  < 7 <=   0.0800
 15
 16                                                 0.0800  < 8 <=   0.0900
 17
 18                                                 0.0900  < 9 <=   0.1000
 19
 20                                                 0.1000  < *


      TOTAL =     201.9856    MG N
```

VOLUMETRIC WATER CONTENT OF SOIL
AT THE END OF MAIN

DAY 50

UNITS - CM**3/CM**3 SOIL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	1	1	1	1	2	2	2	2	2	2	2	2	2	2	2	2	1	1	1	1
2	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
3	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
4	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
5	3	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	3
6	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3
7	3	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3
8	3	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	3
9	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
10	4	4	4	4	4	4	4	4	5	5	5	5	4	4	4	4	4	4	4	4
11	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5	4	4	4	4	4
12	4	4	4	4	5	5	5	5	5	5	5	5	5	5	5	5	4	4	4	4
13	4	4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	4	4
14	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
15	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
16	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
17	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
18	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
19	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
20	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5

LEGEND

```
                <=    0.0000
0.0000 < 0 <=   0.0500
0.0500 < 1 <=   0.1000
0.1000 < 2 <=   0.1500
0.1500 < 3 <=   0.2000
0.2000 < 4 <=   0.2500
0.2500 < 5 <=   0.3000
0.3000 < 6 <=   0.3500
0.3500 < 7 <=   0.4000
0.4000 < 8 <=   0.4500
0.4500 < 9 <=   0.5000
0.5000 < *
```

TOTAL = 235.3067 MM WATER

ROOTS IN EACH CELL, TOTAL
AT THE END OF RUTGRO

DAY 50

UNITS - G/CM**3 SOIL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2	1	0																	
2	2	2	1	0	0															
3	3	2	2	1	0	0														
4	3	2	2	1	0	0														
5	2	2	2	1	0	0														
6	2	2	2	1	0															
7	2	2	1	1	0															
8	2	2	1	0																
9	2	1	0	0																
10	1	1	0																	
11	1	0																		
12	0																			
13																				
14																				
15																				
16																				
17																				
18																				
19																				
20																				

LEGEND

```
                <=    0.0000
0.0000 < 0 <=   0.0001
0.0001 < 1 <=   0.0005
0.0005 < 2 <=   0.0050
0.0050 < 3 <=   0.0100
0.0100 < 4 <=   0.0150
0.0150 < 5 <=   0.0200
0.0200 < 6 <=   0.0250
0.0250 < 7 <=   0.0300
0.0300 < 8 <=   0.0350
0.0350 < 9 <=   0.0400
0.0400 < *
```

TOTAL = 0.0518 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN
AT THE END OF MAIN

DAY 50

UNITS - CM**3/CM**3 SOIL

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1						1	1	2	2	2	2	2	2	1	1					
2	4	5	5	6	7	7	7	7	7	7	7	7	7	7	7	7	6	5	5	4
3	4	5	5	6	7	7	8	8	8	8	8	8	8	8	7	7	6	5	5	4
4	4	5	5	6	7	8	8	8	8	8	8	8	8	8	8	7	6	5	5	4
5	4	5	5	7	7	8	8	8	8	8	8	8	8	8	8	7	7	5	5	4
6	5	5	6	7	8	8	8	8	8	8	8	8	8	8	8	8	7	6	5	5
7	5	5	7	7	8	8	8	8	8	9	9	8	8	8	8	8	7	7	5	5
8	5	6	7	8	8	8	9	9	9	9	9	9	9	9	8	8	8	7	6	5
9	6	7	8	8	8	9	9	9	9	9	9	9	9	9	9	8	8	8	7	6
10	7	7	8	8	9	9	9	9	9	9	9	9	9	9	9	9	8	8	7	7
11	8	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	8	8	8
12	8	8	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	8	8
13	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
14	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
15	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
16	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
17	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
18	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
19	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
20	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9

LEGEND

```
                 <= -15.0000
-15.0000 < 0 <= -10.0000
-10.0000 < 1 <=  -6.0000
 -6.0000 < 2 <=  -3.0000
 -3.0000 < 3 <=  -1.5000
 -1.5000 < 4 <=  -1.0000
 -1.0000 < 5 <=  -0.6000
 -0.6000 < 6 <=  -0.4000
 -0.4000 < 7 <=  -0.2000
 -0.2000 < 8 <=  -0.1000
 -0.1000 < 9 <=   0.0000
  0.0000 < *
```

TOTAL = 235.3067 MM WATER

```
  DAY SITES  SQRZ   GBZ    OBZ    ABZ MAINODES HEIGHT  LAI  FSTRES   PSIAVG
   50    4   2.73   0.00   0.00   1.18   3      31.63  0.29  1.00    -0.47
   51    5   3.69   0.00   0.00   0.05   3      33.05  0.30  1.00    -0.50
   52    6   4.64   0.00   0.00   0.05   4      34.03  0.33  1.00    -0.30
   53    6   4.60   0.00   0.00   0.05   4      36.57  0.37  1.00    -0.32
   54    7   5.60   0.00   0.00   0.00   4      38.48  0.40  1.00    -0.32
   55    8   6.55   0.00   0.00   0.05   5      39.86  0.44  1.00    -0.33
  FERTILIZER SUBROUTINE CALLED  ##################
   56    8   6.50   0.00   0.00   0.05   5      42.49  0.52  1.00    -0.35
   57   10   9.50   0.00   0.00   0.00   6      44.32  0.61  1.00    -0.40
   58   13  11.41   0.00   0.00   0.09   6      46.85  0.68  1.00    -0.43
   59   14  12.28   0.00   0.00   0.14   6      49.06  0.79  1.00    -0.32
   60   16  14.23   0.00   0.00   0.05   7      50.89  0.89  0.59    -0.19
   61   17  15.14   0.00   0.00   0.09   7      53.81  1.00  0.39    -0.19
   62   18  16.09   0.00   0.00   0.05   7      56.01  1.13  0.46    -0.21
   63   19  17.05   0.00   0.00   0.05   8      57.60  1.26  0.68    -0.25
   64   19  17.00   0.00   0.00   0.05   8      60.38  1.29  0.11    -0.25
   65   21  19.00   0.00   0.00   0.00   8      62.43  1.36  0.24    -0.26
   66   24  21.91   0.00   0.00   0.09   8      63.91  1.43  0.23    -0.28
   67   25  22.77   0.00   0.00   0.14   8      64.90  1.57  0.58    -0.33
   68   30  27.17   0.00   0.00   0.61   9      65.54  1.72  0.79    -0.41
   69   31  27.73   0.00   0.00   0.44   9      67.26  1.82  0.57    -0.43
   70   33  29.68   0.00   0.00   0.05  10      68.48  1.76  0.36    -0.36
************ FIRST BLOOM ON DAY  71 *************
   71   34  28.36   0.43   0.00   1.89  10      70.97  1.90  0.78    -0.41
   72   37  30.11   0.39   0.00   1.29  11      72.84  2.02  0.55    -0.46
   73   40  31.30   0.78   0.00   1.42  11      75.32  2.20  0.61    -0.55
   74   49  40.17   0.78   0.00   0.14  12      77.54  2.36  0.60    -0.62
   75   49  39.32   1.21   0.00   0.41  12      79.80  2.52  0.75    -0.75
   76   51  39.86   2.67   0.00   0.00  13      81.83  2.62  0.60    -0.83
   77   53  40.42   3.33   0.00   0.78  13      84.04  2.69  0.45    -0.82
   78   54  41.33   3.33   0.00   0.09  14      85.99  2.78  0.58    -0.91
   79   57  43.55   4.06   0.00   0.05  14      87.88  2.87  0.52    -1.05
   80   60  45.67   4.81   0.00   0.14  15      89.63  2.93  0.40    -1.09
   81   61  46.53   4.81   0.00   0.14  15      91.46  2.98  0.37    -1.20
   82   64  48.00   6.29   0.00   0.05  15      93.06  3.04  0.35    -1.32
   83   65  45.85   9.30   0.00   0.14  16      94.22  3.09  0.35    -1.43
  FERTILIZER SUBROUTINE CALLED  ##################
   84   65  45.60   9.24   0.00   0.31  16      95.87  3.11  0.25    -1.42
   85   65  43.33  11.51   0.00   0.00  16      97.14  3.14  0.28    -1.43
   86   70  47.57  11.93   0.00   0.00  16      98.02  3.16  0.34    -1.53
   87   74  50.19  12.90   0.00   0.75  17      98.65  3.19  0.27    -1.58
   88   74  49.54  12.34   0.00   0.82  17      99.86  3.21  0.26    -1.60
   89   76  47.31  16.24   0.00   0.72  17     100.73  3.23  0.27    -1.62
   90   76  45.97  16.35   0.00   0.83  17     101.35  3.25  0.26    -1.61
   91   77  42.45  18.74   0.00   1.20  18     101.77  3.22  0.19    -0.40
   92   77  41.01  19.74   0.00   1.11  18     103.63  3.24  0.65    -0.40
   93   81  44.52  20.09   0.00   0.80  19     104.95  3.27  0.46    -0.42
   94   81  42.20  20.49   0.00   1.28  19     107.61  3.31  0.39    -0.44
   95   81  38.34  23.22   0.00   1.14  19     109.69  3.33  0.25    -0.45
   96   81  35.25  25.85   0.00   1.10  19     111.18  3.36  0.29    -0.48
   97   85  38.61  24.13   0.00   1.14  20     112.16  3.37  0.37    -0.55
   98   87  32.51  29.39   0.00   1.65  20     114.29  3.40  0.31    -0.60
   99   87  32.42  31.79   0.00   0.09  20     115.86  3.42  0.18    -0.62

  SPN       PN       ES       EP       RI       RN      TAVG     TDAY    TNYT
168.91     3.44     0.00     2.59   400.00   260.14    22.83    24.33   20.78
STEMCN    STEMN   LEAFCN   SLEAFN   ROOTCN    ROOTN    BURCN    BURRN  SEEDCN
  0.035    0.515    0.043    2.407    0.027    1.052    0.020    0.144   0.041
 SEEDN   TOTNUP     PLTN   PLANTN    NPOOL    XTRAN     RESN   SUPNO3   VEGWT
  0.430    0.000    4.576    4.498    1.241   -0.027    1.191    0.050 109.312
   NF       NV       CD    CPOOL   CSTRES   VSTRES      INT     DTOP   DROOT
 1.000    1.000   13.882    3.437    0.248    0.000     1.00     1.00    0.70
SLEAF    SSTEM    SROOT    SBOLL    SQUAR   SDWLEF    DWSTM   SDWBOL  SDWSQR
 56.25    17.71    44.47    27.05    10.01     0.30     0.04     2.52    0.18
NUMPFN    NDLAY   CDLAYV   CDLAYF    FLOSS    GBLOS   LEFABS    PQFLR  WTSLFD
  6        0.00    0.64     0.82     1.71     1.49     3.31     6.29    0.15
  DAY     DATE   CSTRES   NSTRES   WSTRSD   WSTRSN    TNNO3    TNNH4
  100   8-16-74   0.248      1      0.768    0.874   171.00     6.65
 TH2O   CUMRAN    CAPUP    CUMES    CUMEP   CUMSOK   H2OBAL      LAI
212.08   95.76    19.20    31.37   135.48     0.46   264.43     3.44
 HEIGHT  WEIGHT   LEAFWT   STEMWT   ROOTWT   SQARWT   GBOLWT   DEADWT   XTRAC
116.96  152.637   56.183   14.864   38.819    1.254   28.035   16.931  13.482

          X-I
            I-X
          X-I
            I-O
          X-I
            I-X
        X-X-I
            I-*-X
        X-*-I
            I-*-X
      X-X-*-I
            I-*-*-X
    X-X-*-*-I
            I-O-O-*-X                   I-X
X-X-*-O-O-I                           X-I                         X-I
            I-*-O-*-X-X                 I-X                         I-X
X-*-*-O-*-I                         O-*-I                         X-I
            I-*-O-*-*-X                 I-*-O-X                     I-*-O
O-*-O-O-*-I                       X-*-O-*-I                   X-O-*-I
            I-O-*-O-*-*                 I-O-*-*-*-X                 I-*-*-*-X
            I                           I                           I
            I                           I                           I
            I                           I                           I
```

```
      VOLUMETRIC NITRATE CONTENT OF SOIL                    DAY 100
      AT THE END OF MAIN

      UNITS -  MG/N PER CM**3                              LEGEND

                                1 1 1 1 1 1 1 1 1 1 2
      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                  <=   0.0000

                                                     0.0000 < 0 <=    0.0100
  1   0     0 0 0 0 1 1 1 1 1 1 0 0 0 0 0 0 0
  2   1 2 * 1 2 2 4 6 6 6 6 7 5 4 2 2 1 1 1 1        0.0100 < 1 <=    0.0200
  3   2 * * 2 3 3 4 4 4 5 4 5 4 4 3 3 2 2 2 1
  4   2 8 * 2 3 3 3 3 4 4 3 4 3 3 3 3 2 2 2 2        0.0200 < 2 <=    0.0300
  5   1 2 * 1 1 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1
  6   0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 0 0 0        0.0300 < 3 <=    0.0400
  7   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
  8   0 0 0 0 0 0 0 0 0 0 0 0 0                      0.0400 < 4 <=    0.0500
  9
 10                                                  0.0500 < 5 <=    0.0600
 11
 12                                                  0.0600 < 6 <=    0.0700
 13
 14                                                  0.0700 < 7 <=    0.0800
 15
 16                                                  0.0800 < 8 <=    0.0900
 17
 18                                                  0.0900 < 9 <=    0.1000
 19
 20                                                  0.1000 < *

      TOTAL =     171.0041   MG N
```

```
      VOLUMETRIC WATER CONTENT OF SOIL                      DAY 100
      AT THE END OF MAIN

      UNITS - CM**3/CM**3 SOIL                             LEGEND

                                1 1 1 1 1 1 1 1 1 1 2
      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                  <=   0.0000

                                                     0.0000 < 0 <=    0.0500
  1   4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4
  2   3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3        0.0500 < 1 <=    0.1000
  3   3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3
  4   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3        0.1000 < 2 <=    0.1500
  5   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3
  6   3 3 3 3 3 3 3 4 4 4 4 4 4 3 3 3 3 3 3 3        0.1500 < 3 <=    0.2000
  7   3 3 3 3 3 3 3 4 4 4 4 4 4 3 3 3 3 3 3 3
  8   3 3 3 3 3 3 3 4 4 4 4 4 4 3 3 3 3 3 3 3        0.2000 < 4 <=    0.2500
  9   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3
 10   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3        0.2500 < 5 <=    0.3000
 11   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3
 12   3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3        0.3000 < 6 <=    0.3500
 13   3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3
 14   3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3        0.3500 < 7 <=    0.4000
 15   3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3
 16   3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3        0.4000 < 8 <=    0.4500
 17   4 4 4 4 4 4 4 4 5 5 5 5 4 4 4 4 4 4 4 4
 18   4 4 4 4 4 4 5 5 5 5 5 5 5 4 4 4 4 4 4 4        0.4500 < 9 <=    0.5000
 19   4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 5 5 4 4 4
 20   5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5        0.5000 < *

      TOTAL =     212.0813   MM WATER
```

```
      ROOTS IN EACH CELL, TOTAL                             DAY 100
          AT THE END OF RUTGRO

      UNITS - G/CM**3 SOIL                                 LEGEND

                                1 1 1 1 1 1 1 1 1 1 2
      1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                  <=   0.0000

                                                     0.0000 < 0 <=    0.0001
  1   2 2 2 1 1 1 0 0
  2   2 2 2 2 2 2 2 1 1 0                            0.0001 < 1 <=    0.0005
  3   3 3 3 3 2 2 2 2 1 1 0
  4   4 4 4 4 3 2 2 2 2 1 0 0                        0.0005 < 2 <=    0.0050
  5   5 5 5 4 4 3 2 2 2 1 0 0
  6   6 6 6 5 4 3 2 2 2 1 0                          0.0050 < 3 <=    0.0100
  7   6 7 6 5 4 3 2 2 2 1 0
  8   7 7 6 5 4 3 2 2 2 1 0                          0.0100 < 4 <=    0.0150
  9   7 7 6 5 4 3 2 2 1 1 0
 10   6 6 6 4 3 2 2 2 1 0 0                          0.0150 < 5 <=    0.0200
 11   5 5 4 3 3 2 2 2 1 0
 12   5 4 3 3 2 2 2 1 0 0                            0.0200 < 6 <=    0.0250
 13   4 4 3 2 2 2 1 1 0
 14   3 3 2 2 2 1 1 0 0                              0.0250 < 7 <=    0.0300
 15   3 2 2 2 2 1 0 0
 16   2 2 2 2 1 0 0                                  0.0300 < 8 <=    0.0350
 17   2 2 2 1 1 0
 18   2 2 1 1 0                                      0.0350 < 9 <=    0.0400
 19   1 1 1 0
 20   1 1 0 0                                        0.0400 < *

      TOTAL =       0.9831   GM. DRY WEIGHT
```

```
     PSIS FOR EACH LAYER AND COLUMN                                DAY 100
     AT THE END OF MAIN

     UNITS - CM**3/CM**3 SOIL                                      LEGEND

                       1 1 1 1 1 1 1 1 1 1 2
     1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                       <= -15.0000

                                                     -15.0000 < 0 <= -10.0000
 1   7 7 7 7 7 7 8 8 8 8 8 8 8 8 7 7 7 7 7 7
 2   6 6 6 6 7 7 7 8 8 8 8 8 8 7 7 7 6 6 6 6         -10.0000 < 1 <=  -6.0000
 3   5 5 5 5 6 6 7 7 7 8 8 7 7 7 6 6 5 5 5 5
 4   5 5 5 5 5 6 6 7 7 7 7 7 7 6 6 5 5 5 5 5          -6.0000 < 2 <=  -3.0000
 5   5 5 5 5 5 5 6 6 7 7 7 7 6 6 5 5 5 5 5 5
 6   5 5 5 5 5 5 6 6 7 7 7 7 6 6 5 5 5 5 5 5          -3.0000 < 3 <=  -1.5000
 7   4 4 4 5 5 5 6 6 7 7 7 7 6 6 5 5 5 4 4 4
 8   4 4 4 5 5 5 6 6 7 7 7 7 6 6 5 5 5 4 4 4          -1.5000 < 4 <=  -1.0000
 9   4 4 4 5 5 5 6 7 7 7 7 7 7 6 5 5 5 4 4 4
10   4 4 4 5 5 5 6 7 7 8 8 7 7 6 5 5 5 4 4 4          -1.0000 < 5 <=  -0.6000
11   2 2 3 5 5 6 7 7 8 8 8 8 7 7 6 5 5 3 2 2
12   2 3 3 3 5 6 7 7 8 8 8 8 7 7 6 5 3 3 3 2          -0.6000 < 6 <=  -0.4000
13   3 3 3 3 4 7 7 8 8 8 8 8 8 7 7 4 3 3 3 3
14   3 3 3 4 6 7 8 8 8 8 8 8 8 8 7 6 4 3 3 3          -0.4000 < 7 <=  -0.2000
15   3 3 4 5 7 8 8 8 8 9 9 8 8 8 8 7 5 4 3 3
16   3 4 6 7 8 8 8 9 9 9 9 9 9 8 8 8 7 6 4 3          -0.2000 < 8 <=  -0.1000
17   6 7 7 8 8 8 9 9 9 9 9 9 9 9 8 8 8 7 7 6
18   7 8 8 8 9 9 9 9 9 9 9 9 9 9 9 9 8 8 8 7          -0.1000 < 9 <=   0.0000
19   8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 8
20   9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9           0.0000 < *

     TOTAL =     212.0813  MM WATER
```

DAY	SITES	SQRZ	GBZ	OBZ	ABZ	MAINODES	HEIGHT	LAI	FSTRES	PSIAVG
100	87	30.74	31.49	0.00	0.22	20	116.96	3.44	0.25	-0.65
101	87	30.49	32.37	0.00	0.55	20	117.67	3.47	0.33	-0.21
102	89	30.14	33.01	0.00	1.71	21	118.26	3.46	0.26	-0.22
103	89	28.61	33.49	0.00	1.63	21	119.86	3.50	0.22	-0.24
104	94	30.89	32.37	0.00	1.14	21	120.95	3.53	0.30	-0.29
105	94	27.84	35.95	0.00	1.64	21	121.72	3.55	0.23	-0.31
106	94	26.98	32.69	0.00	2.02	21	122.21	3.57	0.33	-0.37
107	94	25.55	34.54	0.00	1.71	21	122.58	3.54	0.21	-0.42
108	95	23.97	36.31	0.00	1.32	22	122.93	3.55	0.13	-0.45
109	95	22.61	35.02	0.00	1.71	22	123.96	3.56	0.26	-0.53
110	95	21.87	32.92	0.00	1.81	22	124.65	3.58	0.22	-0.60
111	95	21.24	32.58	0.00	1.48	22	125.09	3.43	0.23	-0.69
112	95	20.37	33.12	0.00	1.79	22	125.40	3.44	0.19	-0.22
113	100	21.80	31.47	0.00	1.35	22	125.76	3.45	0.22	-0.24
114	100	18.49	36.55	0.00	2.10	22	126.12	3.47	0.16	-0.26
115	105	22.60	34.51	0.00	2.20	23	126.48	3.48	0.13	-0.28
116	105	20.64	35.34	0.00	1.86	23	127.24	3.25	0.14	-0.31
117	107	21.88	33.35	0.35	1.81	23	127.74	3.26	0.16	-0.36
118	107	20.52	33.18	0.35	1.86	23	128.11	3.27	0.13	-0.39
119	108	18.78	33.14	0.75	1.94	23	128.45	3.11	0.19	-0.44
120	112	21.98	32.16	0.75	1.88	23	128.78	2.93	0.17	-0.50
121	112	20.74	31.31	1.15	2.28	23	129.10	2.78	0.17	-0.55
122	112	19.59	28.77	2.49	2.22	23	129.43	2.63	0.15	-0.17
123	113	19.28	27.74	2.49	2.17	24	129.78	2.64	0.24	-0.17
124	113	16.40	28.07	3.15	2.12	24	130.31	2.52	0.15	-0.18
125	113	14.31	28.01	3.15	2.22	24	130.69	2.42	0.18	-0.21
126	113	13.12	26.58	3.80	1.97	24	131.06	2.42	0.12	-0.22
127	113	11.78	25.89	3.80	2.03	24	131.43	2.25	0.07	-0.22
128	113	9.74	25.21	4.43	2.02	24	131.81	1.97	0.07	-0.23
129	113	8.21	24.93	4.43	1.85	24	132.18	1.89	0.07	-0.24
130	113	6.89	24.81	4.43	1.47	24	132.54	1.75	0.27	-0.26
131	113	5.22	24.73	4.43	1.74	24	132.90	1.69	0.29	-0.28
132	113	3.63	24.69	4.43	1.63	24	133.25	1.63	0.27	-0.31
133	113	1.81	24.67	4.43	1.83	24	133.61	1.58	0.21	-0.35
134	113	0.91	24.66	4.43	0.92	24	133.97	1.58	0.18	-0.40
135	113	0.39	24.73	4.43	0.46	24	134.33	1.46	0.16	-0.49
136	113	0.19	23.48	5.65	0.23	24	134.69	1.29	0.11	-0.44
137	113	0.10	21.06	8.04	0.11	24	135.04	1.24	0.09	-0.41
138	114	1.05	21.06	8.04	0.06	25	135.39	1.07	0.11	-0.46
139	114	0.52	18.70	10.39	0.53	25	135.73	1.05	0.10	-0.43
140	114	0.26	18.70	10.39	0.26	25	136.07	0.99	0.07	-0.46
141	114	0.13	18.12	10.97	0.13	25	136.40	0.97	0.12	-0.43
142	114	0.07	18.12	10.97	0.07	25	136.74	0.92	0.11	-0.45
143	114	0.03	15.42	13.67	0.03	25	137.07	0.88	0.10	-0.47
144	114	0.02	14.89	14.20	0.02	25	137.40	0.77	0.12	-0.51
145	114	0.01	12.26	16.83	0.01	25	137.73	0.77	0.09	-0.46
146	114	0.00	12.26	16.83	0.00	25	138.08	0.75	0.04	-0.46
147	114	0.00	12.26	16.83	0.00	25	138.44	0.73	0.00	-0.46
148	114	0.00	12.26	16.83	0.00	25	138.78	0.72	0.21	-0.46
149	114	0.00	12.26	16.83	0.00	25	139.13	0.68	0.26	-0.47

SPN	PN	ES	EP	RI	RN	TAVG	TDAY	TNYT
306.38	0.98	0.75	0.50	553.00	369.59	14.00	17.19	10.75
STEMCN	STEMN	LEAFCN	SLEAFN	ROOTCN	ROOTN	BURCN	BURRN	SEEDCN
0.027	0.428	0.113	1.202	0.023	0.926	0.007	0.263	0.013
SEEDN	TOTNUP	PLTN	PLANTN	NPOOL	XTRAN	RESN	SUPNO3	VEGWT
0.787	0.000	3.623	3.605	0.929	-0.017	0.927	0.002	66.727
NF	NV	CD	CPOOL	CSTRES	VSTRES	INT	DTOP	DROOT
1.000	1.000	5.387	0.983	0.182	0.000	0.24	1.00	0.70
SLEAF	SSTEM	SROOT	SBOLL	SQUAR	SDWLEF	DWSTM	SDWBOL	SDWSQR
62.31	19.38	48.50	146.46	16.31	0.00	0.04	0.79	0.16
NUMPFN	NDLAY	CDLAYV	CDLAYF	FLOSS	GBLOS	LEFABS	PQFLR	WTSLFD
6	0.00	0.78	0.86	2.33	8.01	55.96	12.41	0.21
DAY	DATE	CSTRES	NSTRES	WSTRSD	WSTRSN	TNNO3	TNNH4	
150	10- 5-74	0.182	1	0.875	1.000	63.14	2.21	
TH2O	CUMRAN	CAPUP	CUMES	CUMEP	CUMSOK	H2OBAL	LAI	
211.06	229.36	42.34	37.85	276.53	8.08	261.82	0.65	

```
:HT   LEAFWT  STEMWT  ROOTWT  SQARWT  GBOLWT   DEADWT  XTRAC
)0  10.471  15.661  40.439   0.147   48.287  84.638  13.482

      O

     -O

     -O

     -O

    :-O-O
    [
    I-O-O
    I
    I-O-O-O
   .I
    I-*-O-O
   -I
    I-$-O-*-O
   -I                  O-I
    I-O-O-*-O-O          I-O                 I-O
  )-I                O-O-I                O-I
    I-$-O-*-O-O          I-*-O               I-O-O
  $-I              O-O-*-I              O-*-I
    I-$-O-$-O-*          I-$-O-O-O           I-*-O-O
  $-I          O-O-*-O-$-I            O-*-O-$-I
    I-O-$-O-$-*          I-O-O-$-*-O         I-$-O-*-O-O
    I                    I                   I
    I                    I                   I
    I                    I                   I
```

```
'LUMETRIC NITRATE CONTENT OF SOIL                    DAY 150
: THE END OF MAIN

NITS -  MG/N PER CM**3                             LEGEND

                    1 1 1 1 1 1 1 1 1 1 2
  2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                <=    0.0000

                                              0.0000 < 0 <=    0.0100
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0   0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0       0.0100 < 1 <=    0.0200
0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0
0 1 * 0 0 1 1 2 2 2 1 3 2 1 0 0 0 0 0 0       0.0200 < 2 <=    0.0300
0 4 * 1 1 1 2 2 3 3 2 4 2 2 1 1 0 0 0 0
0 4 * 0 1 1 1 1 2 2 1 2 2 1 1 1 0 0 0 0       0.0300 < 3 <=    0.0400
0 1 9 0 0 0 1 1 1 1 0 1 1 1 0 0 0 0 0 0
0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0       0.0400 < 4 <=    0.0500
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0               0.0500 < 5 <=    0.0600
0 0 0 0 0 0 0 0 0 0 0 0 0

                                              0.0600 < 6 <=    0.0700
```

```
TOTAL =      63.1369  MG N

VOLUMETRIC WATER CONTENT OF SOIL                     DAY 150
AT THE END OF MAIN

UNITS - CM**3/CM**3 SOIL                           LEGEND

                    1 1 1 1 1 1 1 1 1 1 2
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                <=    0.0000

                                              0.0000 < 0 <=    0.0500
 1   4 3 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 3 4
 2   4 4 3 3 3 3 3 3 4 4 4 4 3 3 3 3 3 3 4 4      0.0500 < 1 <=    0.1000
 3   3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3
 4   3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3      0.1000 < 2 <=    0.1500
 5   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3
 6   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3      0.1500 < 3 <=    0.2000
 7   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3
 8   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3      0.2000 < 4 <=    0.2500
 9   3 3 3 3 3 3 4 4 4 4 4 4 4 4 3 3 3 3 3 3
10   3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3      0.2500 < 5 <=    0.3000
11   3 3 3 3 3 4 4 4 4 4 4 4 4 4 4 3 3 3 3 3
12   3 3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3 3      0.3000 < 6 <=    0.3500
13   3 3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3 3
14   3 3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3 3      0.3500 < 7 <=    0.4000
15   3 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 3
16   4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4      0.4000 < 8 <=    0.4500
17   4 4 4 4 4 4 4 4 5 5 5 5 4 4 4 4 4 4 4 4
18   4 4 4 4 5 5 5 5 5 5 5 5 5 5 5 5 4 4 4 4      0.4500 < 9 <=    0.5000
19   5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5
20   5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5      0.5000 < *

TOTAL =     211.0622  MM WATER
```

```
       ROOTS IN EACH CELL, TOTAL                                       DAY 150
           AT THE END OF RUTGRO

       UNITS - G/CM**3 SOIL                                          LEGEND

                           1 1 1 1 1 1 1 1 1 1 2
       1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                          <=   0.0000

                                                          0.0000 < 0 <=   0.0001
   1   2 2 2 1 1 1 1 0
   2   2 2 2 2 2 2 2 1 1 0                                0.0001 < 1 <=   0.0005
   3   3 3 3 3 2 2 2 2 1 1 0
   4   4 4 4 4 3 2 2 2 2 1 0 0                            0.0005 < 2 <=   0.0050
   5   5 5 5 4 4 3 2 2 2 1 0 0
   6   6 6 6 5 4 3 2 2 2 1 0                              0.0050 < 3 <=   0.0100
   7   6 7 6 5 4 3 2 2 2 1 0
   8   7 7 6 5 4 3 2 2 2 1 0                              0.0100 < 4 <=   0.0150
   9   7 7 6 5 4 3 2 2 2 1 0
  10   6 6 6 5 3 2 2 2 1 0 0                              0.0150 < 5 <=   0.0200
  11   5 5 4 4 3 2 2 2 1 0
  12   5 4 4 3 2 2 2 1 1 0                                0.0200 < 6 <=   0.0250
  13   4 4 3 2 2 2 2 1 0
  14   3 3 2 2 2 2 1 0 0                                  0.0250 < 7 <=   0.0300
  15   3 2 2 2 2 1 1 0
  16   2 2 2 2 1 1 0                                      0.0300 < 8 <=   0.0350
  17   2 2 2 1 1 0
  18   2 2 1 1 0                                          0.0350 < 9 <=   0.0400
  19   2 1 1 0 0
  20   1 1 0 0                                            0.0400 < *

       TOTAL =       1.0242  GM. DRY WEIGHT

       PSIS FOR EACH LAYER AND COLUMN                                  DAY 150
       AT THE END OF MAIN

       UNITS - CM**3/CM**3 SOIL                                      LEGEND

                           1 1 1 1 1 1 1 1 1 1 2
       1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0                          <= -15.0000

                                                        -15.0000 < 0 <= -10.0000
   1   6 3                                 3 6
   2   6 6 6 5 5 5 6 6 6 6 6 6 6 6 5 5 5 6 6 6          -10.0000 < 1 <=  -6.0000
   3   5 5 5 6 6 6 6 7 7 7 7 7 7 6 6 6 6 5 5 5
   4   5 5 5 5 5 6 6 7 7 7 7 7 7 6 6 5 5 5 5 5           -6.0000 < 2 <=  -3.0000
   5   5 5 5 5 5 6 6 7 7 7 7 7 7 6 6 5 5 5 5 5
   6   5 5 5 5 5 5 6 7 7 7 7 7 7 6 5 5 5 5 5 5           -3.0000 < 3 <=  -1.5000
   7   5 5 5 5 5 5 6 7 7 7 7 7 7 6 5 5 5 5 5 5
   8   5 5 5 5 5 5 6 7 7 7 7 7 7 6 5 5 5 5 5 5           -1.5000 < 4 <=  -1.0000
   9   5 5 5 5 5 6 6 7 7 7 7 7 7 6 6 5 5 5 5 5
  10   5 5 5 5 5 6 7 7 7 8 8 7 7 7 6 5 5 5 5 5           -1.0000 < 5 <=  -0.6000
  11   5 5 5 5 6 7 7 7 8 8 8 8 7 7 7 6 5 5 5 5
  12   5 5 5 6 6 7 7 8 8 8 8 8 8 7 7 6 6 5 5 5           -0.6000 < 6 <=  -0.4000
  13   3 5 5 6 7 7 8 8 8 8 8 8 8 8 7 7 6 5 5 3
  14   3 3 6 7 7 8 8 8 8 8 8 8 8 8 8 7 7 6 3 3           -0.4000 < 7 <=  -0.2000
  15   5 6 7 8 8 8 8 8 8 8 8 8 8 8 8 8 8 7 6 5
  16   7 7 8 8 8 8 9 9 9 9 9 9 9 9 8 8 8 8 7 7           -0.2000 < 8 <=  -0.1000
  17   8 8 8 8 9 9 9 9 9 9 9 9 9 9 9 9 8 8 8 8
  18   8 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 8           -0.1000 < 9 <=   0.0000
  19   9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9
  20   9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9            0.0000 < *

       TOTAL =      211.0622   MM WATER
  DAY SITES   SQRZ    GBZ     OBZ     ABZ MAINODES HEIGHT  LAI  FSTRES  PSIAVG
  150  114    0.00   12.26   16.83   0.00   25     139.48  0.65  0.18   -0.48
  151  114    0.00   12.26   16.83   0.00   25     139.84  0.64  0.16   -0.49
  152  114    0.00   12.26   16.83   0.00   25     140.20  0.60  0.11   -0.51
  153  114    0.00   12.26   16.83   0.00   25     140.58  0.59  0.01   -0.51
  154  114    0.00   12.26   16.83   0.00   25     140.94  0.59  0.07   -0.54
  155  114    0.00   12.26   16.83   0.00   25     141.29  0.59  0.09   -0.47
  156  114    0.00   12.26   16.83   0.00   25     141.64  0.50  0.09   -0.47
  157  114    0.00   11.75   17.34   0.00   25     141.99  0.42  0.07   -0.47
  158  114    0.00   11.75   17.34   0.00   25     142.34  0.42  0.05   -0.48
  159  114    0.00   11.75   17.34   0.00   25     142.69  0.38  0.08   -0.48
  160  114    0.00   11.75   17.34   0.00   25     143.04  0.38  0.10   -0.48
  161  114    0.00   11.75   17.34   0.00   25     143.40  0.36  0.06   -0.48
  162  114    0.00   11.75   17.34   0.00   25     143.75  0.36  0.05   -0.49
  163  114    0.00   11.75   17.34   0.00   25     144.11  0.28  0.04   -0.50
  164  114    0.00   11.75   17.34   0.00   25     144.47  0.28  0.02   -0.51
  165  114    0.00   11.75   17.34   0.00   25     144.84  0.28  0.05   -0.52
  166  114    0.00   11.75   17.34   0.00   25     145.21  0.28  0.02   -0.54
  167  114    0.00   11.75   17.34   0.00   25     145.57  0.23  0.04   -0.46
  168  114    0.00   11.75   17.34   0.00   25     145.95  0.20  0.02   -0.46
  169  114    0.00   11.75   17.34   0.00   25     146.32  0.20  0.01   -0.46
  170  114    0.00   11.75   17.34   0.00   25     146.70  0.20  0.00   -0.46

            YIELD BALES/ACRE   YIELD LBS/ACRE   YIELD KGS/HA
                 2.57             1285.58         1440.95
```

```
 39              I-O
 40           O-I
 41              I-O
 42           O-I
 43              I-O
 44           O-I
 45              I-O
 46        O-O-I
 47              I-O-O
 48        O-O-I
 49              I-O-O
 50        O-O-I
 51              I-O-O-O
 52     O-O-*-I
 53              I-*-O-O
 54   O-O-O-*-I
 55              I-$-O-*-O
 56   O-O-*-$-I                        O-I
 57              I-O-O-*-O-O              I-O                            I-O
 58 O-O-*-O-O-I                     O-O-I                             O-I
 59              I-$-O-*-O-O              I-*-O                          I-O-O
 60 O-O-$-O-$-I                  O-O-*-I                           O-*-I
 61              I-$-O-$-O-*              I-$-O-O-O                      I-*-O-O
 62 O-O-O-O-$-I             O-O-*-O-$-I                     O-*-O-$-I
 63              I-O-$-O-$-*              I-O-O-$-*-O                    I-$-O-*-O-O
 64              I                        I                              I
 65              I                        I                              I
 66              I                        I                              I
 67 END OF SEASON.
```

Initial Model Calibration and Some Tests of Reasonableness

GOSSYM was initially calibrated with the data from the AAA, ABB, ACC, and ADD treatments of the Bruce and Römkens (1965) experiment. This experiment was conducted in rainout shelters in Mississippi. The treatments ranged from moist soil conditions throughout the season (AAA) to droughty conditions from the time of first bloom (ADD). Their irrigation inputs and the resulting soil water potential for the AAA and ADD treatments are presented in Figure 35. The results from the ABB treatment have been presented earlier. All four treatments were simulated with the same program. The required input data are shown in Appendix B. Seasonal time courses for the ADD crop are presented in Figures 36 and 37. A slightly better simulation of the AAA crop was obtained than of the other treatments.

These results along with some validation results from Arizona (Fye et al. 1981) are presented in Table 3. About six cards from the source deck were changed to simulate the Arizona data. All of these changes pertained to the model's response to atmospheric demand for water, which, obviously, is radically different between Arizona and Mississippi. This points up the major area of the modelling effort requiring further research. It is not now general in its capability to simulate drought effects in the irrigated desert. Further validation efforts are now under way in Israel.

Generally, the model performs in a reasonable manner in response to changes in cultural and other environmental conditions. Several analyses using GOSSYM and demonstrating the reasonableness of its performance are presented in Baker et al. (1979b). One example in the area of pest management is presented here.

Developmental rates both of crops and pest populations are determined by climate. Both classes of systems are now being simulated and GOSSYM was designed from the outset for the purpose of pest management decision making. Crops with and without insects are simulated in Figure 38. Irrigation was applied on the same calendar dates in both simulations. An ovipositing boll weevil population with levels shown in Figure 39 (Jenkins (1980)) was imposed on the crop and allowed to remove 10 squares or young bolls per day. The fruit loss was included in a slightly modified form of the model. The insect damage caused an increase in vegetative growth, shown in the plant height and square data beginning 100 days from emergence. One manifestation of this extra growth was a more complete mining of water from the soil in the damaged crop. As expected, the results of the damage were reduced boll numbers and lint yields.

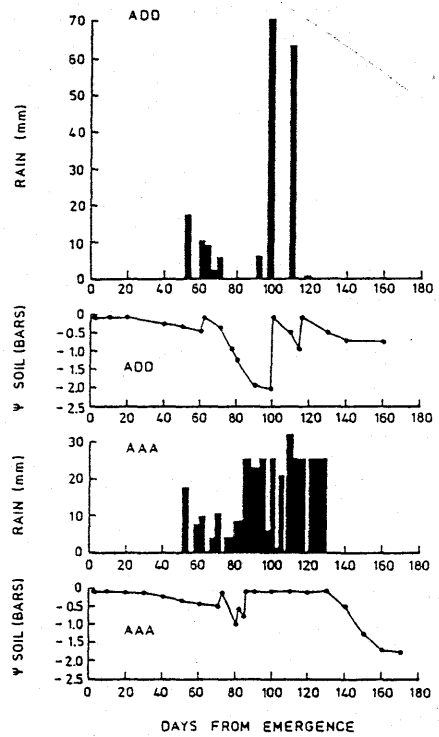


Figure 35. Rainfall inputs and simulated soil water potential (at 30 cm) values for the AAA and ADD treatments of the experiment of Bruce and Römkens (1965).

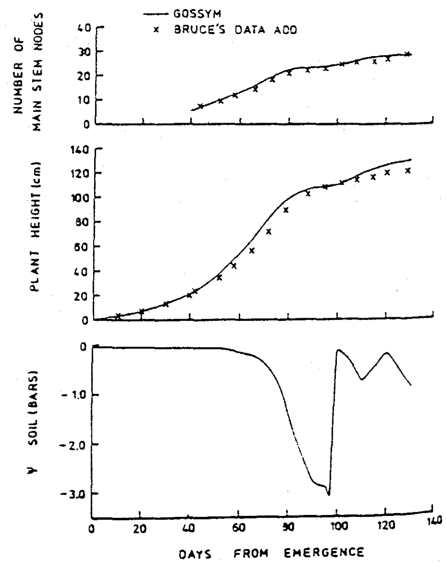


Figure 36. Simulated and real observations of mainstem node numbers, plant height, and simulated soil water potential (at 30 cm) in the ADD treatment of the Bruce and Römkens experiment (1965).

Table 3. Summary of GOSSYM validation results in terms of peak or end season number per plant.

Data Source	Mainstem Nodes	Fruiting Sites	Peak Squares	Bolls	(Kg/ha) Yield	(cm) Z
AAA[1]	30(32)	120(129)	62(57)	38(38)	1725(1723)	152(156)
ABB[1]	30(30)	111(102)	51(45)	27(24)	1467(1397)	140(128)
ADD[1]	29(29)	97(86)	45(43)	20(21)	1276(1316)	130(122)
76 T[2]	30(27)	102(102)	43(49)	50(33)	688(1060)	95(89)
76 U[2]	27(25)	65(63)	37(36)	15(16)	1224(1297)	81(83)

[1]Data of Bruce and Römkens (1965) (Mississippi). All treatments heavily fertilized. AAA = high moisture, ABB = moderate drought after first bloom and ADD = severe drought after first bloom.
[2]Data of Fye (Arizona commercial cotton). ( ) = Real crop observations.

Levels of insect damage generally depend on the developmental stage of the crop when the attack occurs, so in a series of "runs" with the Bruce-Römkens weather data we have varied planting dates. Crops with no insects are simulated in Figure 40. Irrigation was applied on the same dates in all of the simulations. The model predicted the typical decline in yield as the crop emergence date became later from April 29 to May 29.

The insect damage described above was inflicted on the same dates on the three crops in Figure 41. All crops were severely damaged. However, yield losses were slightly less severe in the later crops because of the declining insect populations. Whether or not such a population would decline in this way in the field depends on pest management practices, and on the attributes of the crop and pest systems.

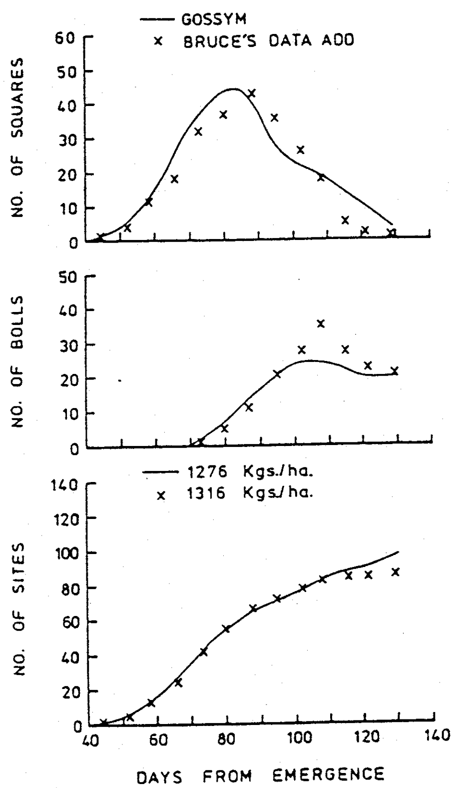


Figure 37. Simulated and real observations of numbers of squares, bolls, and fruiting sites in the Bruce and Römkens' ADD treatment (1965).

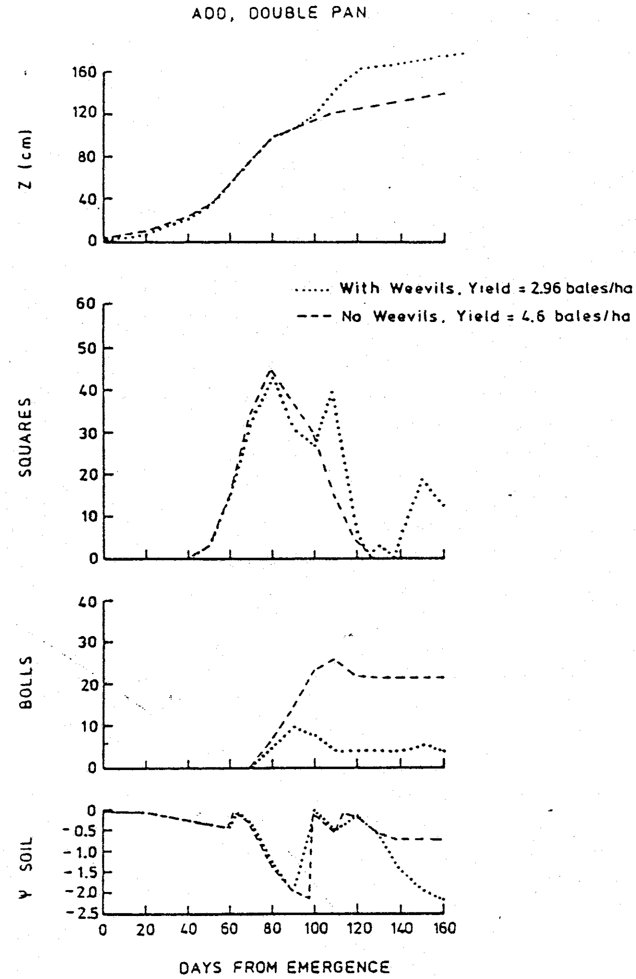


Figure 38. Model predictions of the effects of a boll weevil population on plant height development, numbers of squares and bolls, and on the seasonal time course of soil water potential in a season like that of the Bruce and Römkens' (1965) ADD treatment.

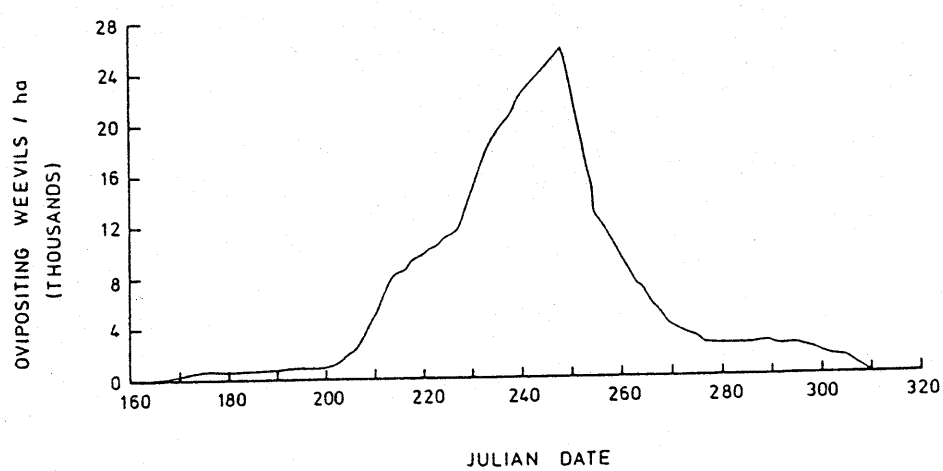


Figure 39. Seasonal time course of oviposition.

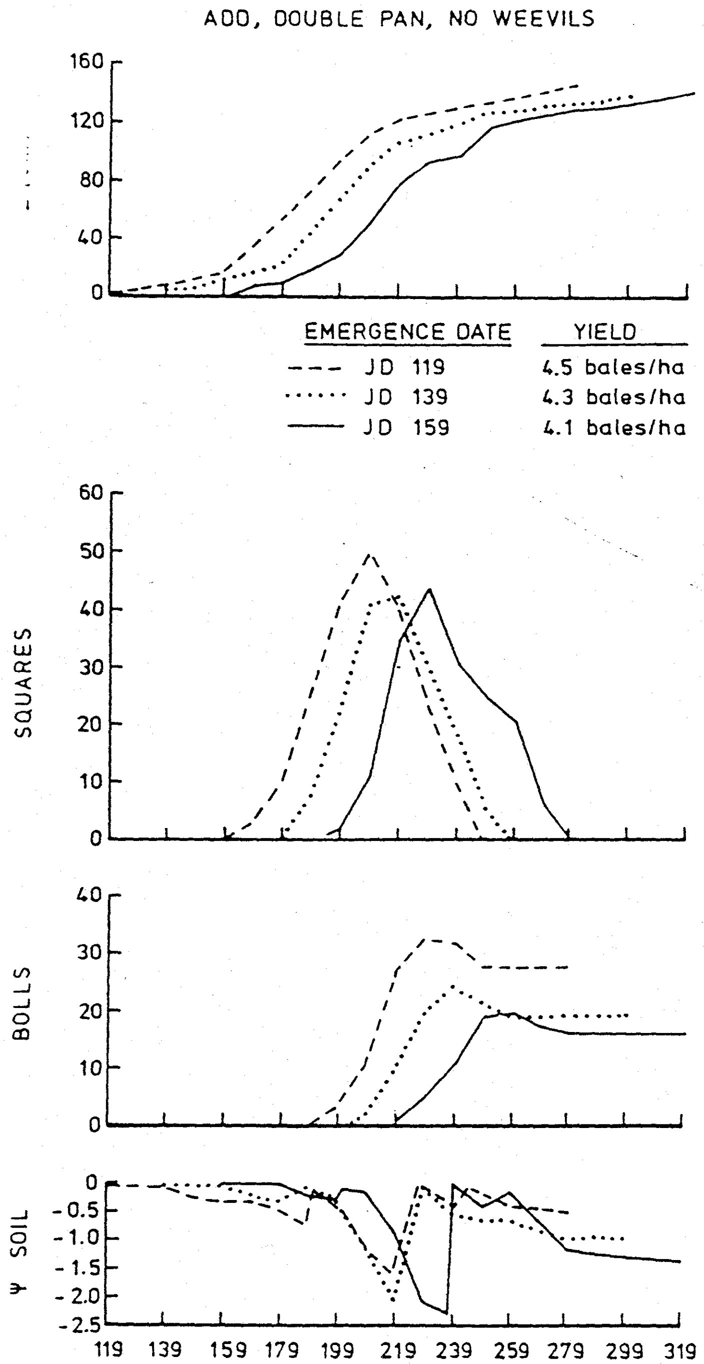


Figure 40. Model predictions of crop development as influenced by planting date in a year comparable to the ADD treatment of Bruce and Römkens (1965).

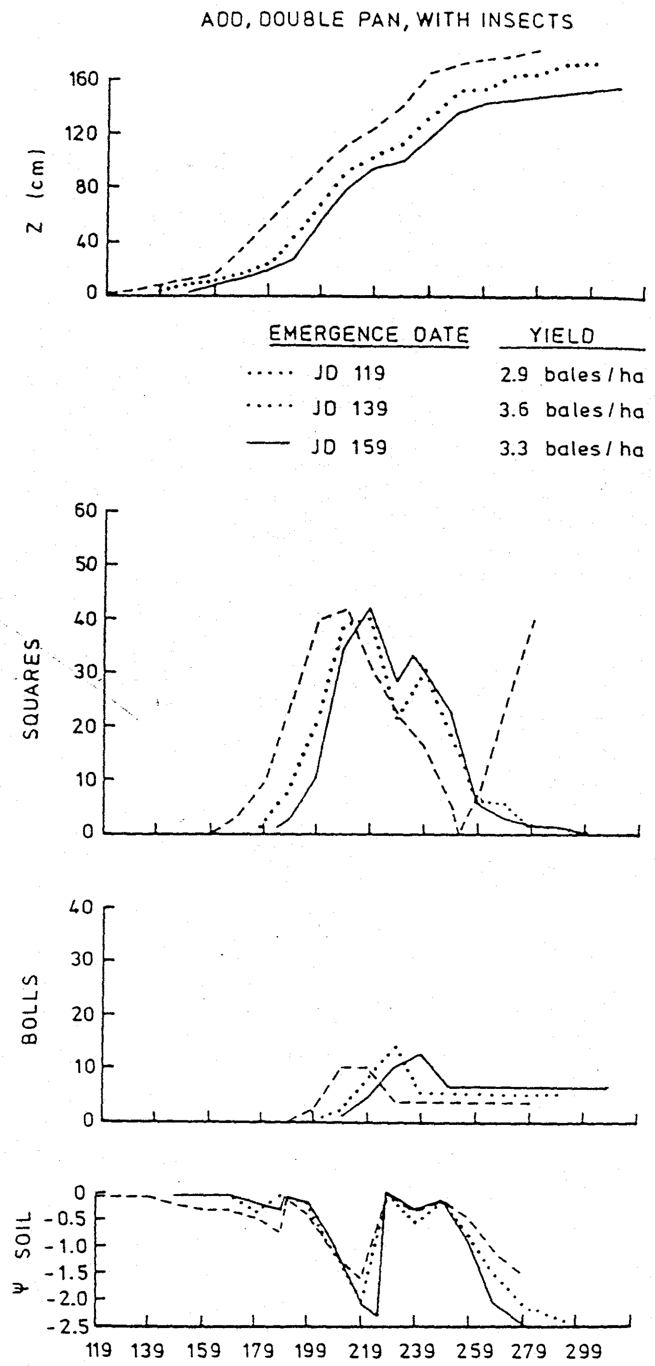


Figure 41. Model predictions of crop development as influenced by planting date in a year comparable (except that damage by a boll weevil population is assumed) to the ADD treatment of Bruce and Römkens (1965).

Conclusions and Future Research Needs

GOSSYM now simulates cotton growth and yield over a considerable range of climate and soil conditions. It has been validated against several commercially grown crops in Arizona (Fye et al. 1981) and against several others grown in the Mississippi Delta (Reddy 1981). The version which simulates the Arizona crops is slightly different from that simulating Mississippi cotton, i.e., about six source statements require some modification. All of these modifications relate to the impact of extremely low humidity on the physiology of the plant. This difference indicates the need for further research to extend present functional relationships and logic relative to water stress. SPAR research at Mississippi State in 1980 was designed to extend our information base on the effect of severe drought in a slowly developing drying cycle on photosynthesis and transpiration. Briefly, this experiment showed that cotton plants do not have the ability to osmoregulate to an extent that will have any significant effect on the decline in photosynthetic efficiency with drought. Rapid and continuous decline in canopy photosynthesis was observed over the entire range of the experiment, i.e. leaf water potentials ranging down to -26 bars. This decline was due in part to the effect of water stress on metabolite supply:demand ratios and morphogenesis, which resulted in the senescence of upper leaves in the canopy. These results will be built into later versions of GOSSYM.

Another area of model development needed to make GOSSYM and other plant models more general, especially in their capacity to simulate drought under a wider range of soil and climate conditions, is in the development of a mechanism oriented model of transpiration and leaf water potential to replace the (more empirical and therefore less general) Ritchie (1972) model in the RHIZOS section.

Marani et al. (1981) validated GOSSYM against 57 Acala cotton crops grown under a wide range of climatic conditions (19 locations) in Israel. Excellent results were obtained in about 80% of the cases with no change in the code for any of the crops.

Some of the crops in Israel for which good simulations were not obtained showed indications of insect damage, and of course, GOSSYM does not simulate damage unless it is read in as a time vector input. Indications of some insect damage affecting the fidelity of the simulations in the Arizona crops and (especially) in the Mississippi crops were also present. These facts and the fact that integrated pest management was one of the original objectives of the GOSSYM effort point to the need for research to incorporate pest simulation models. This capability will provide a package of research information of practical value in on-farm decision making.

Finally, research is needed to develop GOSSYM as a tool in cotton breeding programs. It has already proved useful (Landivar et al. 1981) in the identification and preliminary evaluation of certain characters and new combinations of characters in the breeding work at Mississippi State.

In conclusion, 12 years of research by several state and federal scientists have resulted in the creation of a model simulating growth and yield in cotton. This model is sufficiently general in character to be useful in the areas of pest, tillage, irrigation, and fertilizer management decision making at the farm level. A comparatively small further research investment is needed to make it a useful farm management tool. GOSSYM is a fairly comprehensive crop simulation model. It is not, however, in any of its parts, complicated. By today's standards it is quite compact and economical in terms of computer cost. Computers capable of handling this model already reside on many of today's larger farms.

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APPENDIX A
Source Listing

```
C  JAN,01,1982
C                         G O S S Y M
C
C   THIS PROGRAM FILE WAS CREATED BY MODIFYING THE JLAGOS GOSSYM FILE
C   CHANGES INCLUDE WATER STRESS TERM TO REDUCE PDWBOLL AS REPORTED IN
C   BAKER, D.N., J.A. LANDIVAR AND J.R. LAMBERT. 1979. DISCUSSION OF
C   PART 1. PRODUCTION OF FRUTING POINTS BY J.R. MAUNEY. IN PROC. OF
C   BELTWIDE COTTON RES CONFERENCE. THIS PROGRAM FILE WAS ALSO USED
C   FOR J.A. LANDIVAR MASTER THESIS, "THE APPLICATION OF THE COTTON
C   SIMULATION MODEL GOSSYM IN GENETIC FEASIBILITY STUDIES". MISS.
C   STATE UNIVERSITY. AUGUST 1979.
C
C
      BLOCK DATA
C ***********************************************************
C *                                                         *
C *   BLOCK DATA SUBPROGRAM.   USED FOR INITIALIZATION OF   *
C *   VARIABLES FOUND IN COMMON STATEMENTS.                 *
C *                                                         *
C ***********************************************************
C
      INTEGER DACNT, DAY, DAYINC, DAZE, FCODE, XTRES, YR, COUNT
     .        ,DAYABS, DAYNUM, SCODE, AGEBOL, BAGE
      REAL INT, LAREA, LATUDE, LEAFR, LEAFRS, LEAFR1, LAI, LEAFCN,
     .  LEAFW , LEAFWT, LEFABS, NF, NPLT, NOPEN, NSIDE, NV, LOSSQR
C
      COMMON /CALEN / DACNT(12), DAZE, MO, YR
      COMMON /CLIM  / CLIMAT(250,7)
      COMMON /CODES / FCODE(3,30,5), LCODE(3,30,5), SCODE(7), SITES,
     .                SITEZ
      COMMON /COM   / AREA, LAREA(3,30,5)
      COMMON /COM1  / EMERGE, KARDS, LAI, SEASON, VARITY, YIELD
      COMMON /CONS  / BURCN, ROOTCN, SEEDCN, STEMCN, LEAFCN
      COMMON /DAYOFF/ DAYABS(3,30,5), ISQ
      COMMON /DIFFU / DIFF(20,20)
      COMMON /DTDTDT/ DRAD(21), DTAH(21), DTAL(21)
      COMMON /EVTR  / EP, ES, SESI, SESII, T , NEWES , NEWEP
      COMMON /FACTOR/ DAYWTF, NYTWTF, DAYTYM, NYTTYM, DROOT, NROOT
      COMMON /FERT  / APDAY, DD, DR, FERN, FNH4, FNO3, NPLT, NSIDE,
     .                OMA, RNNH4, RNNO3
      COMMON /FIELD / FC(20)
      COMMON /FRUIT / COUNT, FLOSS, SFLOSS, PINHED, SQRZ, GBZ,
     .                NOPEN, ABZ, GBZ2
      COMMON /FRUTE / FFRUT(3,30,5), MCODE(3,30,5), SQLOSS(170),
     .                BOLOSS(170), SBLUM(170), LOSSQR(170)
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
      COMMON /INCRS / DAY, DAYINC, NDAYS
      COMMON /KLM   / AVGT(3,30,5), AVTEMP
      COMMON /LEAFAV/ FRATIO
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /LOST  / GBLOS, LEFABS, PQFLR, WTSLFD, XTRAC
      COMMON /MATR  / KRL(20), LR
      COMMON /NIT   / BURRN, ROOTN, SEEDN, SLEAFN, STEMN
      COMMON /NITLIZ/ VNH4C(4,20), VNC(4,20)
      COMMON /NUMS  / NFBR(3), NNOD(3,30), NVBRCH
      COMMON /PDGR  / PDBOLL, PDLEAF, PDRES, PDROOT, PDSQ, PDSTEM, RESC
      COMMON /PDKLM / PDADAY(3,30,5), PDANYT(3,30,5), PDWBOD(3,30,5),
     .                PDWBON(3,30,5),
     .                PDWLD(3,30,5), PDWLN(3,30,5), PDWSQ(3,30,5)
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /POP   / PN, POPFAC
      COMMON /POTN  / BURR, LEAFR, ROOTR, SEEDR, STEMR
      COMMON /PREFRT/ AGEPFN(9), AVTPFN(9), NUMPFN, PFAL(9), PFAREA,
     .                PFDAL, PFDALN(9), PFDWL, PFDWLD(9), PFDWLN(9),
     .                PFWL(9), PFDALD(9)
      COMMON /PS    / PSIS(20,20)
      COMMON /REQS  / BOLL1, BURMIN, BURR1, LEAFR1, REQ1, ROOTR1, SEEDR1
      COMMON /RESV  / F2, LEAFRS, RESN, ROOTRS, STEMRS
      COMMON /RUTDUM/ DUMMY0(1610)
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,20), RTWT(20,20,3)
      COMMON /SIZES / POPPLT, ROWSP, Z
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /SPD   / SPDWL, SPDWLD, SPDWLN, SPDWRT, SPDWSQ
      COMMON /STRESS/ CSTRES, NF, NSTRES, NV, WSTRSD, WSTRSN, XTRES,
     .                 STRSD, STRSN, VSTRES, FSTRES
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TIMKLM/ AGE(3,30,5), AGEBOL(3,30,5), DELAY(3,30),
     .                VDELAY(3), LAGE(3,30,5), BAGE(3,30,5)
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(4)
      COMMON /UPS   / SUPNO3, UPNO3
      COMMON /WEIGHT/ COTXX, GBOLWT, LEAFWT, PLANTW, ROOTWT,SQWT, STEMWT
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
      COMMON /WTKLM / BOLWGT(3,30,5), LEAFW(3,30,5), SQRWT(3,30,5),
     .                STMWT(170)
C
C  VARIABLES OF 1 CHARACTER
      DATA D/5./, G/5./, T/0./, W/5./, Z/.1/
C  VARIABLES OF 2 CHARACTERS
      DATA DD/0./, DR/0./, EP/0./, ES/0./,
     .     FC/20*.267/, F2/.5/, LR/3/, MO/1/, NK/20/, NL/20/,
     .     RI/0./, RN/0./, YR/74/
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C  VARIABLES OF 3 CHARACTERS
      DATA AGE/450*0./,DAY/1/,
     .      INT/0./, ISQ/0/, KRL/2,1,1,17*0/, LAI/0./,
     .      NPD/0/, NPN/0/, NPP/0/, NPR/0/, NPW/0/, OMA/600./, SLF/.02/,
     .      VNC/80*0./
C  VARIABLES OF 4 CHARACTERS
      DATA AREA/0./, AVGT/450*0./, BAGE/450*0/, BURR/0./,
     .      DAZE/0/,
     .      DIFF/400*258.3/, DAMP/.002/, FERN/20./, FNH4/0./, FNO3/1./,
     .      DRAD/21*500./, DTAH/21*80./, DTAL/21*60./,
     .      IDAY/1/, LAGE/450*0/, NFBR/3*0/, NFRQ/1/, NNOD/90*0/
      DATA PDSQ/0./, PFAL/.94284,8*0./, PFWL/.2,8*0./,
     .      PSIS/400*-.175/, REQ1/0./, RESC/.06/, RESN/0./,
     .      RTP1/.3/, RTP2/.1/, SESI/0./, SQRZ/0./,
     .      RTWT/1200*0./, SQWT/0./, TAVG/0./, TDAY/0./, TMAX/0./,
     .      TMIN/0./, TNYT/0./
C  VARIABLES OF 5 CHARACTERS
      DATA BOLL1/0./, BURCN/0./, BURRN/0./, BURR1/0./,
     .      CAPUP/0./, COTXX/0./, COUNT/0/, CUMEP/0./, CUMES/0./,
     .      DACNT/31,28,31,30,31,30,31,31,30,31,30,31/, DTAVG/7*20./,
     .      DELAY/90*0./, GBLOS/0./, FFRUT/450*0./,
     .      FCODE/450*0/, FLOSS/0.0/, LAREA/450*0.04/
      DATA LCODE/450*0/,MCODE/450*0/,LEAFR/0./, LEAFW/450*0./, NFRQX/0/,
     .      PDRES/0./, PDWLD/450*0./, PDWLN/450*0./, PDWSQ/450*0./,
     .      PQFLR/0./, NOPEN/0./,
     .      PFDAL/0./, PFDWL/0./, RCH2O/.0002/, ROOTN/.00450/,
     .      MH2O/0/, RNNH4/50./, RNNO3/10./
      DATA ROOTR/0./, ROOTS/0./, ROWSP/101.6/, SBLUM/170*0./, SEEDN/0./,
     .      SEEDR/0./, SESII/0./, SPDWL/0./, SQRWT/450*0./, SCODE/7*0/,
     .      SITES/0./, SITEZ/0./, STEMN/.0074/, STEMR/0./,THRLN/0.3E-4/,
     .      VH2OC/400*.267/,
     .      VNH4C/80*0./, VNO3C/400*0./, XTRAC/0./, XTRES/0/, YIELD/0./
C  VARIABLES OF 6 CHARACTERS
      DATA AGEBOL/450*0/, AGEPFN/9*0./, AVTEMP /20./, AVTPFN/9*0./,
     .      BOLWGT/450*0./, BOLOSS/170*0./, BURMIN/0./, CLIMAT/1750*0./,
     .      CSTRES/1./, CUMRAN/0./, CUMSOK/0./, DAYABS/450*0/, DAYINC/1/,
     .      DAYLNG/13./, DAYNUM/1/
      DATA GBOLWT/0./, LATUDE/35./,LEAFCN/.037/,LEAFRS/0./, LEAFR1/0./,
     .      LEFABS/0./, LEAFWT/.2/, LOSSQR/170*0./,
     .      NSTRES/1/, NUMPFN/1/, NVBRCH/1/, PDADAY/450*0./,
     .      PDANYT/450*0./, PDBOLL/0./, PDLEAF/0.0001/, PDROOT/.0001/,
     .      PDSTEM/.0001/, PDWBOD/450*0./, PFAREA/0./, PFDALN/9*0./,
     .      PDWBON/450*0./
      DATA PFDWLD/9*0./, PFDWLN/9*0./, PLANTW/0./, PINHED/0.0/,
     .      POPPLT/41000./, PSIAVG/-.175/, PSIMAX/-.175/, RCHOSS/0.0/,
     .      ROOTCN/.037/, ROOTRS/0./, ROOTR1/0./, ROOTSV/400*0./,
     .      ROOTWT/.200/, SEEDCN/0./, SFLOSS/0.0/, SQLOSS/170*0./,
     .      SLEAFN/.0074/, SPDWLD/0./
      DATA SPDWLN/0./, SPDWRT/0./, SPDWSQ/0./, STEMCN/.037/, STEMRS/0./,
     .      STEMWT/.2/, SUPNO3/0./, TSOILD/20*0./, TSOILN/20*0./,
     .      VDELAY/3*0./,
     .      TSOLAV/4*0./, WATTSM/0./, WSTRSD/1./, WSTRSN/1./, WTSLFD/0./
C  LEAF AREA & LEAF WEIGHT INITIALIZED ACCORDING TO COTYLEDON DATA
C  FOR 'M-8' COTTONOF CHRISTIANSEN, M. N. (1962) A METHOD OF
C  MEASURING AND EXPRESSING EPIGNEOUS SEEDLING GROWTH RATE.
C  CROP SCI. 2:487-488.
      END

      PROGRAM GOSSYM
C  ************************************************************
C  *                                                          *
C  *                     G O S S Y M                          *
C  *                                                          *
C  ************************************************************
      REAL INT,LEAFWT,LEAFR,LEAFRS,LEAFR1,LEAFW,LATUDE,LAREA,LAI
      REAL LEFABS, NV, NF, NPLT, NSIDE, NOPEN, MH2O
      INTEGER DAY,DAYABS,DAYINC,DAYNUM,DAZE,YR,FCODE,DACNT,XTRES
      INTEGER SCODE, AGEBOL
      INTEGER TTL1(10),TTL2(10),TTL3(10),TTL4(10),TTL5(10),TTL6(10),
     . UNITST(4),VNOUNI(6),VH2UNI(6),PSIUNI(6),DIFUNI(6),NITUNT(4)
      INTEGER TTL1R(10), TTL2R(10), UNITS(6), UNITSR(4)
      DIMENSION CAPSCA(11),PSISCA(11),VNOSCA(11),DIFSCA(11)
      DIMENSION ROOSCA(11), ID(18)
C
      COMMON /CALEN / DACNT(12), DAZE, MO, YR
      COMMON /CALIB / CZD, CZN, CSQ, CBL, CL, CM, CPF, CVB,DPSMX,DPBMX
      COMMON /CAL2  / XTR1, XTR2, XTR3, XTR4, A1, A21, A22, A31, A32
      COMMON /CLIM  / CLIMAT(250,7)
      COMMON /CODES / FCODE(3,30,5), LCODE(3,30,5), SCODE(7), SITES,
     .                SITEZ
      COMMON /COM   / AREA, LAREA(3,30,5)
      COMMON /COM1  / EMERGE, KARDS, LAI, SEASON, VARITY, YIELD
      COMMON /CONS  / BURCN, ROOTCN, SEEDCN, STEMCN, LEAFCN
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /DAYOFF/ DAYABS(3,30,5), ISQ
      COMMON /DIFFU / DIFF(20,20)
      COMMON /DTDTDT/ DRAD(21), DTAH(21), DTAL(21)
      COMMON /EVTR  / EP, ES, SESI, SESII, T , NEWES , NEWEP
      COMMON /FERT  / APDAY, DD, DR, FERN, FNH4, FNO3, NPLT, NSIDE,
     .                OMA, RNNH4, RNNO3, LASTAP
      COMMON /FIELD / FC(20)
      COMMON /FRUIT / COUNT, FLOSS, SFLOSS, PINHED, SQRZ, GBZ,
     .                NOPEN, ABZ, GBZ2
      COMMON /FRUTE / FFRUT(3,30,5), MCODE(3,30,5), FRLOS(170)
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
      COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
      COMMON /INCRS / DAY, DAYINC, NDAYS
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 404  FORMAT('  FREQUENCY OF ',I2,' DAYS. '/' ENTER 1 UNDER THE FIRST ',
     . 'LETTER OF EACH PLOT YOU WISH TO SEE.'/
     . ' TOPS ROOTS PSIS VH2OC DIFF VNO3C ')
      READ(2,409) NPC, NPR, NPP, NPW, NPD, NPN
      WRITE(3,406) NPC, NPR, NPP, NPW, NPD, NPN
 406  FORMAT(1X,I1,4X,I1,5X,I1,4X,I1,5X,I1,4X,I1)
 409  FORMAT(I1,4X,I1,5X,I1,4X,I1,5X,I1,4X,I1)
      WRITE(4,410)
 410  FORMAT(1X,'XTR1 XTR2 XTR3 XTR4 A1   A21  A22  A31  A32')
      READ(2,411) XTR1,XTR2,XTR3,XTR4,A1, A21,A22, A31, A32
 411  FORMAT(9F5.2)
      WRITE(3,410)
      WRITE(3,600) XTR1,XTR2,XTR3,XTR4,A1,A21,A22,A31,A32
 600  FORMAT(9F5.2)
      WRITE(4,407)
 407  FORMAT(1X,'CZD  CZN  CSQ  CBL  CL   CM   CPF  CVB  DPSMXDPBMX')
      READ(2,408) CZD, CZN, CSQ, CBL, CL, CM, CPF, CVB, DPSMX, DPBMX
 408  FORMAT(10F5.2)
      WRITE(3,407)
      WRITE(3,601) CZD,CZN,CSQ,CBL,CL,CM,CPF,CVB,DPSMX,DPBMX
 601  FORMAT(10F5.2)
      NFRQX = NFRQ
      POPFAC = 404685.6/POPPLT
      RTWT(1,1,1) = .045 / POPFAC
      RTWT(2,1,1) = .027 / POPFAC
      RTWT(3,1,1) = .018 / POPFAC
      RTWT(1,2,1) = .009 / POPFAC
      IF(CLIMAT(1,7).EQ.EMERGE) GO TO 16
      II = 1
      DO 15 I=1,KARDS
        IF(CLIMAT(I,7).LT.EMERGE) GO TO 15
        CLIMAT(II,1) = CLIMAT(I,1)
        CLIMAT(II,2) = CLIMAT(I,2)
        CLIMAT(II,3) = CLIMAT(I,3)
        CLIMAT(II,4) = CLIMAT(I,4)
        CLIMAT(II,5) = CLIMAT(I,5)
        CLIMAT(II,6) = CLIMAT(I,6)
        CLIMAT(II,7) = CLIMAT(I,7)
        II = II + 1
  15  CONTINUE
 16   CONTINUE
      NDAYS = IFIX(SEASON)
      DO 998 DAY=1,NDAYS
      MH2O = CLIMAT(DAY,4)
      IDAY = DAY
      CALL CLYMAT
C CLYMAT CALLS TMPSOL & DATE
      IF(DAY.EQ.1) AVTPFN(1) = TAVG
      CALL SOIL
C SOIL CALLS FRTLIZ, GRAFLO, ET, UPTAKE, CAPFLO, NITRIF.
      CALL PNET
      SPN = SPN + PN
      IF(NFRQX.EQ.IDAY) WRITE(3,1004)SPN,PN,ES,EP,RI,RN,TAVG,TDAY,TNYT
 1004 FORMAT(/,'  SPN       PN        ES        EP        RI        RN        TAVG     '
     .,'  TDAY     TNYT',/,1X,9(F6.2,2X))
      CALL GROWTH
C GROWTH CALLS RUTGRO
      CALL PLTMAP
      PLANTW = ROOTWT + STEMWT + GBOLWT + LEAFWT + SQWT + XTRAC + COTXX
     . + RESC
      IF(NFRQX.NE.IDAY.AND.IDAY.NE.1) GO TO 8011
 5    DEAD = LEFABS + PQFLR + GBLOS + (WTSLFD * POPFAC * 2.)
C  WTSLFD DOUBLED TO ACCOUNT FOR FULL PROFILE.
      WRITE(3,751)DAY,MO,DAZE,YR,CSTRES,NSTRES,WSTRSD,WSTRSN,TNNO3,TNNH4
 751  FORMAT('   DAY     DATE     CSTRES  NSTRES  WSTRSD  WSTRSN    TNNO3
     .TNNH4'/,3X,I3,3X,I2,'-',I2,'-',I2,1X,F5.3,5X,I1,5X,F5.3,3X,F5.3,
     .3X,F6.2,1X,F6.2)
      H2OBAL = TH2O - CUMRAN - CAPUP + CUMEP + CUMES + CUMSOK
      WRITE (3,500) TH2O,CUMRAN,CAPUP,CUMES,CUMEP,CUMSOK,H2OBAL,LAI
 500  FORMAT('  TH2O    CUMRAN  CAPUP   CUMES   CUMEP   CUMSOK  H2OBAL',
     . '    LAI'/,1X,7(F6.2,2X),F5.2)
      WRITE(3,752) Z,PLANTW,LEAFWT,STEMWT,ROOTWT,SQWT,GBOLWT,DEAD,XTRAC
 752  FORMAT('  HEIGHT  WEIGHT  LEAFWT  STEMWT  ROOTWT  SQARWT  GBOLWT '
     . ,'  DEADWT  XTRAC ',/1X,F6.2,1X,5(F7.3,1X),1X,3(F7.3,1X)/)
      IF(FCODE(1,1,1).NE.0.AND.NPC.EQ.1) CALL COTPLT
      IF(NPN.EQ.1) CALL OUT(VNO3C,TTL5,TTL3,VNOSCA,
     .  VNOUNI,TNNO3,NITUNT,1)
      IF(NPW.EQ.1) CALL OUT(VH2OC,TTL1,TTL3,CAPSCA,
     .  VH2UNI,TH2O,UNITST,1)
      IF(NPR.EQ.1) CALL OUT(ROOTSV,TTL1R,TTL2R,
     .  ROOSCA,UNITS,ROOTS,UNITSR,1)
      IF(NPP.EQ.1) CALL OUT(PSIS,TTL4,TTL3,PSISCA,
     .  VH2UNI,TH2O,UNITST,1)
      WRITE(3,1003)
      IF(NFRQX.EQ.IDAY)NFRQX = IDAY + NFRQ
      DAYINC = NFRQX
8011  CONTINUE
      NSITES = IFIX(SITEZ)
      NBR = NFBR(1) + NUMPFN
      WRITE(3,1002)
     .DAY,NSITES,SQRZ,GBZZ,NOPEN,ABZ,NBR,Z,LAI,FSTRES,PSIAVG
 1002 FORMAT(2(2X,I3),4(2X,F5.2),2X,(I2),4X,F6.2,2(2X,F4.2),2X,F6.2)
 1003 FORMAT('  DAY SITES  SQRZ   GBZ    OBZ    ABZ MAINODES HEIGHT  LAI
     . FSTRES  PSIAVG')
      YLBSAC = YIELD * 500.0
      YKGSHA = YLBSAC * 1.12085
C YLBSAC = LINT YIELD IN LBS PER ACRE
```

```
      COMMON /KLM    / AVGT(3,30,5), AVTEMP
      COMMON /LEAFAV/ FRATIO
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /LOST  / GBLOS, LEFABS, PQFLR, WTSLFD, XTRAC
      COMMON /MATR  / KRL(20), LR
      COMMON /NIT   / BURRN, ROOTN, SEEDN, SLEAFN, STEMN
      COMMON /NITLIZ/ VNH4C(4,20), VNC(4,20)
      COMMON /NUMS  / NFBR(3), NNOD(3,30), NVBRCH
      COMMON /PDGR  / PDBOLL, PDLEAF, PDRES, PDROOT, PDSQ, PDSTEM, RESC
      COMMON /PDKLM / PDADAY(3,30,5), PDANYT(3,30,5), PDWBOD(3,30,5),
     .                PDWBON(3,30,5),
     .                PDWLD(3,30,5), PDWLN(3,30,5), PDWSQ(3,30,5)
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /POP   / PN, POPFAC
      COMMON /POTN  / BURR, LEAFR, ROOTR, SEEDR, STEMR
      COMMON /PREFRT/ AGEPFN(9), AVTPFN(9), NUMPFN, PFAL(9), PFAREA,
     .     PFDAL(9), PFDALN(9), PFDWL(9), PFDWLD(9), PFDWLN(9), PFWL(9)
      COMMON /PS    / PSIS(20,20)
      COMMON /REQS  / BOLL1, BURMIN, BURR1, LEAFR1, REQ1, ROOTR1, SEEDR1
      COMMON /RESV  / F2, LEAFRS, RESN, ROOTRS, STEMRS
      COMMON /RUTDUM/ DUMMY0(1610)
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,20), RTWT(20,20,3)
      COMMON /SIZES / POPPLT, ROWSP, Z
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /SPD   / SPDWL, SPDWLD, SPDWLN, SPDWRT, SPDWSQ, SPDWBO
      COMMON /STRESS/ CSTRES, NF, NSTRES, NV, WSTRSD, WSTRSN, XTRES,
     .                STRSD, STRSN, VSTRES, FSTRES
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TIMKLM/ AGE(3,30,5), AGEBOL(3,30,5), DELAY(3,30),
     .                VDELAY(3), LAGE(3,30,5), BAGE(3,30,5)
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(4)
      COMMON /UPS   / SUPNO3, UPNO3
      COMMON /WEIGHT/ COTXX, GBOLWT, LEAFWT, PLANTW, ROOTWT,SQWT, STEMWT
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
      COMMON /WTKLM / BOLWGT(3,30,5), LEAFW(3,30,5), SQRWT(3,30,5),
     .                STMWT(170)
C
      DATA ROOSCA/0.0,.0001,.0005,.005,.01,.015,.02,.025,.03,.035,.04/
      DATA TTL1R/'ROOT','S IN',' EAC','H CE','LL, ','TOTA','L   ',
     . '    ','    ','    '/
      DATA TTL2R/'    ','AT T','HE E','ND O','F RU','TGRO','    ',
     . '    ','    ','    '/
      DATA UNITS/'G/CM','**3 ','SOIL','    ','    ','    '/
      DATA UNITSR/' GM.',' DRY',' WEI','GHT '/
      DATA LPLOT /5/
      DATA  ISTOP/0/
      DATA TTL1/'VOLU','METR','IC W','ATER',' CON','TENT',' OF ',
     . 'SOIL','    ','    '/
      DATA TTL2/'AT T','HE B','EGIN','NING',' OF ','CAPF','LO  ',
     . '    ','    ','    '/
      DATA TTL3/'AT T','HE E','ND O','F MA','IN  ','    ','    ',
     . '    ','    ','    '/
      DATA TTL4/'PSIS',' FOR',' EAC','H LA','YER ','AND ','COLU',
     . 'MN  ','    ','    '/
      DATA TTL5/'VOLU','METR','IC N','ITRA','TE C','ONTE','NT O',
     . 'F SO','IL  ','    '/
      DATA TTL6/'DIFF','USIV','ITY ','OF S','OIL ','    ','    ',
     . '    ','    ','    '/
      DATA PSISCA/-15.,-10.,-6.,-3.,-1.5,-1.,-.6,-.4,-.2,-.1,0./
      DATA VNOSCA/0.0,.01,.02,.03,.04,.05,.06,.07,.08,.09,.1/
      DATA DIFSCA/1.,10.,100.,200.,400.,1000.,2000.,4000.,6000.,8000.,
     . 10000./
      DATA PSIUNI/' BAR','S   ','    ','    ','    ','    '/
      DATA VNOUNI/' MG/','N PE','R CM','**3 ','    ','    '/
      DATA VH2UNI/'CM**','3/CM','**3 ','SOIL','    ','    '/
      DATA UNITST/' MM ','WATE','R   ','    '/
      DATA CAPSCA/0.0,.05,.1,.15,.2,.25,.3,.35,.4,.45,.5/
      DATA DIFUNI/' CM*','*2/D','AY  ','    ','    ','    '/
      DATA NITUNT/' MG ','N   ','    ','    '/, SPN /0./
C
C
      CALL READ
      WRITE(4,394)
      WRITE(3,394)
  394 FORMAT(' ENTER RUN IDENTIFICATION')
      READ(2,393)ID
      WRITE(3,397)ID
  397 FORMAT(1X,18A4)
  393 FORMAT(18A4)
      WRITE(4,401)
      WRITE(3,401)
  401 FORMAT(' ENTER NOITR -  I1 FORMAT ')
      READ(2,403) NOITR
  403 FORMAT(I1)
      WRITE(3,399) NOITR
  399 FORMAT(1X,I2)
      WRITE(4,400)
      WRITE(3,400)
  400 FORMAT(' ENTER FREQUENCY INTEGER.  I2 FORMAT. ')
      READ(2,402) NFRQ
      WRITE(3,398) NFRQ
  398 FORMAT(1X,I2)
  402 FORMAT(I2)
      DAYINC = NFRQ
      WRITE(4,404) NFRQ
      WRITE(3,404) NFRQ
```

```
C YKGSHA = LINT YIELD IN KGS PER HA.
      IF(DAY.EQ.NDAYS.AND.YIELD.GT.0.0)
     .WRITE(3,501)YIELD,YLBSAC,YKGSHA
  501 FORMAT(/,11X,' YIELD BALES/ACRE    YIELD LBS/ACRE   YIELD KGS/HA',/,
     .17X,F4.2,13X,F7.2,8X,F7.2,/)
      IF(LPLOT.NE.IDAY)GO TO 3
      BOLLS = GBZ2 + NOPEN
      DIA = FLOAT(IDAY)
      NODES = NFBR(1) + NUMPFN
      BRANCH = FLOAT(NODES)
      IF(DIA.LT.150.) WRITE(9,30)DIA,SQRZ,BOLLS,SITEZ,BRANCH,Z
 30   FORMAT(6F10.2)
      LPLOT = IDAY + 2
    3 CONTINUE
  998 CONTINUE
      CALL COTPLT
      WRITE(3,1050)
 1050 FORMAT(' END OF SEASON. ')
      STOP
      END

      SUBROUTINE CLYMAT
C   ***********************************************************
C   *                                                         *
C   *                  CLIMATE SUBROUTINE                     *
C   *                                                         *
C   ***********************************************************
      REAL INT,LATUDE,MAXMIN,MH2O,LAI,LMAX
      INTEGER DAY, DAYINC, DAZE, YR, DACNT, DAYABS, DAYNUM
C
      COMMON /CALEN / DACNT(12), DAZE, MO, YR
      COMMON /CALIB / CZD, CZN, CSQ, CBL, CL, CM, CPF, CVB,DPSMX,DPBMX
      COMMON /COM1  / EMERGE, KARDS, LAI, SEASON, VARITY, YIELD
      COMMON /CLIM  / CLIMAT(250,7)
      COMMON /DTDTDT/ DRAD(21), DTAH(21), DTAL(21)
      COMMON /INCRS / DAY, DAYINC, NDAYS
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /SIZES / POPPLT, ROWSP, Z
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(4)
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
      COMMON /PS    / PSIS(20,20)
      DATA LMAX/0./
C
      POLYNA = 1.
C  POLLINATION SWITCH DEPENDS ON RAIN.
      RI     = CLIMAT(DAY,1)
      TMAX   = (CLIMAT(DAY,2)-32.) * .5555556
      TMIN   = (CLIMAT(DAY,3)-32.) * .5555556
      RAIN   = CLIMAT(DAY,5) * 25.4
      DAYNUM = CLIMAT(DAY,7)
      WATTSM = RI * .8942
      RN = WATTSM * .8 - 26.
C NET RADIATION IN WATTS/M**2
      MAXMIN=TMAX-TMIN
      TDAY=.55*MAXMIN+TMIN
      TNYT=.15*MAXMIN+TMIN
C  CONVERTS MAX & MIN TEMPS TO DAYTIME & NIGHTIME AVERAGES FOR
C  MISSISSIPPI STATE.  ]]] MUST BE CHECKED FOR OTHER LOCATIONS.]]]
      POLYNA = 1.
      IF(RAIN.GE.12.7.AND.MH2O.EQ.0.) POLYNA = 0.
      DUMY01 = 0.38366 + LATUDE * (0.018457 + 0.001086*LATUDE)
      DUMY02 = 12.1824 + LATUDE * (-0.004851 + 0.0001172*LATUDE)
      DAYLNG = DUMY01 * SIN(DAYNUM*0.0172-1.61165) + DUMY02
C
      CALL DATES
C
      TAVG=(TDAY*DAYLNG+TNYT*(24.-DAYLNG))/24.
      INT = (1.0756*Z/ROWSP)
  100 CONTINUE
C  INT = FRACTION OF INCIDENT LIGHT INTERCEPTED BY PLANT CANOPY.
C  BAKER ET. AL. CANOPY ARCHITECTURE IN RELATION TO YIELD.
C  CHAPTER 3 IN 'CROP PHYSIOLOGY' ED. V. S. GUPTO.
      IF(INT.LT.0.) INT = 0.
      IF(INT.GE.1.) INT = 1.
      IF(LAI.GT.LMAX)LMAX = LAI
      IF(LAI.GT.(LMAX-.20))GO TO 20
      IF(INT.GE.1..AND.LAI.LT.2.9)INT = INT * LAI/2.9
   20 CONTINUE
      IF(INT.LT.0.) INT = 0.
      IF(INT.GE.1.) INT = 1.
C
      CALL TMPSOL
C
      RETURN
      END
```

```
      SUBROUTINE DATES
C   *********************************************************
C   *                                                       *
C   *   DATE SUBROUTINE.  CONVERTS JULIAN TO CALENDAR AND   *
C   *    ALLOWS FOR LEAP YEARS.                             *
C   *                                                       *
C   *********************************************************
      REAL LATUDE
      INTEGER DAZE,DACNT,YR,DAYNUM
C
      COMMON /CALEN / DACNT(12), DAZE, MO, YR
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
C
      DACNT(2) = 28
      IYR = YR/4
      IF(YR.EQ.IYR*4) DACNT(2) = 29
      MO = 1
      DAZE = DAYNUM
      DO 1 I=1,12
      IF(DAZE.LE.DACNT(I)) GO TO 2
      MO = MO + 1
      DAZE = DAZE - DACNT(I)
  1   CONTINUE
  2   CONTINUE
      RETURN
      END

      SUBROUTINE TMPSOL
C*********************************************************
C   THIS SUBROUTINE CALCULATES A TEMPERATURE PROFILE IN THE*
C SOIL. ASSUMES HORIZONTAL HOMOGENEITY OF TEMPERATURE &    *
C DISREGARDS MOISTURE CONTENT EFFECTS.                     *
C FIRST, MAXIMUM (H) & MINIMUM (L) TEMPERATURES ARE        *
C CALCULATED AT 2, 4, 8, & 16 INCH DEPTHS BY MULTIPLE      *
C REGRESSION EQUATIONS OF                                  *
C J. C. MCWHORTER & B. P. BROOKS, JR.  1965. CLIMATOLOGICAL*
C AND SOLAR RADIATION RELATIONSHIPS. BULL. 715, MISS.      *
C AGRI. EXP. STA., STARKVILLE.                             *
C NOTE THAT THE GRID SIZE (D*W) IS NOT VARIABLE IN THIS    *
C SUBROUTINE, BUT THE LAYER THICNESS IS FIXED AT 5 CM.     *
C   MAX & MIN SOIL TEMPS FOR EACH OF THE LAYERS ARE THEN   *
C OBTAINED BY INTERPOLATION & EXTRAPOLATION OF THE 2, 4,   *
C 8, & 16 INCH TEMPS.                                      *
C    FINALLY, DAYTIME AND NIGHTIME TEMPS(TSMX & TSMN)      *
C ARE OBTAINED AS AVERAGE HOURLY VALUES FROM 7 A.M. THRU   *
C SUNSET, & SUNSET THRU 7 A.M., RESPECTIVELY, USING AN     *
C ALGORITHM FOR AIR TEMP PUBLISHED BY H. N. STAPLETON,     *
C D. R. BUXTON, F. L. WATSON, D. J. NOLTING, AND D         *
C D. N. BAKER.  UNDATED.  COTTON: A COMPUTER SIMULATION OF *
C COTTON GROWTH.  TECH. BULL. 206, ARIZONA AGRI. EXP. STA. *
C TUCSON.                                                  *
C*********************************************************
      REAL INT,LATUDE
      DIMENSION TSMX(20), TSMN(20), RECDAT(24)
C
      COMMON /DTDTDT/ DRAD(21), DTAH(21), DTAL(21)
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(4)
C
      DO 1 I = 1,6
      J = 8 - I
      JM1 = J - 1
    1 DTAVG(J) = DTAVG(JM1)
      DTAVG(1) = TAVG
      WTAVG = 0.
      DO 2 J = 1,7
    2 WTAVG = WTAVG +  DTAVG(J)
      WTAVG = WTAVG/7.
      WTAVGF = WTAVG*1.8 + 32.
C THE NEXT EIGHT EQUATIONS ARE FROM MCWHORTER AND BROOKS.
        T2H  = 1.1962*WTAVGF + 0.27389
        T2L  = 0.960*WTAVGF + 1.4404
        T4H  = 1.1493*WTAVGF + 1.1452
        T4L  = 0.9126*WTAVGF + 2.9961
        T8H  = 0.9655*WTAVGF + 8.3121
        T8L  = 0.8700*WTAVGF + 7.9217
        T16H = 0.8409*WTAVGF + 13.988
        T16L = 0.8341*WTAVGF + 13.029
C GET TEMP OF SOIL ( MAX ) BY INTERPOLATION OR EXTRAPOLATION.
      T24 = T2H - T4H
      T48 = T4H - T8H
      TSMX(1) = T2H + (.507874) * T24
      TSMX(2) = T4H + (.523622) * T24
      TSMX(3) = T8H + (.769685) * T48
      TSMX(4) = T8H + (.277559) * T48
      T816 = .0492126 * (T8H - T16H)
      DO 6 I=5,20
        TSMX(I) = T8H - (2.18+(I-5)*5.) * T816
  6   CONTINUE
C GET TEMP OF SOIL (MIN) BY INTERPOLATION OR EXTRAPOLATION.
      T24 = T2L - T4L
      T48 = T4L - T8L
      TSMN(1) = T2L + (.507874) * T24
      TSMN(2) = T4L + (.523622) * T24
```

```
      TSMN(3) = T8L + (.769685) * T48
      TSMN(4) = T8L + (.277559) * T48
      T816 = .0492126 * (T8L - T16L)
      DO 7 I=5,20
        TSMN(I) = T8L - (2.18+(I-5)*5.) * T816
        IF(TSMN(I).LT.TSMX(I)) GO TO 7
        TSMN(I) = (TSMN(I) + TSMX(I))/2.
        TSMX(I) = TSMN(I)
 7    CONTINUE
      DO 8 I=1,20
C CONVERT TEMPS TO CENTIGRADE.
        TSMX(I) = (TSMX(I)-32.)*.555556
        TSMN(I) = (TSMN(I)-32.)*.555556
 8    CONTINUE
      ISR = 12 - IFIX(DAYLNG*.5)
      ISS = ISR + IFIX(DAYLNG+0.5)
C HOUR OF SUNSET.
C SEE PP 37 OF STAPLETON, ET AL. FOR EQUATIONS DETERMINING RECDAT.
      DO 9 LAYER = 1,20
      TMEAN = (TSMX(LAYER)+TSMN(LAYER)) * .5
      SWINGH = (TSMX(LAYER)-TSMN(LAYER)) * .5
      DO 11 IH=7,15
      RECDAT(IH) = TMEAN - SWINGH*COS(0.3927*(IH-7.))
      IH9 = IH + 9
      RECDAT(IH9) = TMEAN + SWINGH*COS(0.19635*(IH9-15.))
 11   CONTINUE
      DO 12 IH=1,6
 12   RECDAT(IH) = TMEAN - SWINGH*COS(0.19635*(6-IH))
      SHRTD = 0.
      SHRTN = 0.
      DO 13 IH=7,ISS
      SHRTD = SHRTD + RECDAT(IH)
C SUM OF HOURLY TEMPS IN DAYTIME.
 13   CONTINUE
      TSOILD(LAYER) = SHRTD/(ISS-6)
C AVERAGE TEMP OF SOIL DURING DAYTIME, DEG C.
      ISS1 = ISS + 1
      DO 14 IH=ISS1,24
      SHRTN = SHRTN + RECDAT(IH)
C SUM OF HOURLY TEMPS IN NIGHTIME.
 14   CONTINUE
      DO 15 IH=1,6
      SHRTN = SHRTN + RECDAT(IH)
 15   CONTINUE
      TSOILN(LAYER) = SHRTN/(30-ISS)
C AVERAGE TEMP OF SOIL DURING NIGHTIME.
 9    CONTINUE
      DO 16 LAYER = 1, 4
      TSOLAV(LAYER)= (TSOILD(LAYER)*DAYLNG+TSOILN(LAYER)*(24.-DAYLNG))
     . /24.
C AVERAGE SOIL TEMPERATURE, DEG C.
 16   CONTINUE
      RETURN
      END

      SUBROUTINE SOIL
C  **********************************************************
C  *                                                        *
C  *    SOIL SUBROUTINE.  CALLS FRTLIZ, GRAFLO, ET,         *
C  *      UPTAKE, CAPFLO, AND NITRIF.                       *
C  *                                                        *
C  **********************************************************
      REAL INT, NPLT, NSIDE , NEWES , NEWEP
C
      COMMON /DIFFU / DIFF(20,20)
      COMMON /EVTR  / EP, ES, SESI, SESII, T , NEWES , NEWEP
      COMMON /FERT  / APDAY, DD, DR, FERN, FNH4, FNO3, NPLT, NSIDE,
                      OMA, RNNH4, RNNO3
      COMMON /FIELD / FC(20)
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
      COMMON /MATR  / KRL(20), LR
      COMMON /NITER / ITER
      COMMON /NITLIZ/ VNH4C(4,20), VNC(4,20)
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /POP   / PN, POPFAC
      COMMON /PS    / PSIS(20,20)
      COMMON /RUTDUM/ DUMMY0(1610)
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,20), RTWT(20,20,3)
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(4)
      COMMON /UPS   / SUPNO3, UPNO3
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
      NAPDAY = IFIX(APDAY)
      IF(IDAY.EQ.1) FERN = NPLT
      IF(IDAY.EQ.NAPDAY) FERN = NSIDE
      IF(FERN.LE.2.) GO TO 2

      IF(IDAY.GT.1) GO TO 3
      CALL FRTLIZ
      WRITE(3,1000) VNO3C(1,1)
 1000 FORMAT(' VNO3C(1,1) = ',F10.4)
C  ALL FERTILIZER IS NO3.
      GO TO 2
```

```
 3     OMA = 0.
       DR = 4.
       DD = 3.
       RNNO3 = 0.
       RNNH4 = 0.
       CALL FRTLIZ
C   ************************ BRUCE CONDITIONS ###################
       IF(IDAY.GT.56)GO TO 2
       APDAY = APDAY + 28.
C   ************************ BRUCE CONDITIONS ###################
C   ########### REMOVE FOR NORMAL RUNS ###########################
 2     CONTINUE
C
       IF(RAIN.GT.0.) CALL GRAFLO
C
       CALL ET
C
       SUPNO3 = 0.
C
       DO 10 ITER=1, NOITR
       CALL UPTAKE
       IF(UPNO3.GT.0.) SUPNO3 = SUPNO3 +  UPNO3
       CALL CAPFLO
 10    CONTINUE
       CUMEP = CUMEP + NEWEP
       CUMES = CUMES + NEWES
C
       SUPNO3 = SUPNO3 * POPFAC * .001
C
       DO 11 N=1, NOITR
       CALL CAPFLO
 11    CONTINUE
       CALL NITRIF
C
       RETURN
       END

       SUBROUTINE FRTLIZ
C****************************************************************
C SUBROUTINE ADDS FERTILIZER TO PROFILE. MUST BE CALLED AT      *
C PLANTING DATE TO INITIALIZE NITROGEN & ORGANIC MATTER         *
C PROFILE.  MAY BE CALLED FOR SIDE DRESSING.  INPUTS ARE:       *
C FERN:  FERTILIZER INORGANIC NITROGEN, LBS N/ACRE.             *
C FNH4:  FRACTION OF INORGANIC N  IN AMMONIA FORM. 0 TO 1       *
C FNO3:  FRACTION OF INORGANIC N  IN NITRATE FORM. 0 TO 1       *
C DR:  DISTANCE TO RIGHT OF ROW OF BAND OF FERTILIZER, INCHES.  *
C      EQUALS 0 IF BROADCAST.                                   *
C DD:  DISTANCE BELOW SOIL SURFACE OF BAND OF FERTILIZER,       *
C      INCHES.  IGNORED IF DR = 0.                              *
C OMA:  ORGANIC MATTER PLOWED AT BEGINNING OF SEASON, LBS/ACRE, *
C       MUST BE .GT. 0 TO INITIALIZE N & ORGANIC MATTER ARRAYS. *
C RNNO3: RESIDUAL N  AS NITRATE IN UPPER 20 CM, LBS/ACRE.       *
C RNNH4: RESIDUAL N AS AMMONIUM IN UPPER 20 CM, LBS/ACRE.       *
C****************************************************************
C
       COMMON /FERT  / APDAY, DD, DR, FERN, FNH4, FNO3, NPLT, NSIDE,
      .                OMA, RNNH4, RNNO3
       COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
       COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
       COMMON /NITLIZ/ VNH4C(4,20),VNC(4,20)
       WRITE(3,1000)
 1000  FORMAT('  FERTILIZER SUBROUTINE CALLED  ################## ')
       IF(OMA.LE.0.) GO TO 2
C OMA .GT. 0. IMPLIES INITIAL FERTILIZATION AT PLANTING DATE &
C PLOWDOWN OF ORGANIC MATTER.
       DO 3 L=1 , 4
       DO 3 K=1 ,NK
       VNC(L,K) =OMA * 5.6E-4 * .01
       VNO3C(L,K) = RNNO3 * 5.6E-4
       VNH4C(L,K) = RNNH4 * 5.6E-4
  3    CONTINUE
  2    CONTINUE
       IF(DR.GT.0.0)GO TO 4
C DR .GT. 0.BANDED FERTILIZER APPLICATION. OTHERWISE BROADCAST
C AND MIXED INTO UPPER 20 CM OF SOIL.
       DUMY08 = FERN * FNO3 * 5.6E-4
       DUMY09 = FERN * FNH4 * 5.6E-4
       DO 5 LAYER  = 1, 4
       DO 5 KOLUMN = 1,20
       VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + DUMY08
C      ADDITION OF BROADCAST NITRATE FERTILIZER.
       VNH4C(LAYER,KOLUMN) = VNH4C(LAYER,KOLUMN) + DUMY09
C ADDITION OF BROADCAST AMMONIUM FERTILIZER.
 5     CONTINUE
       FERN = 0.
       RETURN
 4     LAYER = 1 + (DD*2.54)/D
       KOLUMN = 1 + (DR*2.54)/W
C IDENTIFIES CELL IN WHICH BAND IS PLACED.
       VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + FERN*FNO3*1.12/(D*W)
C ADDITIONOF BANDED NITRATE FERTILIZER TO CELL.
       VNH4C(LAYER,KOLUMN) = VNH4C(LAYER,KOLUMN) + FERN*FNH4*1.12/(D*W)
C ADDITION OF BANDED AMMONIUM FERTILIZER TO CELL.
       FERN = 0.
       RETURN
       END
```

```
      SUBROUTINE GRAFLO
C  ***********************************************************
C  *                                                         *
C  *   GRAVITY FLOW OF NO3 AND H2O, AFTER RAIN OR IRRIGATION. *
C  *                                                         *
C  ***********************************************************
C RAIN OR IRRIGATION IS IN MM.
      DIMENSION SOAKW(21), SOAKN(21)
C WATER SOAKING INTO LAYER.
C NITROGEN SOAKING INTO LAYER BY MASS FLOW OF H2O.
C
      COMMON /FIELD / FC(20)
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
C
C VH2OC: VOLUMETRIC WATER CONTENT, CM**3/CM**3.
C FC:  FIELD CAPACITY, BY LAYER, CM**3/CM**3.
C VNO3C: VOLUMETRIC NITROGEN CONTENT AS NITRATE, MG N/CC SOIL.
C D:  DEPTH OF SOIL CELL, CM.
C NL: NUMBER OF LAYERS IN PROFILE.
C NK: NUMBER OF COLUMNS IN PROFILE.
      CUMRAN = CUMRAN + RAIN
      TSOAK = 0.
      DO 2 KOLUMN = 1, NK
      SOAKW(NL+1) = 0.
      SOAKW(1) = RAIN*.10
C H2O SOAKING INTO TOP LAYER, IN CM**3/CM**2.
      SOAKN(1) = 0.
C NITROGEN SOAKING INTO LAYER, IN MG/CM**2.
C IF NITROGEN IN RAINFALL IS TO BE ADDED, DO IT HERE.
      DO 3 LAYER = 1, NL
      H2O = SOAKW(LAYER) + VH2OC(LAYER,KOLUMN)*D
C TOTAL TEMPORARY AND RESIDUAL VOLUME OF H2O IN SOIL
C CELL, IN CM**3/CM**2.
      SOAKW(LAYER+1) = AMAX1(0., H2O-FC(LAYER)*D)
C H2O SOAKING INTO LAYER BENEATH, IN CM**3/CM**2.
      SOAKN(LAYER+1) = AMAX1(0.,SOAKW(LAYER+1)*(VNO3C(LAYER,KOLUMN) /
     .(VH2OC(LAYER,KOLUMN)+SOAKW(LAYER)/D)))
C NITROGEN SOAKING INTO LAYER BENEATH, IN MG/CM**2.
 3    CONTINUE
      TSOAK = TSOAK + SOAKW(NL+1)
C      WRITE (3,810) IDAY,KOLUMN,TSOAK
C  810 FORMAT(' IDAY=',I3,' KOL=',I2,' TSOAK=',F10.4)
      DO 4 LAYER = 1, NL
      IF(SOAKW(LAYER).LE.0.) GO TO 4
C WHEN SOAKW .LT. 0, NO GRAVITY PERCOLATION OCCURS.
      VH2OC(LAYER,KOLUMN) = VH2OC(LAYER,KOLUMN) + (SOAKW(LAYER) -
     . SOAKW(LAYER+1))/D
C VOLUMETRIC MOISTURE CONTENT OF SOIL CELL, IN CM**3/CM**3.
      VNO3C(LAYER,KOLUMN) = AMAX1(0.,VNO3C(LAYER,KOLUMN)+(SOAKN(LAYER)
     .-SOAKN(LAYER+1))/D)
C VOLUMETRIC NITROGEN CONTENT OF SOIL CELL, IN MG/CM**3.
 4    CONTINUE
 2    CONTINUE
      CUMSOK = CUMSOK + 10.*TSOAK/FLOAT(NK)
      RETURN
      END

      SUBROUTINE ET
C  ***********************************************************
C  *                                                         *
C  *             EVAPOTRANSPIRATION SUBROUTINE               *
C  *                                                         *
C  ***********************************************************
C SUBROUTINE TAKEN ALMOST ENTIRELY FROM RITCHIE, A MODEL
C  FOR PREDICTING EVAPORATION FROM A ROW CROP WITH INCOMPLETE COVER.
C  WATER RESOURCES RESEARCH VOL. 8:1204.
C
      REAL LAMDAC, LAMDAS, LAMDA, INT
C
      COMMON /EVTR  / EP, ES, SESI, SESII, T , NEWES , NEWEP
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
C
      DATA W/44./, LAMDAC/.23/, LAMDAS/.80/, U/6./,ALPHA/3.5/,
     .     GAMMA/.653/, TD/0./, TW/0./
      VP(TMP) = EXP(1.8282+TMP*(0.07046136-TMP*0.000215743))
      P = RAIN
      RS = RI*.0169491525
C RS = SOLAR RADIATION IN MM H2O/DAY.
      TAVM1 = TAVG-1.
      DEL = VP(TAVG) - VP(TAVM1)
C DEL=SLOPE OF SATURATION VAPOR PRESSURE CURVE AT MEAN AIR TEMP.
      LAMDA = INT*LAMDAC + (1.-INT)*LAMDAS
C LAMDAC & LAMDAS = ALBEDOS OF CROP & SOIL.
C INT=INTERCEPTION (FRACTION OF INCIDENT RS)
C RNO=NET RADIATION ABOVE CANOPY (MM/DAY)
      RNO=(RS-LAMDA*RS)
C TD & TW = DRY AND WET BULB TEMPERATURES.
      TD = TAVG
      VPO = VP(TD)
      TW = TMIN
```

```
C EO=POTENTIAL EVAPORATION RATE ABOVE CANOPY (MM/DAY)
C MODIFIED PENMAN EQ.
C W=WINDSPEED AT 2 METERS (MILES/DAY)
C GAMMA=PSYCHROMETER CONSTANT
      VPA = VP(TW)
      EO=(RNO*DEL/GAMMA+.262*(1.+0.0061*W)*(VPO-VPA))/(DEL/GAMMA+1.)
C THE FOLLOWING CALCULATES ESO(POTENTIAL EVAP. RATE AT SOIL SURFACE1
C RNS=NET RADIATION AT SOIL SURFACE BELOW CANOPY
      RNS=((1.-INT)-(1.-INT)*LAMDAS)*RS
      ESO=DEL*RNS/(DEL+GAMMA)
C STAGE I DRYING
C SESI=CUMULATIVE STAGE ONE EVAPORATION FROM SOIL SURFACE
C U=UPPER LIMIT OF SESI
      IF(SESI.GT.U)GOTO 100
C P=RAINFALL
      IF(P.GE.SESI)GOTO 101
      SESI=SESI-P
99    SESI=SESI+ESO
      IF(SESI.GE.U)GOTO 102
      ES=ESO
      GOTO 110
102   ES=ESO-.4*(SESI-U)
      SESII=.6*(SESI-U)
      DUMY01 = SESII / ALPHA
      T = DUMY01 * DUMY01
      GO TO 110
101   SESI=0.
      GO TO 99
C STAGE II DRYING
100   IF(P.GE.SESII)GO TO 103
      T=T+1.
      ES = ALPHA * (SQRT(T)-SQRT(T-1.))
      IF(P.GT.0.)GO TO 104
      IF(ES.GT.ESO)GO TO 105
106   SESII=SESII+ES-P
      DUMY02 = SESII / ALPHA
      T = DUMY02 * DUMY02
      GO TO 110
105   ES=ESO
      GO TO 106
104   ESX=0.8*P
      IF(ESX.LT.ES)GO TO 107
111   IF(ESX.GT.ESO)GO TO 108
109   ES=ESX
      GO TO 106
108   ESX=ESO
      GO TO 109
107   ESX=ES+P
      GO TO 111
103   P=P-SESII
      SESI=U-P
      IF(P.GT.U)GO TO 101
      GO TO 99
C TRANSPIRATION IS PROPORTIONAL TO LIGHT INTERCEPTION (INT).
C  THIS REPRESENTS A MODIFICATION TO RITCHIE'S MODEL.
110   EP=INT*EO
      IF(EP.GT.(EO-ES))EP=EO-ES
      E = ES + EP
      AVGPSI = -1. * PSIAVG
      IF(AVGPSI.GT.9.0) AVGPSI = 9.0
      RN = RI*.71536-26.
C  RFEP = REDUCTION FACTOR FOR EVAPORATION FROM PLANT.  BASED ON
C  UNPUBLISHED DATA OF BAKER & HESKETH. 1969.
      RFEPN = 749.5831405 + 0.9659065*RN - 54.6600986*TAVG
     . - 194.6508431*AVGPSI - 0.0010226*RN*RN + 1.0153007*TAVG*TAVG +
     . 29.775978*AVGPSI*AVGPSI + 0.0293687*RN*TAVG
     . - 4.206856*TAVG*AVGPSI
      RFEPD = 749.5831405 + 0.9659065*RN
     . - 54.6600986*TAVG - 19.46508431 - 0.0010226*RN*RN +
     . 1.0153007*TAVG*TAVG + .29775978 + 0.0293687*RN*TAVG
     . - .4206856*TAVG
      RFEP = RFEPN/RFEPD
      IF(RFEP.LE.0.0) RFEP = 0.01
      EP = EP * RFEP
      RETURN
      END

      SUBROUTINE UPTAKE
C*************************************************************
C   UPTAKE OF WATER FROM EACH SOIL CELL IS PROPORTIONAL TO *
C THE PRODUCT OF ROOT WEIGHT CAPABLE OF UPTAKE AND THE     *
C HYDRAULIC CONDUCTIVITY OF THE CELL.  THE SUM OF THE      *
C UPTAKE FROM THE CELLS EQUALS TRANSPIRATION.  ALL NO3 IN  *
C THE WATER TAKEN UP BY THE ROOTS IS ALSO TAKEN UP.        *
C*************************************************************
C EP - TRANSPIRATION BY PLANTS, MM/DAY.
C SUPNO3 - SUPPLY OF NITRATE FROM SOIL, MG.
      DIMENSION DUMAY(800)
      REAL INT , NEWES , NEWEP
C UPF - UPTAKE FACTOR, GM CM/DAY.
C ROOT WEIGHT CAPABLE OF UPTAKE, GM/CELL.
C
      COMMON /DIFFU / DIFF(20,20)
      COMMON /EVTR  / EP, ES, SESI, SESII, T , NEWES , NEWEP
      COMMON /FIELD / FC(10)
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
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      COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
      COMMON /MATR  / KRL(20), LR
      COMMON /NITER / ITER
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /PS    / PSIS(20,20)
      COMMON /RUTDUM/ RTWTCU(20,20), UPF(20,20), DUMMY0(810)
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,20), RTWT(20,20,3)
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /UPS   / SUPNO3, UPNO3
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
C
C
      EQUIVALENCE(RTWTCU(1,1),DUMAY(1))
      DATA NEWDAY/0/
      DELT = 1. / NOITR
      DUMY01 = (.10*NK*W*EP)*DELT
      DUMY02 = D * W
      NKES = IFIX((1.-INT)*FLOAT(NK))
      IF(NKES.LT.2) NKES = 2
      K1 = (NK-NKES)/2
      IF(K1.LT.1) K1 = 1
      K2 = NK-K1+1
      ADJES = ES*FLOAT(NK)/FLOAT((K2-K1))
C ES REMOVED FROM KOLUMNS NOT SHADED BY CANOPY
      FWU = (ADJES*W*.10) * DELT
      DUMY03 = FWU / DUMY02
      DO 8 I=1,800,2
      DUMAY(I) = 0.
 8    DUMAY(I+1) = 0.
      IF (IDAY.GT.NEWDAY) GOTO 11
      IF (IDAY.EQ.NEWDAY) GOTO 14
   11 NEWDAY=IDAY
      SUMES=0.
      SUMEP=0.
   14 CONTINUE
      KINT=K2-K1
      DO 7 KOLUMN = K1,K2
      IF (DUMY03.GT.VH2OC(1,KOLUMN)-.25*FC(1)) DUMY03=
     *          VH2OC(1,KOLUMN)-.25*FC(1)
      ADJDUM=(DUMY03*DUMY02)/(W*.1)
      VH2OC(1,KOLUMN) = VH2OC(1,KOLUMN) - DUMY03
  7   CONTINUE
      SUMES=SUMES+ADJDUM
      IF (ITER.EQ.NOITR) NEWES=SUMES/FLOAT(NK)*FLOAT(KINT)
      DO 1 LAYER  =1, LR
      KR = KRL(LAYER)
      DO 1 KOLUMN =1, KR
      RTWTCU(LAYER,KOLUMN) = (RTWT(LAYER,KOLUMN,1) +
     .  .20*(RTWT(LAYER,KOLUMN,2)+RTWT(LAYER,KOLUMN,3)))
C SUMS THE WEIGHT OF ROOTS 15 DAYS OLD OR LESS IN CELL.
 1    CONTINUE
      DO 4 LAYER  = 1, LR
      KR = KRL(LAYER)
      DO 4 KOLUMN = 1, KR
      RTWTCU(LAYER,KOLUMN) = RTWTCU(LAYER,KOLUMN) +
     .  RTWTCU(LAYER,NK-KOLUMN+1)
C ADDS THE ROOTS GROWN BY THE PLANTS IN THE NEXT ROW TO GET
C THE TOTAL WEIGHT OF ROOTS CAPABLE OF UPTAKE.
 4    CONTINUE
      NKH = NK/2
      SUPF = 0.
      DO 5 LAYER  = 1, LR
      KR = KRL(LAYER)
      IF (KR.GT.NKH) KR=NKH
      DO 5 KOLUMN = 1, KR
      UPF(LAYER,KOLUMN)=RTWTCU(LAYER,KOLUMN)*DIFF(LAYER,KOLUMN)
C UPTAKE FACTOR FOR EACH CELL, HAS UNITS OF GM CM/DAY.
  99  SUPF = SUPF + UPF(LAYER,KOLUMN)
C SUM OF UPTAKE FACTORS IN THE PROFILE.  USED FOR APPORTIONING
C UPTAKE AMONG CELLS.
 5    CONTINUE
      UPNO3 = 0.
      SN = 0.
      SH =0.
      DO 6 LAYER  = 1, LR
      KR = KRL(LAYER)
      IF (KR.GT.NKH) KR=NKH
      DO 6 KOLUMN = 1, KR
      UPTH2O = (UPF(LAYER,KOLUMN)/SUPF) * DUMY01 / 2.
      H2OUPT=UPTH2O/DUMY02
C UPTAKE OF WATER FROM EACH CELL, CM**3/DAY.
C EP HAS UNITS OF MM/DAY.
      IF (H2OUPT.GT.VH2OC(LAYER,KOLUMN)-.001) H2OUPT=
     *          VH2OC(LAYER,KOLUMN)-.001
      UPTH2O=H2OUPT*DUMY02
      VH2OC(LAYER,KOLUMN)=VH2OC(LAYER,KOLUMN)-H2OUPT
      SUMEP=SUMEP+H2OUPT
   10 CONTINUE
C VOLUMETRIC WATER CONTENT OF CELL IS DECREASED BY AMOUNT
C OF UPTAKE FROM CELL.
      IMGKOL = NK - KOLUMN + 1
C           IMAGE COLUMN, MIRRORED ABOUT CENTERLINE OF PLANE.
      VH2OC(LAYER,IMGKOL) = VH2OC(LAYER,IMGKOL) - H2OUPT
      SUMEP=SUMEP+H2OUPT
C           VOLUMETRIC WATER CONTENT OF IMAGE CELL IS ALSO REDUCED.
      UPNO3C = UPTH2O*(VNO3C(LAYER,KOLUMN)/VH2OC(LAYER,KOLUMN))
```

```
C UPTAKE OF NO3 FROM CELL, MG N/DAY.
C ALL NO3 IN WATER UPTAKE STREAM IS TAKEN UP.
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) - UPNO3C/DUMY02
C VOLUMETRIC NITRATE CONTENT OF CELL IS DECREASED BY AMOUNT OF
C UPTAKE FROM CELL, MG N/CC SOIL.
      UPNO3 = UPNO3 + UPNO3C
C SUM OF UPTAKE OF NITROGEN AS NITRATE FROM THE SOIL PROFILE,
C MG FOR THE DAY.
      SH = SH + UPTH2O
      SN = SN + UPNO3C
      UPNO3I = UPTH2O*(VNO3C(LAYER,IMGKOL)/VH2OC(LAYER,IMGKOL))
C            UPTAKE OF NO3 FROM IMAGE CELL, MG N/DAY.
      VNO3C(LAYER,IMGKOL) = VNO3C(LAYER,IMGKOL) - UPNO3I/DUMY02
C VOLUMETRIC NITRATE CONTENT OF IMAGE CELL IS ALSO DECREASED.
      UPNO3 = UPNO3 + UPNO3I
 6    CONTINUE
      NEWEP=SUMEP*D/NK*10.
      RETURN
      END

      SUBROUTINE CAPFLO
C   ************************************************************
C   *                                                          *
C   *  CAPILLARY FLOW OF NO3 AND H2O IN ALL DIRECTIONS.        *
C   *                                                          *
C   ************************************************************
C APPROPIATE UNITS CONVERSION HAVE NOT BEEN MADE IN COMMENTS
C AFTER ITERATIONS DURING THE DAY HAVE BEEN ADDED.
      DIMENSION DUMAY1(1270)
C FLUX OF H2O TO THE LEFT OUT OF THE CELL, CM**3/CELL/DAY.
C FLUX OF H2O UPWARD OUT OF THE CELL, CM**3/CELL/DAY.
C FLUX OF NITROGEN TO THE LEFT OUT OF THE CELL, MG N/CELL/DAY.
C FLUX OF NITROGEN UPWARD OUT OF THE CELL, MG N/CELL/DAY.
C
      COMMON /DIFFU / DIFF(20,20)
      COMMON /FIELD / FC(20)
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SIF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
      COMMON /PS    / PSIS(20,20)
      COMMON /RUTDUM/ FNL(20,21), FNU(21,20), FWL(20,11), FWU(21,10),
     .                DUMMY0(340)
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
C
      EQUIVALENCE( FNL(1,1),DUMAY1(1)), (FNU(1,1),DUMAY1(421))
      EQUIVALENCE(FWL(1,1),DUMAY1(841)), (FWU(1,1),DUMAY1(1061))
      DO 860 I=1,1270,2
      DUMAY1(I) = 0.0
860   DUMAY1(I+1) = 0.0
      DELT = .5 / NOITR
      NKH = NK/2
C ASSUME NO FLOW ACROSS VERTICAL BOUNDARY DUE TO SYMMETRY,
C UNDER ROW AND MIDWAY BETWEEN ROWS.
C ASSUME NO FLUX INTO ROOT ZONE FROM BENEATH.
      DO 4 LAYER  = 1, NL
      DO 4 KOLUMN = 1, NKH
      IF(PSIS(LAYER,KOLUMN).LT.0.) GO TO 10
      WRITE(3,200) PSIS(LAYER,KOLUMN)
200   FORMAT(' PSIS .GE. 0.     = ',F11.5)
10    COND = .0005161*(-PSIS(LAYER,KOLUMN))**(-3.97)
      DPSIDT = (-1520.0Q)*(-39.7/EXP(39.7*VH2OC(LAYER,KOLUMN)))
      DIFF(LAYER,KOLUMN) = COND*DPSIDT*1017.
      IF(DIFF(LAYER,KOLUMN).LT.1.) DIFF(LAYER,KOLUMN) = 1.
      IF(DIFF(LAYER,KOLUMN).GT.1.E4) DIFF(LAYER,KOLUMN) = 1.E4
C UNSATURATED HYDRAULIC CONDUCTIVITY, IN CM/DAY.
C FOR HOUSTON CLAY. SEE RITCHIE ET. AL. (1972).  DRYLAND EVAPORATIVE
C  FLUX IN A SUBHUMID CLIMATE. III. SOIL WATER INFLUENCE.
C  AGRON. JOUR. 64:172. FIG. 5 .
 4    CONTINUE
      DUMY01 = D * DAMP * DELT
      DO 5 LAYER  = 1, NL
      DO 5 KOLUMN = 2, NKH
C ONLY LEFT HALF OF MATRIX IS NECESSARY DUE TO SYMMETRY.
      FWL(LAYER,KOLUMN) = ((DIFF(LAYER,KOLUMN)+DIFF(LAYER,KOLUMN-1))
     ./2.)*((VH2OC(LAYER,KOLUMN)-VH2OC(LAYER,KOLUMN-1))/W) * DUMY01
C FLOW OF WATER TO THE LEFT, OUT OF CELL, CM**3/CELL/DAY.
C SIMPLY DARCY'S LAW USING MEAN CONDUCTIVITY.
      FNL(LAYER,KOLUMN) = FWL(LAYER,KOLUMN)*VNO3C(LAYER,KOLUMN)/
     . VH2OC(LAYER,KOLUMN)
C FLOW OF NO3 TO THE LEFT, OUT OF CELL, MG N/CELL/DAY.
C MASS FLOW OF NO3 IN H2O, GM/CELL.
 5    CONTINUE
C MUST LOOK AT RIGHT-HAND HALF OF PLANE SEPARATELY FOR NITROGEN
C DUE TO SIDE DRESSING BEING NON-SYMMETRICAL.
      NKHP2 = NKH + 2
      DO 1 KOLUMN = NKHP2, NK
      NKK = NK + 1 - KOLUMN
      DO 1 LAYER  = 1, NL
    1 FNL(LAYER,KOLUMN) = (-FWL(LAYER,NKK)*VNO3C(LAYER,KOLUMN)/
     .   VH2OC(LAYER,KOLUMN))
      DO 6 LAYER  = 2, NL
      DO 6 KOLUMN = 1,NKH
      FWU(LAYER,KOLUMN) = ((DIFF(LAYER,KOLUMN)+DIFF(LAYER-1,KOLUMN))/
     . 2.)*((VH2OC(LAYER,KOLUMN)-VH2OC(LAYER-1,KOLUMN))/D)*W*DAMP
     .  * DELT
C FLOW OF WATER UPWARD, OUT OF CELL, CM**3/CELL/DAY.
C SIMPLY DARCY'S LAW USING MEAN CONDUCTIVITY.
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      FNU(LAYER,KOLUMN) = FWU(LAYER,KOLUMN)*VNO3C(LAYER,KOLUMN)/
     . VH2OC(LAYER,KOLUMN)
C FLOW OF NO3 UPWARD IN THE WATER, MG N/CELL/DAY.
 6    CONTINUE
      NKHP1 = NKH + 1
      DO 3 KOLUMN = NKHP1, NK
      NKK = NK + 1 - KOLUMN
      DO 3 LAYER = 1, NL
    3 FNU(LAYER,KOLUMN) = FWU(LAYER,NKK)*VNO3C(LAYER,KOLUMN)/
     .  VH2OC(LAYER,KOLUMN)
      DO 7 LAYER  = 1, NL
      DO 7 KOLUMN = 1,NKH
      FWICN = FWL(LAYER,KOLUMN+1) - FWL(LAYER,KOLUMN) +
     . FWU(LAYER+1,KOLUMN) - FWU(LAYER,KOLUMN)
      IF (FWICN.GT.-1.AND.FWICN.LT.1.) GO TO 11
      WRITE(3,104) FWICN,LAYER,KOLUMN
 104  FORMAT(' FWICN ',F11.4,2X,I3,2X,I3)
C FLUX OF H2O INTO THE CELL, NET, CM**3/CELL.
 11   VH2OC(LAYER,KOLUMN) = VH2OC(LAYER,KOLUMN) + FWICN/(D*W)
C VOLUMETRIC MOISTURE CONTENT OF SOIL CELL, CM**3/CM**3.
      FNICN = FNL(LAYER,KOLUMN+1) - FNL(LAYER,KOLUMN) +
     . FNU(LAYER+1,KOLUMN) - FNU(LAYER,KOLUMN)
C FLUX OF NO3 INTO THE CELL, NET, MG N/CELL/DAY.
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + FNICN/(D*W)
C VOLUMETRIC NITROGEN CONTENT OF SOIL CELL, MG N/CM**3.
 7    CONTINUE
      DO 13 KOLUMN = NKHP1, NK
      DO 13 LAYER  = 1, NL
      FNICN = FNL(LAYER,KOLUMN+1) - FNL(LAYER,KOLUMN)
     .  + FNU(LAYER+1,KOLUMN) - FNU(LAYER,KOLUMN)
   13 VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + FNICN/(D * W)
      D10 = D*10./FLOAT(NKH)
      FLDCAP = FC(20)
      DO 12 KOLUMN=1, NKH
      CAPUP = CAPUP + (FLDCAP-VH2OC(20,KOLUMN)) * D10
C  CAPILLARY UPTAKE OF WATER ACROSS BOTTOM OF PROFILE, MM.
 12   VH2OC(20,KOLUMN) = FLDCAP
C  RESET BOTTOM LAYER TO FIELD CAPACITY.
      TH2O = 0.
      DO 8 LAYER  = 1, NL
      DO 8 KOLUMN = 1, NKH
      PSIS(LAYER,KOLUMN) = (-1520.00)/EXP(39.7*VH2OC(LAYER,KOLUMN))
C H2O POTENTIAL OF SOIL CELL, IN BARS.
C FOR HOUSTON CLAY. FROM SANFORD (PERS. COMM.)
C OF STARKVILLE RICHEY FARM.
      TH2O = TH2O + VH2OC(LAYER,KOLUMN)
 8    CONTINUE
      TH2O = TH2O*D*W*.2
C TOTAL WATER PROFILE
      TNNO3 = 0.
      DO 14 LAYER  = 1, NL
      DO 14 KOLUMN = 1, NK
   14 TNNO3 = TNNO3 + VNO3C(LAYER, KOLUMN)
      TNNO3 = TNNO3*D*W
      NKH = NKH + 1
      DO 9 KOLUMN = NKH, NK
      NKK = NK + 1 - KOLUMN
      DO 9 LAYER  = 1, NL
      VH2OC(LAYER,KOLUMN) = VH2OC(LAYER,NKK)
      PSIS(LAYER,KOLUMN) = PSIS(LAYER,NKK)
      DIFF(LAYER,KOLUMN) = DIFF(LAYER,NKK)
C SETS RIGHT HALF OF PLANE SYMMETRICALLY EQUAL IN H2O
 9    CONTINUE
      RETURN
      END

      SUBROUTINE NITRIF
C  ***************************************************************
C  *                                                             *
C  *  SIMPLIED VERSION BASED ON KAFKAF1,HADAS,BAR-YOSEF MODEL    *
C  *                                                             *
C  ***************************************************************
      COMMON /FIELD /FC(20)
      COMMON /GEOM  /D,G,NK,NL,RCHOSS,RTP1,RTP2,SLF,THRLN,W
      COMMON/H2ONO3/ VH2OC(20,20),VNO3C(20,20)
      COMMON/NITLIZ/ VNH4C(4,20),VNC(4,20)
      COMMON/TOTS  /DAMP,NOITR,TH2O,TNNH4,TNNO3
      COMMON/TSDN / TSOILD(20),TSOILN(20),TSOLAV(4)
      TNNH4 = 0.
      LPLOW = 20/D
      DO 5 L=1,LPLOW
      T = TSOLAV(L)
      FMIN = 7300000. * 10.**(-2758./(T+273.))
      FNIT = .05 * 10.**(12.-3573./(T+273))
      DO 5 K=1,NK
      WFMIN = VH2OC(L,K)/FC(L)
      DNMIN = VNC(L,K) * FMIN * WFMIN
      VNC(L,K) = VNC(L,K) - DNMIN
      VNH4C(L,K) = VNH4C(L,K) + DNMIN
      WFNIT = 0.7 - 1.30 * (FC(L)- VH2OC(L,K))/FC(L)
      IF(WFNIT.LT.0.) WFNIT =0.
      DNIT = VNH4C(L,K) * FNIT * WFNIT
      VNH4C(L,K) = VNH4C(L,K) -DNIT
      VNO3C(L,K) = VNO3C(L,K) + DNIT
      TNNH4 = TNNH4 + VNH4C(L,K)
    5 CONTINUE
      TNNH4 = TNNH4 * D * W
```

```
      RETURN
      END

      SUBROUTINE PNET
***********************************************************
*                                                         *
*                     PNET  SUBROUTINE                    *
*                                                         *
***********************************************************
      REAL INT,LEAFWT,LYTRES

      COMMON /POP   / PN, POPFAC
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /WEIGHT/ COTXX, GBOLWT, LEAFWT, PLANTW, ROOTWT,SQWT, STEMWT
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN

      DATA CO2/0./, RSUBO/.0032/, GSUBR/.375/
PSILIN IS AN INDEX PSI(L) AT 0.3 BARS.
PSIS AND 27 C. - FULLY TURGID
PINDEX IS AN INDEX NET P RATE(SAME CONDITIONS).
      AVGPSI = PSIAVG
PSIL IS MINIMUM LEAF WATER POTENTIAL FOR THE DAY.
      IF(AVGPSI.LT.-2.0) AVGPSI = -2.0
      PSIL = -12.63 + 0.01799*WATTSM - 26.1097*AVGPSI -
     . 0.00001553*WATTSM*WATTSM - 18.289*AVGPSI*AVGPSI +
     . 0.025497*WATTSM*AVGPSI
      PSILIN = -3.82193 - 0.00333224*WATTSM
      PINDEX = -0.101235 + WATTSM*(0.0234135 - WATTSM*0.000017396)
      DPN =  0.24*(PSILIN-PSIL)
      PTSRED = (PINDEX-DPN)/PINDEX
      IF(PTSRED.GT.1.0)PTSRED = 1.0
      IF(PTSRED.LT.0.6)PTSRED = 0.6
 DATA LEADING TO THIS PTSRED ARE FROM CHAMBER EXPERIMENTS IN INTACT
 CROP CANOPY (BAKER & HESKETH, UNPUBLISHED 1969).
 PSTAND, RSUBL, RSUBO, GSUBR FROM BAKER ET. AL. (1972)
 SIMULATION OF GROWTH AND YIELD IN COTTON: I. GROSS PHOTOSYNTHESIS,
 RESPIRATION AND GROWTH.  CROP SCI. 12:431-435.
      PSTAND = 2.3908 + WATTSM*(1.37379 - WATTSM*0.00054136)
      PPLANT=PSTAND*INT*POPFAC*PTSRED*0.001*1.06
 VALUES BASED ON DATA OF HARPER ET. AL. (1973) CARBON DIOXIDE AND
 THE PHOTOSYNTHESIS OF FIELD CROPS.  A METERED CARBON DIOXIDE
 RELEASE IN COTTON UNDER FIELD CONDITIONS.  AGRON. JOUR. 65:7-11.
 AND ON BAKER (1965)  EFFECTS OF CERTAIN ENVIRONMENTAL FACTORS
 ON NET ASSIMILATION IN COTTON.  CROP SCI. 5:53-56. FIG 5.
      IF(CO2.EQ.1)PPLANT=PPLANT*1.405
CO2 IS A FERTILIZATION TRIGGER.WHEN CO2 IS EQUAL TO 1,PPLANT IS
INCREASED 20% DUE TO  500 PPM CO2 CONCENTRATION.
      RSUBL=0.0032125+0.0066875*TDAY
      LYTRES = RSUBL*PPLANT
      BMAIN=(PLANTW-COTXX)*RSUBO
      PTS=PPLANT-LYTRES-BMAIN
      IF(PTS.LE..01)PTS=.01
      PN= (PTS/(1.+GSUBR) * 0.68182)
 0.68182 CONVERTS CO2 TO CH2O
      RETURN
      END

      SUBROUTINE NITRO
***********************************************************
*                                                         *
*                    NITRO SUBROUTINE                     *
*                                                         *
***********************************************************
*   IN THIS SUBROUTINE, THE MAXIMUM AND MINIMUM N         *
*   CONCENTRATIONS FOR THE VARIOUS ORGANS ARE AS REPORTED *
*   BY JONES ET. AL. (1974) DEVELOPMENT OF A NITROGEN     *
*   BALANCE FOR COTTON GROWTH MODELS: A FIRST APPROXIMATION *
*   CROP SCI. 14:541-546.                                 *
***********************************************************

      INTEGER FCODE, XTRES, SCODE, AGEBOL, AGE
      REAL NF,NV,LEFABS,LEAFWT,LEAFRS,LEAFR,LEAFR1,LEFR,LEFW,LEAFRN
      REAL LEAFCN,NSHORT,LAREA,LEAFW,LNMAX,NPOOL


      COMMON /CODES / FCODE(3,30,5), LCODE(3,30,5), SCODE(7), SITES,
     .                SITEZ
      COMMON /COM   / AREA, LAREA(3,30,5)
      COMMON /CONS  / BURCN, ROOTCN, SEEDCN, STEMCN, LEAFCN
      COMMON /INCRS / DAY, DAYINC, NDAYS
      COMMON /LOST  / GBLOS, LEFABS, PQFLR, WTSLFD, XTRAC
      COMMON /NIT   / BURRN, ROOTN, SEEDN, SLEAFN, STEMN
      COMMON /NUMS  / NFBR(3), NNOD(3,30), NVBRCH
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /PDGR  / PDBOLL, PDLEAF, PDRES, PDROOT, PDSQ, PDSTEM, RESC
      COMMON /POTN  / BURR, LEAFR, ROOTR, SEEDR, STEMR
      COMMON /REQS  / BOLL1, BURMIN, BURR1, LEAFR1, REQ1, ROOTR1, SEEDR1
      COMMON /RESV  / F2, LEAFRS, RESN, ROOTRS, STEMRS
      COMMON /STRESS/ CSTRES, NF, NSTRES, NV, WSTRSD, WSTRSN, XTRES,
     . STRSD,STRSN, VSTRES, FSTRES
      COMMON /TIMKLM/ AGE(3,30,5), AGEBOL(3,30,5), DELAY(3,30),
     .        VDELAY(3), LAGE(3,30,5), BAGE(3,30,5), SCDLAY(3,30,5)
      COMMON /UPS   / SUPNO3, UPNO3
      COMMON /WEIGHT/ COTXX, GBOLWT, LEAFWT, PLANTW, ROOTWT,SQWT, STEMWT
      COMMON /WTKLM / BOLWGT(3,30,5), LEAFW(3,30,5), SQRWT(3,30,5),
     .                STMWT(170)
```

```
C
      DATA TOTNUP/0./, XTRAN/0./
      NF = 1.
      SEEDR1 = 0.
      BURADD = 0.
      SEDADD = 0.
      PLANTN = SLEAFN + ROOTN + STEMN + SEEDN + BURRN
      NV = 1.
      LEAFRS = (SLEAFN- .02 * LEAFWT) * F2
C THE MIN N CONC. IN LEAVES IS .02 ACCORD. TO JONES & HESKETH 73
      STEMRS = (STEMN - .009 * STEMWT) * F2
C THE MIN N CONC. IN STEMS IS .009 ACCORD TO JONES & HESKETH 73
      ROOTRS = (ROOTN - .009 * ROOTWT) * F2
C THE MIN. N CONC. IN STEMS & ROOTS IS .009 ACCORD. TO JONES & HESKETH
      RESN =LEAFRS + STEMRS + ROOTRS
C RESN IS RESERVE NITROGEN.
      IF(RESN.LT.0.) RESN = 0.
C 0.2258 CONVERTS NO3 TO N.
      SUPN = SUPNO3 * 0.2258
      NPOOL = SUPN + RESN
C NPOOL IS TOTAL NITROGEN AVAILABLE FOR GROWTH.
C F2 = RESERVE NITROGEN AVAILABILITY COEFFICIENT.
C THE FOLLOWING REPRESENTS POTENTIAL GROWTH REQUIREMENT
      LEAFR1=.042 * PDLEAF
C THE MIN N CONC. IN BURRS IS .006 ACCORD. TO JONES & HESKETH 73
      STEMR1= .02 * PDSTEM
      ROOTR1= .02 * PDROOT
      REQV = LEAFR1 + STEMR1 + ROOTR1
C  IF THERE IS A GREEN BOLL ON PLANT, CALCULATE SEED & BURR REQS
      IF(GBOLWT.LE.0.) GO TO 1
      SEEDR1 = PDBOLL * .04 * .416
      BURMIN = PDBOLL * .006 * .278
      BURR1  = PDBOLL * .014 * .278
      BOLL1  = BURMIN + SEEDR1
      REQ1   = BOLL1 + BURR1
      BURADD = BURR1 + BURMIN
      SEDADD = SEEDR1
 1    IF((REQV+REQ1).GT.NPOOL) GO TO 3
      GO TO 8
 3    IF(GBOLWT.LE.0.) GO TO 7
      IF((REQV+REQ1-BURR1).GT.NPOOL) GO TO 4
      BURADD = NPOOL-REQV-REQ1+BURR1
      GO TO 8
 4    IF(BOLL1.GT.NPOOL) GO TO 6
      NV = (NPOOL-BOLL1) / REQV
      IF(NV.GT.1.) NV = 1.
      BURADD = BURMIN
      GO TO 8
 6    CONTINUE
      NV = 0.
      BURADD = NPOOL*BURMIN / (BURMIN+SEEDR1)
      SEDADD = NPOOL*SEEDR1 / (BURMIN+SEEDR1)
      NF = NPOOL/BOLL1
      IF(NF.GT.1.) NF = 1.
      GO TO 8
 7    CONTINUE
      NV = NPOOL / REQV
      IF(NV.GT.1.) NV = 1.
 8    CONTINUE
C VEGETATIVE GROWTH SECTION
      SLEAFN = SLEAFN + LEAFR1 * NV
      STEMN = STEMN + STEMR1 * NV
      ROOTN = ROOTN + ROOTR1 * NV
C BOLL GROWTH SECTION
      BURRN = BURRN + BURADD
      SEEDN = SEEDN + SEDADD
      PLTN = SLEAFN + STEMN + ROOTN + BURRN + SEEDN
      XTRAN = SUPNO3 - (PLTN - PLANTN)
C  THE PART OF XTRAN SUPPLIED BY RESN IS (PLTN-PLANTN)-SUPNO3. IF THIS
C  IS +, THEN SOME CAME FROM RESN & XTRAN MUST BE -.  IF (PLTN-PLANTN)
C  -SUPNO3 IS - , THEN ALL CAME FROM SUPNO3 & XTRAN MUST BE +.
      VEGWT  = LEAFWT + STEMWT + ROOTWT
      IF(XTRAN.LT.0.) GO TO 9
      SLEAFN = SLEAFN + XTRAN * (LEAFWT/VEGWT)
      STEMN  = STEMN  + XTRAN * (STEMWT/VEGWT)
      ROOTN  = ROOTN  + XTRAN * (ROOTWT/VEGWT)
      GO TO 12
 9    IF(RESN.LE.0.)XTRAN = 0.0
      IF(RESN.LE.0.)GO TO 12
      SLEAFN = SLEAFN + XTRAN * (LEAFRS/RESN)
      STEMN = STEMN + XTRAN * (STEMRS/RESN)
      ROOTN = ROOTN + XTRAN * (ROOTRS/RESN)
 12   CONTINUE
      IF(GBOLWT.EQ.0.) GO TO 11
      IF(NF.LT.1.0)  NSTRES = 1
      IF(NF.LT.0.8)  NSTRES = 2
      IF(NF.LT.0.4)  NSTRES = 3
      IF(NF.LT.0.2)  NSTRES = 4
 11   STEMCN = STEMN / STEMWT
      LEAFCN = SLEAFN / LEAFWT
      ROOTCN = ROOTN / ROOTWT
      IF(GBOLWT.EQ.0.) GO TO 22
      XXWT = COTXX + GBOLWT
      SEEDCN = SEEDN / (XXWT*.416)
      BURCN  = BURRN / (XXWT*.278)
 22   CONTINUE
      IF(NFRQX.EQ.IDAY) WRITE(3,401) STEMCN, STEMN, LEAFCN, SLEAFN,
```

```
     . ROOTCN, ROOTN, BURCN, BURRN, SEEDCN
 401  FORMAT(' STEMCN    STEMN   LEAFCN   SLEAFN   ROOTCN    ROOTN    BURCN
     .  BURRN  SEEDCN  '/9(2X,F6.3))
      IF(NFRQX.EQ.IDAY)WRITE(3,400)SEEDN,TOTNUP,PLTN,PLANTN,NPOOL,XTRAN,
     .RESN,SUPNO3,VEGWT
 400  FORMAT('   SEEDN    TOTNUP    PLTN    PLANTN    NPOOL    XTRAN    RESN ',
     .'  SUPNO3    VEGWT',/,8(2X,F6.3),2X,F7.3)
      RETURN
      END

      SUBROUTINE GROWTH
C   ***********************************************************
C   *                                                         *
C   *                  GROWTH SUBROUTINE                      *
C   *                                                         *
C   ***********************************************************
      INTEGER FCODE, XTRES, DAYNUM, SCODE, AGEBOL, DAY, BAGE
      REAL NV,NF,LATUDE,LAREA,LEAFWT,LEAFW,INT,LAI,NYTTYM,NYTWTF
      REAL LEFABS,LEAFCN,LEAFRS,LEAFR,LEAFR1,NROOT,NTOP
      DIMENSION SBOLLD(3,30,5), SBOLLN(3,30,5), SLEFAD(3,30,5),
     .SLEFAN(3,30,5), SLEFWD(3,30,5), SLEFWN(3,30,5)
      COMMON /CALIB / CZD, CZN, CSQ, CBL, CL, CM, CPF, CVB,DPSMX,DPBMX
      COMMON /CAL2  / XTR1, XTR2, XTR3, XTR4, A1, A21, A22, A31, A32
      COMMON /CODES / FCODE(3,30,5), LCODE(3,30,5), SCODE(7), SITES,
     .                SITEZ
      COMMON /COM   / AREA, LAREA(3,30,5)
      COMMON /COM1  / EMERGE, KARDS, LAI, SEASON, VARITY, YIELD
      COMMON /CONS  / BURCN, ROOTCN, SEEDCN, STEMCN, LEAFCN
      COMMON /FACTOR/ DAYWTF, NYTWTF, DAYTYM, NYTTYM, DROOT, NROOT
      COMMON /FRUTE / FFRUT(3,30,5), MCODE(3,30,5), SQLOSS(170),
     .                BOLOSS(170)
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
      COMMON /H2ONO3/ VH2OC(20,20), VNO3C(20,20)
      COMMON /INCRS / DAY, DAYINC, NDAYS
      COMMON /KLM   / AVGT(3,30,5), AVTEMP
      COMMON /LEAFAV/ FRATIO
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /LOST  / GBLOS, LEFABS, PQFLR, WTSLFD, XTRAC
      COMMON /MATR  / KRL(20), LR
      COMMON /NIT   / BURRN, ROOTN, SEEDN, SLEAFN, STEMN
      COMMON /NUMS  / NFBR(3), NNOD(3,30), NVBRCH
      COMMON /PDGR  / PDBOLL, PDLEAF, PDRES, PDROOT, PDSQ, PDSTEM, RESC
      COMMON /PDKLM / PDADAY(3,30,5), PDANYT(3,30,5), PDWBOD(3,30,5),
     .                PDWBON(3,30,5),
     .                PDWLD(3,30,5), PDWLN(3,30,5), PDWSQ(3,30,5)
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /POP   / PN, POPFAC
      COMMON /POTN  / BURR, LEAFR, ROOTR, SEEDR, STEMR
      COMMON /PREFRT/ AGEPFN(9), AVTPFN(9), NUMPFN, PFAL(9), PFAREA,
     .                PFDAL, PFDALN(9), PFDWL, PFDWLD(9), PFDWLN(9),
     .                PFWL(9), PFDALD(9)
      COMMON /PS    / PSIS(20,20)
      COMMON /REQS  / BOLL1, BURMIN, BURR1, LEAFR1, REQ1, ROOTR1, SEEDR1
      COMMON /RESV  / F2, LEAFRS, RESN, ROOTRS, STEMRS
      COMMON /RUTDUM/ DUMMY0(1610)
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,20), RTWT(20,20,3)
      COMMON /SIZES / POPPLT, ROWSP, Z
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /SPD   / SPDWL, SPDWLD, SPDWLN, SPDWRT, SPDWSQ
      COMMON /STRESS/ CSTRES, NF, NSTRES, NV, WSTRSD, WSTRSN, XTRES,
     .                STRSD, STRSN, VSTRES, FSTRES
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TIMKLM/ AGE(3,30,5), AGEBOL(3,30,5), DELAY(3,30),
     .                VDELAY(3), LAGE(3,30,5), BAGE(3,30,5)
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(4)
      COMMON /UPS   / SUPNO3, UPNO3
      COMMON /WEIGHT/ COTXX, GBOLWT, LEAFWT, PLANTW, ROOTWT,SQWT,STEMWT,
     .                RUTWT
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
      COMMON /WTKLM / BOLWGT(3,30,5), LEAFW(3,30,5), SQRWT(3,30,5),
     .                STMWT(170)
C
      DATA SBOLLD/450*0./,SBOLLN/450*0./,SLEFAD/450*0./,SLEFAN/450*0./,
     .     SLEFWD/450*0./, SLEFWN/450*0./, DLEFAD/0./, DLEFAN/0./,
     .     DLEFWD/0./, DLEFWN/0./, DBOLLD/0./, DBOLLN/0./, SUMLD/0./,
     .     SUMLN/0./, SSTEMD/0./, SSTEMN/0./, DSTEMD/0./, DSTEMN/.0/,
     .     SLEAF/0./, SBOLL/0./, SQUAR/0./, SSTEM/0./, SROOT/0./
      DAYTYM = DAYLNG / 24.
      NYTTYM = 1. - DAYTYM
      DUMY10 = (0.0160791*TDAY-0.2120865)
      DUMY01 = (0.0160791*TDAY-0.2120865) * DAYTYM * WSTRSD
      DUMY02 = (0.03125*TDAY-0.0508125) * DAYTYM * WSTRSD
      DUMY03 = (2.73285-0.082857*TDAY) * DAYTYM * WSTRSD
      DUMY09 = (0.0160791*TNYT-0.2120865) * NYTTYM * WSTRSN
      DUMY07 = (0.03125*TNYT-0.0508125) * NYTTYM * WSTRSN
      DUMY08 = (2.73285-0.082857*TNYT) * NYTTYM * WSTRSN
      TFACSQ = EXP(DUMY10)/1.228716514
      DAYWTF = 1./(-0.62142855 + TDAY*(0.1093651 - TDAY*0.00137566))
      NYTWTF = 1./(-0.62142855 + TNYT*(0.1093651 - TNYT*0.00137566))
      RADAY = -1.14277 + TDAY*(0.0910026 - TDAY*0.00152344)
      IF(TDAY.LE.24.) RADAY = -0.317136 + TDAY*(0.0300712 -
     .  TDAY*0.000416356)
      RANYT = -1.14277 + TNYT*(0.0910026 - TNYT*0.00152344)
      IF(TNYT.LE.24.) RANYT = -0.317136 + TNYT*(0.0300712 -
     .  TNYT*0.000416356)
      IF(RANYT.LE.0.0) RANYT = 0.
      IF(RADAY.LE.0.0) RADAY = 0.
```

```
      DUMY04 = RADAY * DAYTYM * WSTRSD * CL
      DUMY05 = RANYT * NYTTYM * WSTRSN * CL
      SPDWSQ = 0.0
      SPDWBO = 0.0
      PFAREA = 0.
      SPDWLD = 0.
      SPDWLN = 0.
      TPDWLD = 0.
      TPDWLN = 0.
      AREA = 0.
      IF(AGEPFN(NUMPFN).GT.16.) GO TO 23
      DO 22 J=1,NUMPFN
      IF(AGEPFN(J).GT.16.) GO TO 21
      PFDALD(J) = PFAL(J) * DUMY04
      PFDALN(J) = PFAL(J) * DUMY05
      PFDWLD(J) = PFDALD(J) * DAYWTF
      PFDWLN(J) = PFDALN(J) * NYTWTF
      TPDWLD = TPDWLD + PFDWLD(J)
      TPDWLN = TPDWLN + PFDWLN(J)
      GO TO 22
   21 PFDALD(J) = 0.0
      PFDALN(J) = 0.0
      PFDWLD(J) = 0.0
      PFDWLN(J) = 0.0
   22 CONTINUE
   23 IF(FCODE(1,1,1).EQ.0) GO TO 25
      FRATIO = GBOLWT/PLANTW
      DO 1 K=1,NVBRCH
      NBRCH = NFBR(K)
      DO 1 L=1,NBRCH
      NNID = NNOD(K,L)
      DO 1 M=1,NNID
      NOWGO = FCODE(K,L,M) + 1
      GO TO (7,2,3,7,7,2,3,3), NOWGO
    2 CONTINUE
C CALCULATE POTENTIAL SQUARE GROWTH(PDWSQ)
      DUMY06 = .0160791*AVGT(K,L,M)-.2120865
      TFACSQ = EXP(DUMY06)/1.228716514
      PDWSQ(K,L,M) = EXP(-3.875 + 0.125*AGE(K,L,M))*TFACSQ
     .   -  EXP(-3.875+0.125*(AGE(K,L,M)-1.))*TFACSQ
      SPDWSQ = SPDWSQ + PDWSQ(K,L,M)
      GOTO 7
    3 CONTINUE
C CALCULATE POTENTIAL BOLL GROWTH(PDWBOL)
      PDWBOD(K,L,M) = BOLWGT(K,L,M) * DUMY01
      PDWBON(K,L,M) = BOLWGT(K,L,M) * DUMY09
      IF(BAGE(K,L,M).LT.7.)GO TO 6
C D(LN(W))/DT = B = (1/W)(DW/DT) = F(TAVG)
C LINEAR BOLL GROWTH PHASE
      PDWBOD(K,L,M) = DUMY02*FFRUT(K,L,M)
      PDWBON(K,L,M) = DUMY07*FFRUT(K,L,M)
      IF(TAVG.GT.28.5) PDWBOD(K,L,M) = DUMY03 * FFRUT(K,L,M)
      IF(TAVG.GT.28.5) PDWBON(K,L,M) = DUMY08 * FFRUT(K,L,M)
    6 CONTINUE
      IF(FRATIO.LT.CVB) GO TO 5
      IF(WSTRSD.LT.CM)DBOLLD=((BOLWGT(K,L,M)*(.0160791*TDAY-.2120865)*
     .DAYTYM)-PDWBOD(K,L,M))
      IF(WSTRSD.LT.CM)DBOLLN=((BOLWGT(K,L,M)*(.0160791*TNYT-.2120865)*
     .NYTTYM)-PDWBON(K,L,M))
      IF(BAGE(K,L,M).LT.7) GO TO 93
      IF(WSTRSD.LT.CM)DBOLLD = ((FFRUT(K,L,M)*(.03125*TDAY-.0508125)*
     .DAYTYM)-PDWBOD(K,L,M))
      IF(WSTRSD.LT.CM)DBOLLN = ((FFRUT(K,L,M)*(.03125*TNYT-.0508125)*
     .NYTTYM)-PDWBON(K,L,M))
      IF(TDAY.GT.28.5.AND.WSTRSD.LT.CM)DBOLLD=(((2.73285-.082857*TDAY)
     .*DAYTYM*FFRUT(K,L,M))-PDWBOD(K,L,M))
      IF(TNYT.GT.28.5.AND.WSTRSN.LT.CM)DBOLLN=(((2.73285-.082857*TNYT)
     .*NYTTYM*FFRUT(K,L,M))-PDWBON(K,L,M))
      IF(DBOLLD.LT.0.)DBOLLD = 0.
      IF(DBOLLN.LT.0.)DBOLLN = 0.
   93 SBOLLD(K,L,M) = SBOLLD(K,L,M) + DBOLLD
      SBOLLN(K,L,M) = SBOLLN(K,L,M) + DBOLLN
      DBOLLD = 0.
      DBOLLN = 0.
      IF(WSTRSD.LT..9)GO TO 5
      PDWBOD(K,L,M) = PDWBOD(K,L,M) + SBOLLD(K,L,M)
      PDWBON(K,L,M) = PDWBON(K,L,M) + SBOLLN(K,L,M)
      SBOLLD(K,L,M) = 0.0
      SBOLLN(K,L,M) = 0.0
    5 SPDWBO = SPDWBO + PDWBOD(K,L,M) + PDWBON(K,L,M)
    7 CONTINUE
C CALCULATE POTENTIAL LEAF AREA GROWTH
      IF(LAGE(K,L,M).GT.16.) GO TO 4
C LEAF GROWTH STOPS AFTER 16 DAYS
      PDADAY(K,L,M) = LAREA(K,L,M) * DUMY04
      PDANYT(K,L,M) = LAREA(K,L,M) * DUMY05
C CALCULATE POTENTIAL GROWTH IN LEAF WEIGHT
      PDWLD(K,L,M) = PDADAY(K,L,M) * DAYWTF
      PDWLN(K,L,M) = PDANYT(K,L,M) * NYTWTF
      IF(FRATIO.LT.CVB)GO TO 96
      IF(WSTRSD.LT.CM)DLEFAD=LAREA(K,L,M)*RADAY*DAYTYM*CL-PDADAY(K,L,M)
      IF(WSTRSN.LT.CM)DLEFAN=LAREA(K,L,M)*RANYT*NYTTYM*CL-PDANYT(K,L,M)
      IF(WSTRSD.LT.CM)DLEFWD = (DLEFAD*DAYWTF)
      IF(WSTRSN.LT.CM)DLEFWN = (DLEFAN*NYTWTF)
      SLEFAD(K,L,M) = SLEFAD(K,L,M) + DLEFAD
      SLEFAN(K,L,M) = SLEFAN(K,L,M) + DLEFAN
      SLEFWD(K,L,M) = SLEFWD(K,L,M) + DLEFWD
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      SLEFWN(K,L,M) = SLEFWN(K,L,M) + DLEFWN
      DLEFAD = 0.0
      DLEFAN = 0.0
      DLEFWD = 0.0
      DLEFWN = 0.0
      IF(WSTRSD.LT..9)GO TO 95
      PDADAY(K,L,M) = PDADAY(K,L,M) + SLEFAD(K,L,M)
      PDWLD(K,L,M) = PDWLD(K,L,M) + SLEFWD(K,L,M)
      SLEFAD(K,L,M) = 0.0
      SLEFWD(K,L,M) = 0.0
   95 CONTINUE
      IF(WSTRSN.LT..9)GO TO 96
      PDANYT(K,L,M) = PDANYT(K,L,M) + SLEFAN(K,L,M)
      PDWLN(K,L,M) = PDWLN(K,L,M) + SLEFWN(K,L,M)
      SLEFAN(K,L,M) = 0.0
      SLEFWN(K,L,M) = 0.0
   96 CONTINUE
      SPDWLD = SPDWLD + PDWLD(K,L,M)
      SPDWLN = SPDWLN + PDWLN(K,L,M)
      GO TO 1
    4 PDADAY(K,L,M) = 0.
      PDANYT(K,L,M) = 0.
      PDWLD(K,L,M)  = 0.
      PDWLN(K,L,M)  = 0.
    1 CONTINUE
C CALCULATE POTENTIAL STEM GROWTH
   25 PDSTMD = (.1 + .02*IDAY) * WSTRSD*DAYTYM
      IF(IDAY.GT.42) PDSTMD = (.2 + .06*(STEMWT-STMWT(IDAY - 24)))*
     .WSTRSD*DAYTYM
      PDSTMN = (.1 + .02*IDAY)*WSTRSN*NYTTYM
      IF(IDAY.GT.42) PDSTMN = (.2 + .06*(STEMWT - STMWT(IDAY - 24)))
     .*WSTRSN*NYTTYM
      IF(FRATIO.LT.CVB)GO TO 92
      IF(WSTRSD.LT.CM)DSTEMD=(((.1+.02*IDAY)*DAYTYM)-PDSTMD)
      IF(WSTRSN.LT.CM)DSTEMN =((.1 + .02*IDAY)*NYTTYM-PDSTMN)
      IF(WSTRSD.LT.CM.AND.IDAY.GT.42) DSTEMD =(((.2 + .06*(STEMWT-
     .STMWT(IDAY - 24))) * DAYTYM) - PDSTMD)
      IF(WSTRSN.LT.CM.AND.IDAY.GT.42) DSTEMN =(((.2 + .06*(STEMWT-
     .STMWT(IDAY - 24))) * NYTTYM) - PDSTMN)
      SSTEMD = SSTEMD + DSTEMD
      SSTEMN = SSTEMN + DSTEMN
      DSTEMD = 0.
      DSTEMN = 0.
      IF(WSTRSD.LT..90) GO TO 91
      PDSTMD = PDSTMD + SSTEMD
      SSTEMD = 0.
   91 IF(WSTRSN.LT..90) GO TO 92
      PDSTMN = PDSTMN + SSTEMN
      SSTEMN = 0.
   92 CONTINUE
C CALCULATE POTENTIAL ROOT GROWTH
C  CALL RUTGRO TO GET SPDWRT FOR TODAY.
      CALL RUTGRO(0)
      SPDWRT = SPDWRT * POPFAC * 2.
C  POTENTIAL CHANGE IN ROOT WEIGHT IS DOUBLED FOR FULL PROFILE,
C  AND WILL BE HALVED BEFORE BEING SENT TO RUTGRO.
C  PARTD & PARTN ARE THE FRACTION OF CH2O BUDGETED TO VEGETATIVE
C  WHICH GOES TO ROOTS (DAY & NIGHT RESPECTIVELY).
      PARTD = 1. - .95*WSTRSD
      PARTN = 1. - .95*WSTRSN
      DTOP = 1.
      DROOT = 1.
      NTOP = 1.
      NROOT = 1.
      SPDWRD = SPDWRT*DAYTYM
      SPDWRN = SPDWRT*NYTTYM
      RATIO = ROOTWT/(STEMWT + LEAFWT)
      IF(RATIO.GT.PARTD) GO TO 35
      PDSTMD = 0.7*PDSTMD
      SPDWLD = 0.7*SPDWLD
      TPDWLD = 0.7*TPDWLD
      DTOP   = 0.7
      SPDWRD = 2.0*SPDWRD
      DROOT = 2.0
      GO TO 37
   35 SPDWRD = 0.7*SPDWRD
      DROOT =  0.7
   37 CONTINUE
      IF(RATIO.GT.PARTN) GO TO 36
      PDSTMN = 0.7*PDSTMN
      NROOT = 2.0
      SPDWLN = 0.7*SPDWLN
      TPDWLN = 0.7*TPDWLN
      NTOP   = 0.7
      SPDWRN = 2.0*SPDWRN
      GO TO 38
   36 SPDWRN = 0.7*SPDWRN
      NROOT  = 0.7
   38 CONTINUE
C  CALCULATE CARBOHYDRATE DEMAND (CD)
      CD = SPDWRD + SPDWRN + PDSTMD + PDSTMN + SPDWLD + SPDWLN +
     .     TPDWLD + TPDWLN + SPDWSQ + SPDWBO
      CPOOL = PN + RESC
      CSTRES = CPOOL / CD
      IF(CSTRES.GT.1.) GO TO 30
      RESC = 0.
      GO TO 31
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 30    CSTRES = 1.
       RESC = CPOOL - CD
       IF(RESC.LE.(.3*LEAFWT)) GO TO 31
       XTRAC =  XTRAC + RESC - (.3*LEAFWT)
       RESC = .3 * LEAFWT
 31    CONTINUE
C
       PDSTEM = (PDSTMD + PDSTMN) * CSTRES
       PDLEAF = (SPDWLD + SPDWLN +TPDWLD + TPDWLN)*CSTRES
       PDROOT = (SPDWRD + SPDWRN) * CSTRES
       PDBOLL = SPDWBO * CSTRES
       PDSQ   = SPDWSQ * CSTRES
C  CALL NITRO TO GET TODAYS N STRESS
       CALL NITRO
C
C  CALCULATE EXCESS CH2O CREATED BY N STRESS
       CH2OX = (SPDWRD+SPDWRN+PDSTMD+PDSTMN+SPDWLD+SPDWLN+TPDWLD+TPDWLN)
      . *CSTRES*(1-NV) +  (SPDWBO+SPDWSQ)*CSTRES*(1.-NF)
       XTRAC = XTRAC + CH2OX
       LEAFWT = 0.
       VSTRES = NV * CSTRES
       FSTRES = NF * CSTRES
       IF(NFRQX.EQ.IDAY)
      . WRITE(3,250)NF,NV,CD,CPOOL,CSTRES,VSTRESS,INT,DTOP,DROOT
 250   FORMAT('    NF       NV       CD      CPOOL    CSTRES   VSTRES    ',
      .'INT    DTOP  DROOT',/,1X,6(F6.3,2X),1X,2(F5.2,3X),F5.2,3X,F5.2)
       SDWSQR = 0.0
       SDWBOL = 0.0
       SDWLEF = 0.0
       SDAREA = 0.0
       IF(FCODE(1,1,1).EQ.0) GO TO 26
       SQWT = 0.
       DO 102  K = 1,NVBRCH
       NBRCH = NFBR(K)
       DO 101 L = 1,NBRCH
       NNID = NNOD(K,L)
       DO 100 M = 1,NNID
       NOWGO = FCODE(K,L,M) + 1
       GO TO (100,200,300,700,700,200,300,300), NOWGO
  200 CONTINUE
C CALCULATE GROWTH OF EACH SQUARE
       DWSQ = PDWSQ(K,L,M)*FSTRES
       SQRWT(K,L,M) = SQRWT(K,L,M) + DWSQ
       SDWSQR = SDWSQR + DWSQ
       SQWT = SQWT + SQRWT(K,L,M)
       GO TO 700
  300 CONTINUE
C CALCULATE BOLL GROWTH
       DWBOLL = PDWBOD(K,L,M)*FSTRES + PDWBON(K,L,M)*FSTRES
       BOLWGT(K,L,M) = BOLWGT(K,L,M) + DWBOLL
       SDWBOL = SDWBOL + DWBOLL
       GBOLWT = GBOLWT + DWBOLL
 700   CONTINUE
C CALCULATE LEAF GROWTH
       DWL  = (PDWLD(K,L,M)*DTOP + PDWLN(K,L,M)*NTOP)*VSTRES
       LEAFW(K,L,M) = LEAFW(K,L,M) + DWL
       SDWLEF = SDWLEF + DWL
       LEAFWT = LEAFWT + LEAFW(K,L,M)
C CALCULATE NEW LEAF AREA
       DAL = (PDADAY(K,L,M)*DTOP + PDANYT(K,L,M)*NTOP)*VSTRES
       LAREA(K,L,M) = LAREA(K,L,M) + DAL
       AREA = AREA + LAREA(K,L,M)
 100   CONTINUE
 101   CONTINUE
 102   CONTINUE
 26    DO 28 J=1,NUMPFN
       IF(AGEPFN(J).GT.16.) GO TO 29
       PFDWL = (PFDWLD(J)*DTOP + PFDWLN(J)*NTOP)*VSTRES
       PFWL(J) = PFWL(J) + PFDWL
       PFDAL = (PFDALD(J)*DTOP + PFDALN(J)*NTOP)*VSTRES
       PFAL(J) = PFAL(J) + PFDAL
       SDWLEF = SDWLEF + PFDWL
 29    PFAREA = PFAREA + PFAL(J)
       LEAFWT = LEAFWT + PFWL(J)
 28    CONTINUE
       AREA = AREA + PFAREA
       LAI = AREA/POPFAC
       DWSTM = (PDSTMD + PDSTMN)*VSTRES
       RCH2O = (SPDWRD + SPDWRN)*VSTRES
       SLEAF = SLEAF + SDWLEF
       SBOLL = SBOLL + SDWBOL
       SQUAR = SQUAR + SDWSQR
       SSTEM = SSTEM + DWSTM
       SROOT = SROOT + RCH2O
C SLEAF, SBOLL, SQUAR,SSTEM AND SROOT ARE THE CUMMULATIVE AMMOUNT OF CHO
C ALLOCATED TO THE DIFFERENT SINKS.
       IF(NFRQX.EQ.IDAY)
      . WRITE(3,1003) SLEAF,SSTEM,SROOT,SBOLL,SQUAR,SDWLEF,DWSTM,
      . SDWBOL,SDWSQR
 1003 FORMAT(' SLEAF    SSTEM    SROOT    SBOLL    SQUAR    SDWLEF    DWSTM'
      .,'    SDWBOL  SDWSQR',/,1X,9(F6.2,2X))
       STEMWT = STEMWT + DWSTM
       STMWT(IDAY) = STEMWT
C      IF(NFRQX.EQ.IDAY)
       CALL RUTGRO(1)
C  NOTE THAT STORED CH2O IS USED IN CALCULATION OF TOTAL PLANT WEIGHT.
C CALCULATE VERTICAL GROWTH
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 40   IF (PLANTW.LE.1.0) VSTRES = 1.
      L = NFBR(1)
      L1=L-1
      L2=L-2
      IF (L.NE.1) GOTO 88888
      L1=1
      L2=1
88888 IF (L.EQ.2) L2=1
      IF(FCODE(1,1,1).NE.0) GO TO 41
      DZ = CZN - .34*(AGEPFN(NUMPFN) + 2)
      IF(DZ.GT.1.5) DZ = 1.5
      IF(DZ.LE.0.) DZ = 0.
      IF(NUMPFN.LE.1) GO TO 42
      DZ2 = CZN - .34*(AGEPFN(NUMPFN-1) + 2)
      IF(DZ2.LE.0.) DZ2 = 0.
      IF(DZ2.GT.1.5) DZ2 = 1.5
      IF((AGEPFN(NUMPFN) + 2).LE.2.0) DZ = DZ + DZ2
      GO TO 42
 41   CONTINUE
      AGETOP = (AGE(1,L,1) + AGE(1,L1,1) + AGE(1,L2,1)) / 3.
      DZ = CZN - .34*AGE(1,L,1)
      IF(DZ.GT.1.5) DZ = 1.5
      IF(DZ.LE.0.) DZ = 0.
      IF(L.GT.1) GO TO 43
      DZ2 = CZN - .34*AGEPFN(NUMPFN)
      IF(DZ2.LE.0.) DZ2 = 0.
      IF(DZ2.GT.1.5) DZ2 = 1.5
      IF(AGE(1,L,1).LE. 2.0) DZ = DZ + DZ2
      GO TO 42
 43   CONTINUE
      DZ2 = CZN - .34*AGE(1,L-1,1)
      IF(DZ2.LE.0.) DZ2 = 0.
      IF(DZ2.GT.1.5) DZ2 = 1.5
      IF(AGE(1,L,1).LE. 2.0) DZ = DZ + DZ2
 42   CONTINUE
      IF (AGETOP.GT.10.) AGETOP=10.
      IF(FCODE(1,3,1).NE.0) DZ=(6.176237-1.130496*AGETOP+.0547083*
     *    AGETOP*AGETOP)*CPF
      IF(DZ.GT.3.0) DZ = 3.0
      IF(DZ.LT.0.) DZ = 0.
      WSTRS = (WSTRSD + WSTRSN)/2.
      DZ = DZ * WSTRS
      Z = Z + DZ
      RETURN
      END

      SUBROUTINE RUTGRO(KALL)
C*****************************************************************
C   THIS SUBROUTINE CALCULATES THE GROWTH (IN TERMS OF DRY       *
C MATTER) OF ROOTS IN EACH CELL FOR THE DAY.  FIRST, THE POTENTIAL*
C GROWTH (PDWRT) FOR THE EXISTING SOIL WATER POTENTIAL (PSIS)    *
C AND TEMPERATURE (TSOILD & TSOILN) IS CALCULATED FOR EACH       *
C SOIL CELL, BASED ON THE WEIGHT OF ROOTS CAPABLE OF GROWTH      *
C IN EACH CELL (RTWTCG).  THEN THE ACTUAL GROWTH IS              *
C DETERMINED, BASED ON THE CARBOHYDRATE SUPPLY FOR ROOT GROWTH   *
C AND THE POTENTIAL GROWTH FOR THE CELL.  THE ACTUAL GROWTH      *
C OCCURING FOR A GIVEN CELL MAY OCCUR WITHIN THE CELL OR IN      *
C THE CELLS TO THE RIGHT OR LEFT & BELOW.                        *
C   GROWTH IN THE 4 AVAILABLE CELLS IS BASED ON RELATIVE         *
C WATER POTENTIALS OF THE FOUR, WITH A HEAVIER WEIGHTING         *
C GIVEN TO DOWNWARD GROWTH.                                      *
C    THIS SUBROUTINE DRAWS HEAVILY ON THE IDEAS AND THEORIES OF  *
C  DR. M. G. HUCK, USDA-ARS, AUBURN, ALA.  THIS IS ESPECIALLY    *
C  AS REGARDS SLOUGHING.  C. F. 'A MODEL FOR SIMULATING ROOT     *
C  GROWTH AND WATER UPTAKE ', M. G. HUCK, F. W. T. PENNING DE    *
C  VRIES, AND M. G. KEIZER.  IN PRESS.                           *
C*****************************************************************
      DIMENSION DUMAY(1200)
      REAL INT,LATUDE,LEAFWT,LEFABS, NF, NV
      INTEGER XTRES, DAYNUM
      COMMON /CALIB / CZD, CZN, CSQ, CBL, CL, CM, CPF, CVB,DPSMX,DPBMX
      COMMON /CAL2  / XTR1, XTR2, XTR3, XTR4, A1, A21, A22, A31, A32
      COMMON /COM1  / EMERGE, KARDS, LAI, SEASON, VARITY, YIELD
      COMMON /GEOM  / D, G, NK, NL, RCHOSS, RTP1, RTP2, SLF, THRLN, W
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /LOST  / GBLOS, LEFABS, PQFLR, WTSLFD, XTRAC
      COMMON /MATR  / KRL(20), LR
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
      COMMON /POP   / PN, POPFAC
      COMMON /PS    / PSIS(20,20)
      COMMON /RUTDUM/ DWRT(20,20), PDWRT(20,20), RTWTCG(20,20), DUM(410)
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,20), RTWT(20,20,3)
      COMMON /SIZES / POPPLT, ROWSP, Z
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /SPD   / SPDWL, SPDWLD, SPDWLN, SPDWRT, SPDWSQ
      COMMON /STRESS/ CSTRES, NF, NSTRES, NV, WSTRSD, WSTRSN, XTRES,
     *                STRSD, STRSN, VSTRES, FSTRES
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(4)
      COMMON /WEIGHT/ COTXX, GBOLWT, LEAFWT, PLANTW, ROOTWT,SQWT, STEMWT
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
C
      EQUIVALENCE( DWRT(1,1),DUMAY(1))
      IF(KALL.EQ.1) GO TO 2
      DO 40 I=1,1200,2
      DUMAY(I) = 0.
 40   DUMAY(I+1) = 0.
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C G - WEIGHTING FACTOR FOR GEOTROPISM ( THE PREFERENCE OF ROOTS
C TO GROW DOWNWARD).
C SLF - SLOUGHING FACTOR.
C THRLN - THRESHOLD WEIGHT TO GIVE LENGTH OF ROOTS REACHING
C OPPOSITE BOUNDARIES OF CELL FROM WHICH GROWTH ORIGINATED.
      SPDWRT = 0.
      PSIMAX = -50.
      DO 1 LAYER  = 1, LR
      KR = KRL(LAYER)
      DO 1 KOLUMN = 1, KR
      RTWTCG(LAYER,KOLUMN) = RTWT(LAYER,KOLUMN,1) +
     .  RTWT(LAYER,KOLUMN,2)
C ROOT WEIGHT CAPABLE OF GROWTH IN THE CELL, GM.
C      THE 25 DAY LIMIT IS BASED ON ANALYSES FOR STEM GROWTH. C. F.
C  BAKER, D. N. ET. AL. (1973) 'AN ANALYSIS OF THE RELATION BETWEEN
C  PHOTOSYNTHETIC EFFICIENCY AND YIELD IN COTTON'.  1973 BELTWIDE
C  COTTON PRODUCTION RES. CONF. PROC.
      IF(PSIS(LAYER,KOLUMN).GT.PSIMAX) PSIMAX=PSIS(LAYER,KOLUMN)
 1    CONTINUE
      CALMAX = 1980.7 + PSIMAX*(797.58+PSIMAX*(181.181+PSIMAX*10.9619))
       CALAVG = 1980.7 + PSIAVG*(797.58+PSIAVG*(181.181+PSIAVG*10.9619))
       TSDL = TSOILD(4)
       TSNL = TSOILN(4)
       IF(TSDL.GT.30.)TSDL=30.
       CALTSD = TSDL*(-71.3947+(TSDL*1.22793))
       CALTSN = TSNL*(-71.3947+(TSNL*1.22793))
       WSTRSD = (CALAVG+CALTSD+RN*(-0.512136-0.078977*PSIAVG) +
     .   (0.73493*PSIAVG*TSDL)) / 730.
       WSTRSN = (CALAVG+CALTSN+17.92476+PSIAVG*(2.764195 +
     .   0.73493*TSNL)) / 730.
       IF(WSTRSD.LT.0.0001) WSTRSD = 0.0001
       IF(WSTRSD.GT.1.0) WSTRSD = 1.0
       IF(WSTRSN.LT.0.0001) WSTRSN = 0.0001
       IF(WSTRSN.GT.1.0) WSTRSN = 1.0
      DAYL1 = DAYLNG / 24.
      DAYL2 = (24.-DAYLNG) / 24.
      DO 24 LAYER = 1, LR
      TSDL = TSOILD(LAYER)
      TSNL = TSOILN(LAYER)
      CALTSD = TSDL*(-71.3947+(TSDL*1.22793))
      CALTSN = TSNL*(-71.3947+(TSNL*1.22793))
      STRESD = (CALMAX + CALTSD + RN*(-0.512136-0.078977*PSIMAX) +
     .  (0.73493*PSIMAX*TSDL)) / 730.
      STRESN = (CALMAX + CALTSN + 17.92476 + PSIMAX*(2.764195 +
     . 0.73493*TSNL)) / 730.
      IF(STRESD.LT.0.0001) STRESD = 0.0001
      IF(STRESD.GT.1.) STRESD = 1.
      IF(STRESN.LT.0.0001) STRESN = 0.0001
      IF(STRESN.GT.1.) STRESN = 1.
C  ROOTXP PROVIDES ROOTS SAME EXPONENTIAL GROWTH POTENTIAL AS YOUNG
C  BOLLS.  DID NOT HAVE ROOT GROWTH DATA UNDER LUXURY CH2O SUPPLY.
      ROOTXP = ((-0.2120865+0.016079*TSDL)*DAYL1 +
     .  (-0.2120865+0.016079*TSNL)*DAYL2)
      KR = KRL(LAYER)

      DO 37 KOLUMN = 1, KR
      PDWRT(LAYER,KOLUMN) = RTWTCG(LAYER,KOLUMN) * ROOTXP
C POTENTIAL DELTA WEIGHT OF ROOTS FOR THE CELL, GM.
      SPDWRT = SPDWRT + PDWRT(LAYER,KOLUMN)
C SUM OF POTENTIAL DELTA WEIGHT OF ROOTS FOR ALL CELLS, GM.
 37   CONTINUE
 24   CONTINUE
      WSTRSD = (STRESD + WSTRSD)/2
      WSTRSN = (STRESN + WSTRSN)/2
      RETURN
 2    CONTINUE
      RGCF = RCH2O / SPDWRT
C  RCH2O AND SPDWRT ARE IN GRAMS / PLANT AFTER RETURN FROM MAIN.
C ROOT GROWTH CORRECTION FACTOR.  RATIO OF AVAILABLE CARBOHYDRATE
C TO SINK STRENGTH.
      DO 5 LAYER  = 1, LR
      KR = KRL(LAYER)
      DO 5 KOLUMN = 1, KR
      IF(IDAY.LE.3) GO TO 7
      IF(IDAY.LE.12) GO TO 6
      RTWT(LAYER,KOLUMN,3) = RTWT(LAYER,KOLUMN,3) + RTP2 *
     .  RTWT(LAYER,KOLUMN,2)
      RTWT(LAYER,KOLUMN,2) = RTWT(LAYER,KOLUMN,2) * (1.-RTP2)
 6    CONTINUE
      RTWT(LAYER,KOLUMN,2) = RTWT(LAYER,KOLUMN,2) + RTP1 *
     .  RTWT(LAYER,KOLUMN,1)
      RTWT(LAYER,KOLUMN,1) = RTWT(LAYER,KOLUMN,1) * (1.-RTP1)
 7    DWRT(LAYER,KOLUMN) = RGCF * PDWRT(LAYER,KOLUMN)
C     NOTE THAT RGCF CAN BE MODIFIED BEFORE USE ABOVE.
C DELTA WEIGHT OF ROOTS, ACTUAL, FOR THE CELL, GM DM.
C REDUCED FROM PDWRT DUE TO LACK OF CARBOHYDRATE.
 5    CONTINUE
      LRT = LR
      NLR = LR
      DO 8 L=1,NLR
      LDC = G * (1-L/NL)
      LD1 = L + 1 - (L/NL)
      KR = KRL(L)
      DO 9 K=1,KR
      KR1 = K + 1 -(K/NK)
       KL1 = K - 1 +(1/K)
      IRC = 1 - (K/NK)
```

```
        LC = 1 - (1/K)

        IF(RTWTCG(L,K).LT.THRLN) GO TO 10

        SRWP = (1./PSIS(L,K)**3+IRC/PSIS(L,KR1)**3+LDC/PSIS(LD1,K)**3   +
          LC/PSIS(L,KL1)**3 )
    GROWTH INSIDE CELL
        RTWT(L,K,1) = RTWT(L,K,1) + DWRT(L,K)*(1./PSIS(L,K)**3)/SRWP
    GROWTH TO THE LEFT
        RTWT(L,KL1,1) = RTWT(L,KL1,1) + DWRT(L,K)*(LC/PSIS(L,KL1)**3)/SRWP
    GROWTH TO THE RIGHT
        RTWT(L,KR1,1) = RTWT(L,KR1,1)+DWRT(L,K)*(IRC/PSIS(L,KR1)**3)/SRWP
    GROWTH DOWNWARD
        RTWT(LD1,K,1) = RTWT(LD1,K,1)+DWRT(L,K)*(LDC/PSIS(LD1,K)**3)/SRWP

        IF(K.NE.KR.OR.KR.GE.20) GO TO 11
    INCREMENT KOLUMN COUNTER FOR THIS LAYER
        KRL(L) = KRL(L) + 1
 11     CONTINUE
        IF(L.NE.LR.OR.LR.GE.NL) GO TO 9
    INCREMENT LAYER COUNTER
        IF(K.EQ.1) LRT = LR + 1
        KRL(L+1) = KRL(L+1) + 1
        GO TO 9
 10     CONTINUE
   GROWTH INSIDE CELL ONLY
        RTWT(L,K,1) = RTWT(L,K,1) + DWRT(L,K)

 9      CONTINUE
 8      CONTINUE
        LR =LRT

        ROOTS = 0.
        PSITOT = 0.
        PSINUM = 0.
        DO 23 LAYER  = 1, LR
        KR = KRL(LAYER)
        DO 23 KOLUMN = 1, KR
C SLOUGH ROOTS IN ALL BOX CARS IN ALL CELLS.
        WTBSLF = RTWT(LAYER,KOLUMN,2)
        RTWT(LAYER,KOLUMN,2) = WTBSLF*(1. - SLF)
        WTSLFD = WTSLFD + (WTBSLF-RTWT(LAYER,KOLUMN,2))
        ROOTSV(LAYER,KOLUMN) = RTWT(LAYER,KOLUMN,1) + RTWT(LAYER,KOLUMN,2)
     .     + RTWT(LAYER,KOLUMN,3)
        ROOTS = ROOTS + ROOTSV(LAYER,KOLUMN)
 23     CONTINUE
        ROOTWT = ROOTS * POPFAC * 2.
C   ROOTWT IS DOUBLED TO ACCOUNT FOR FULL PROFILE.
        DO 25 LAYER = 1, LR
        KR = KRL(LAYER)
        DO 26 KOLUMN = 1, KR
        IF(PSIS(LAYER,KOLUMN).LT.-15.0) GO TO 26
        PSITOT = PSITOT + PSIS(LAYER,KOLUMN)
        PSINUM = PSINUM + 1
 26     CONTINUE
 25     CONTINUE
        IF(IFIX(PSINUM).LE.0) GO TO 27
        PSIAVG = PSITOT / PSINUM
        RETURN
   27 PSIAVG = -15.
      WRITE(3,28)
   28 FORMAT(/' ',42(1H*)/' *  PLANT IS DEAD DUE ',
     .'TO MOISTURE STRESS  *'/' ',42(1H*))
      RETURN
      END

      SUBROUTINE PLTMAP
C   ***********************************************************
C   *                                                         *
C   *                    PLTMAP SUBROUTINE                    *
C   *                                                         *
C   ***********************************************************
      INTEGER FCODE,ADDBR,DAY,DAYABS,DAYINC,DAYNUM,TSQ,XTRES
      INTEGER COUNT,SCODE,BOLAGE,AGEBOL,BAGE
      INTEGER FCODES(450), ABSDAY(450)
      REAL LAI,LEAFW,LAREA,LATUDE,NDLAY,INT,LEFABS,LEAFWT,NOPEN,NF,NV
      REAL LOSSQR, NYTWTF, MH2O
      DIMENSION FDLAYC(5), VDLAYC(5), BOLAGE(450), FRUITS(450)
      DIMENSION WTSQ(450), WTBO(450), SQAGE(450), SCDLAY(3,30,5)
      COMMON /CALIB / CZD, CZN, CSQ, CBL, CL, CM, CPF, CVB,DPSMX,DPBMX
      COMMON /CAL2  / XTR1, XTR2, XTR3, XTR4, A1, A21, A22, A31, A32
      COMMON /CODES / FCODE(3,30,5), LCODE(3,30,5), SCODE(7), SITES,
     .                SITEZ
      COMMON /COM   / AREA, LAREA(3,30,5)
      COMMON /COM1  / EMERGE, KARDS, LAI, SEASON, VARITY, YIELD
      COMMON /DAYOFF/ DAYABS(3,30,5), ISQ
      COMMON /INCRS / DAY, DAYINC, NDAYS
      COMMON /FACTOR/ DAYWTF, NYTWTF, DAYTYM, NYTTYM, DROOT, NROOT
      COMMON /FRUIT / COUNT, FLOSS, SFLOSS, PINHED, SQRZ, GBZ,
     .                NOPEN, ABZ, GBZ2
      COMMON /FRUTE / FFRUT(3,30,5), MCODE(3,30,5), SQLOSS(170),
     .                BOLOSS(170), SBLUM(170), LOSSQR(170)
      COMMON /KLM   / AVGT(3,30,5), AVTEMP
      COMMON /LEAFAV/ FRATIO
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /LOST  / GBLOS, LEFABS, PQFLR, WTSLFD, XTRAC
      COMMON /NIT   / BURRN, ROOTN, SEEDN, SLEAFN, STEMN
```

```
      COMMON /NUMS  / NFBR(3), NNOD(3,30), NVBRCH
      COMMON /POP   / PN, POPFAC
      COMMON /PREFRT/ AGEPFN(9), AVTPFN(9), NUMPFN, PFAL(9), PFAREA,
     .                PFDAL, PFDALN(9), PFDWL, PFDWLD(9), PFDWLN(9),
     .                PFWL(9), PFDALD(9)
      COMMON /SIZES / POPPLT, ROWSP, Z
      COMMON /SOLAR / INT, RI, RN, WATTSM
      COMMON /STRESS/ CSTRES, NF, NSTRES, NV, WSTRSD, WSTRSN, XTRES,
     .                STRSD, STRSN, VSTRES, FSTRES
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TIMKLM/ AGE(3,30,5), AGEBOL(3,30,5), DELAY(3,30),
     .                VDELAY(3), LAGE(3,30,5), BAGE(3,30,5)
      COMMON /WEIGHT/ COTXX, GBOLWT, LEAFWT, PLANTW, ROOTWT,SQWT, STEMWT
      COMMON /WETS  / MH2O, POLYNA, PSIAVG, PSIMAX, RAIN
      COMMON /WTKLM / BOLWGT(3,30,5), LEAFW(3,30,5), SQRWT(3,30,5),
     .                STMWT(170)
      EQUIVALENCE (FCODES(1),FCODE(1)), (DAYABS(1),ABSDAY(1))
      EQUIVALENCE (BOLAGE(1),AGEBOL(1)), (FRUITS(1),FFRUT(1))
      EQUIVALENCE (WTSQ(1),SQRWT(1)), (WTBO(1),BOLWGT(1))
      EQUIVALENCE (SQAGE(1),AGE(1))
      DATA V/0./, GIN/0./, FL/0./, FS/0./, IBLUM/0/, MEM/1/
      DATA SCDLAY/450*0./
      J = 0.
      GBZ2 = 0.
      ABZ  = 0.
      SUMSQR = 0.
      SUMBOL = 0.
      SQRZ = 0.
      POLOSS = 0.
      SUMFRU = 0.
      FDROPS = 0.
      FDROPB = 0.
      DSITES = SITEZ-SITES
      SITES = SITEZ
      SITEZ = 0
      SCODE(1) = 0
      SCODE(2) = 0
      SCODE(3) = 0
      SCODE(4) = 0
      SCODE(5) = 0
      SCODE(6) = 0
      SCODE(7) = 0
      BLUM = 0.
      COUNT = 0
      SQABZ = 0.
      BOLABZ = 0.
      NDLAY = 1.33 *(NSTRES-1) / 4.
      CDLAYF = A1 + FSTRES*(A21 + A22*FSTRES)
      IF(CDLAYF.LT.0.) CDLAYF = 0.
      IF(GBOLWT.EQ.0.) CDLAYF = 0.
      CDLAYV = 1.0 + FSTRES*(XTR2 + XTR3*FSTRES)
      IF(CDLAYV.LT.0.) CDLAYV = 0.
      IF(ISQ.GT.0) GO TO 33
C  DECIDE WHETHER TO ADD A PREFRUIT NODE.
      JNUM = NUMPFN
      IF(AGEPFN(JNUM).GT.66.) GO TO 33
      DO 3 J=1,JNUM
        AGEPFN(J) = AGEPFN(J) + 1
        AVTPFN(J) = ( AVTPFN(J)*AGEPFN(J)+TAVG) / (AGEPFN(J)+1)
        IF(ISQ.GT.0) GO TO 3
        IF(J.NE.NUMPFN.OR.NUMPFN.GE.9) GO TO 3
        TI = (41.205 + AVTPFN(J)*(-2.67219+AVTPFN(J)*0.0459705))*1.3
        IF(AGEPFN(J).LT.(TI+CDLAYV+NDLAY )) GO TO 3
        NUMPFN = NUMPFN + 1
        AVTPFN(NUMPFN) = TAVG
        PFAL(NUMPFN) = .04
        PFWL(NUMPFN) = .04 * (DAYWTF + NYTWTF)/2.
        STEMWT = STEMWT - PFWL(NUMPFN)
  3   CONTINUE
 33   CONTINUE
C  IF FIRST SQUARE IS PRESENT, SKIP TO MATRIX CALCULATIONS.
      IF(ISQ.GT.0) GO TO 10
      AVTEMP = ((DAY-1)*AVTEMP + TAVG ) /DAY
C IF COTTON IS A "HI PLAINS" VARIETY, V = 1
C IF COTTON IS A "DELTA" VARIETY, V = 0
      TSQ = (301.26 + AVTEMP*(-19.5287 + AVTEMP*0.363473))*0.78
      IF(V.EQ.1.) TSQ = (801.976 + AVTEMP*(-92.388+AVTEMP*(3.62313-
     .  AVTEMP*.0466709)))*0.78
C  RELATIONSHIPS DERIVED FROM DATA OF MORAGHAN ET. AL. (1968)
C  EFFECTS OF TEMPERATURE AND PHOTOPERIOD ON FLORAL INITIATION
C  AMONG STRAINS OF COTTON.  COTTON GR. REV. 45:91-100 TABLE 2.
C  FOR M-8 AND CA491.
C TSQ=NUMBER OF DAYS FROM EMERGENCE TO FIRST SQUARE
C DAY = JULIAN DAYS FROM EMERGENCE
      IF(DAY.LE.TSQ) RETURN
C HAVE FIRST SQUARE, INITIALIZE THAT NODES AREA, AVGT, AND LEAF.
      ISQ=DAY
      WRITE(3,9) ISQ
  9   FORMAT(' *********** FIRST SQUARE ON DAY ',I3,' ***********')
      FCODE(1,1,1) = 1
      MCODE(1,1,1) = 1
      FFRUT(1,1,1) = 1.
      NFBR(1) = 1
      NNOD(1,1) = 1
      FSTRES = 1.0
      AVGT(1,1,1) = TAVG
C AVGTI=AVERAGE TIME INTERVAL BETWEEN MAINSTEM NODES
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      AVGTI = (41.205 + AVTEMP*(-2.67219 + AVTEMP*0.0459705))
C L=MAINSTEM NODE NUMBER, M= FRUITING BRANCH NODE NUMBER,
C K=VEGETATIVE STEM NUMBER
 10   CONTINUE
C DECIDE WHETHER TO ADD A VEGETATIVE BRANCH.
      PIN = .0457*DSITES
      PINHED = PIN + PINHED
      MVBRCH = NVBRCH
      IF(NVBRCH.EQ.3) GO TO 20
      IF(INT.GE.0.9)  GO TO 20
      TI = 41.205+AVGT(NVBRCH,1,1)*(-2.67219+AVGT(NVBRCH,1,1)*0.0459705)
      TI = TI + CDLAYV * NDLAY + CZD
      IF(AGE(NVBRCH,1,1).LT.TI) GO TO 20
      NVBRCH = NVBRCH + 1
      FFRUT(NVBRCH,1,1) = 1.
      FCODE(NVBRCH,1,1) = 1
      IF(PINHED.LT.1.) GO TO 28
      PINHED = PINHED - 1.
      MCODE(NVBRCH,1,1) = 4
  28  CONTINUE
      LAREA(NVBRCH,1,1) = .04
      LEAFW(NVBRCH,1,1) = .04 * (DAYWTF + NYTWTF)/2.
      STEMWT = STEMWT - LEAFW(NVBRCH,1,1)
      LCODE(NVBRCH,1,1) = 1
      MCODE(NVBRCH,1,1) = 1
      AVGT(NVBRCH,1,1)  = TAVG
      NFBR(NVBRCH)      = 1
      NNOD(NVBRCH,1)    = 1
   20 DO 30 K = 1,MVBRCH
C  DECIDE WHETHER TO ADD A FRUITING BRANCH TO THIS VEGETATIVE BRANCH.
        NBRCH = NFBR(K)
        IF(NBRCH.GE.30) GO TO 31
        AT = AVGT(K,NBRCH,1)
        VDELAY(K) = VDELAY(K) + CDLAYV + NDLAY
        TI = (41.205+AT*(-2.67219+AT*0.0459705))*.51
C THE DATA FOR THIS ESTIMATE OF THE EFFECT OF TEMPERATURE ON TIME
C BETWEEN NODES ON A FRUITING BRANCH ARE PUBLISHED IN HESKETH, J.D.,
C D.N. BAKER, AND W.G. DUNCAN (1972) THE SIMULATION OF GROWTH AND
C YIELD IN COTTON II. ENVIRONMENTAL CONTROL OF MORPHOGENESIS. CROP
C SCI. 12:436-439 - EXCEPT FOR THE FACTOR .51. THIS FACTOR IS REQUIRED
C TO MATCH THE PHYTOTRON GROWTH RATES TO THE FIELD DATA OF BRUCE, R.R.,
C AND ROMKENS. (1965) FRUITING AND GROWTH IN RELATION TO SOIL MOISTURE
C TENSION.AGRON. J. 57:135-140.
        IF(AT.GT.26.8)AT = 26.8
        IF(K.GT.1) TI = (25.1 + AT*(0.81549-AT*0.056055))*.51
C THIS PROVIDES THE SAME MORPHOGENETIC RATE ON SECONDARY VEGETATIVE
C BRANCHES AS ON FRUITING BRANCHES.
        IF(AGE(K,NBRCH,1).LT.(TI+VDELAY(K))) GO TO 31
        NFBR(K) = NFBR(K) + 1
        NEWBR = NFBR(K)
        NNOD(K,NEWBR) = 1
        FFRUT(K,NEWBR,1) = 1.
        MCODE(K,NEWBR,1) = 1
        FCODE(K,NEWBR,1) = 1
        IF(PINHED.LT.1.) GO TO 27
        PINHED = PINHED - 1.
        MCODE(K,NEWBR,1) = 4
   27   LAREA(K,NEWBR,1) = .04
        LEAFW(K,NEWBR,1) = .04 * (DAYWTF + NYTWTF)/2.
        STEMWT = STEMWT - LEAFW(K,NEWBR,1)
        LCODE(K,NEWBR,1) = 1
        AVGT(K,NEWBR,1)  = TAVG
        NBRCH = NFBR(K)
        VDELAY(K) = 0.
C
 31     DO 40 L=1,NBRCH
C  DECIDE WHETHER TO ADD A NODE TO THIS FRUITING BRANCH OF THIS
C      VEGETATIVE BRANCH.
          NNID = NNOD(K,L)
          IF(NNID.EQ.5) GO TO 32
          AT = AVGT(K,L,NNID)
          DELAY(K,L) = DELAY(K,L) + CDLAYF + NDLAY
          IF(DELAY(K,L).GT.25.0)DELAY(K,L) = DELAY(K,L) + 50.
          IF(AT.GT.26.8) AT = 26.8
          TI = (25.1 + AT*(0.81549-AT*0.056055))*.51
          IF(AGE(K,L,NNID).LT.(TI+DELAY(K,L))) GO TO 32
          NNOD(K,L) = NNOD(K,L) + 1
          NEWNOD = NNID + 1
          FFRUT(K,L,NEWNOD) = 1.
          FCODE(K,L,NEWNOD) = 1
          IF(PINHED.LT.1.) GO TO 29
          PINHED = PINHED - 1.
          MCODE(K,L,NEWNOD) = 4
 29       MCODE(K,L,NEWNOD) = 1
          LAREA(K,L,NEWNOD) = .04
          LEAFW(K,L,NEWNOD) = .04 * (DAYWTF + NYTWTF)/2.
          STEMWT = STEMWT - LEAFW(K,L,NEWNOD)
          LCODE(K,L,NEWNOD) = 1
          AVGT(K,L,NEWNOD) = TAVG
          NNID = NNOD(K,L)
          DELAY(K,L) = 0.
C
 32       DO 50 M=1,NNID
C  AGE ALL EXISTING NODES AND UPDATE AVERAGE TEMPERATURE OF EACH.
            AGE(K,L,M) = AGE(K,L,M) + 1
            IF(FRATIO.LT.CVB) LAGE(K,L,M) = LAGE(K,L,M) + 1
            IF(FRATIO.GE.CVB.AND.WSTRSD.GT.CM)LAGE(K,L,M)=LAGE(K,L,M)+1
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```
             AVGT(K,L,M) = (AVGT(K,L,M)*AGE(K,L,M)+TAVG)/(AGE(K,L,M)+1)
C  NOW AVGT(K,L,M) IS BOLL RUNNING AVERAGE TEMPERATURE
             IF(BOLWGT(K,L,M).GT.0.) AVGT(K,L,M) = (AVGT(K,L,M)*
             AGEBOL(K,L,M) + TAVG)/(AGEBOL(K,L,M) + 1)
             SCDLAY(K,L,M) = SCDLAY(K,L,M) + CDLAYF
             AGENOD = AGE(K,L,M) - SCDLAY(K,L,M)*CBL
             AVTNOD = AVGT(K,L,M)
             IF(AGE(K,L,M).LT.70..OR.LCODE(K,L,M).EQ.4) GO TO 52
             LCODE(K,L,M) = 4
             LEFABS = LEFABS + LEAFW(K,L,M)
             LEAFWT = LEAFWT - LEAFW(K,L,M)
             SLEAFN = SLEAFN - LEAFW(K,L,M) * .02
             AREA = AREA - LAREA(K,L,M)
             LAREA(K,L,M) = 0.
             LEAFW(K,L,M) = 0.
 52          CONTINUE
             IF(FCODE(K,L,M).EQ.0) GO TO 50
             NOWGO = FCODE(K,L,M)
             GO TO (60,70,80,90,60,71,71), NOWGO
C  FCODE=1.  A SQUARE - X.  DO CALCULATIONS PERTAINING ONLY TO SQUARES.
C  SQUARES ARE ABSCISED AT 101.
 60          CONTINUE
C  FCODE = 1 ( SQUARE ) ,   FCODE = 5 ( MARKED SQUARE )
             BLOOM = 218.+AVTNOD*(-13.4669+0.227077*AVTNOD)
             IF(FFRUT(K,L,M).LT.0.)FFRUT(K,L,M)=0.
             IF(DAYABS(K,L,M).EQ.DAY) MCODE(K,L,M) = 4
             IF(AGENOD.LT.BLOOM) GO TO 51
C  IF SQUARE IS OLD ENOUGH, MAKE IT A GREEN BOLL.
             AVGT(K,L,M) = TAVG
C THIS SETS AVTNOD TO RUNNING AVERAGE SINCE BOLLSET
             IF(POLYNA.EQ.1.) GO TO 7
             MCODE(K,L,M) = 4
             WRITE(3,1050) POLOSS
 1050        FORMAT('   POLOSS = ',F8.4)
             POLOSS = POLOSS + FFRUT(K,L,M)
             IF(POLOSS.GT.1.) POLOSS = 1.
             SQWT = SQWT - SQRWT(K,L,M)
             SQRWT(K,L,M) = 0.
             GO TO 51
  7          CONTINUE
             IBLUM = IBLUM + 1
             BLUM = BLUM + FFRUT(K,L,M)
             IF(FCODE(K,L,M).EQ.1) MCODE(K,L,M) = 2
             FCODE(K,L,M) = 7
             BOLWGT(K,L,M) = .31 * SQRWT(K,L,M)
             PQFLR = PQFLR + .69 * SQRWT(K,L,M)
             GBOLWT = GBOLWT + BOLWGT(K,L,M)
             SQWT = SQWT - SQRWT(K,L,M)
             SQRWT(K,L,M) = 0.
             GO TO 51
 71          CONTINUE
C  FCODE=7 (YOUNG GREEN BOLL)
             IF(AGEBOL(K,L,M).GE.15) FCODE(K,L,M) = 2
             IF(FFRUT(K,L,M).LT.0.)FFRUT(K,L,M)=0.
C  FCODE=2 (GREEN BOLL),   FCODE=6 (MARKED GREEN BOLL)
  70         IF(DAYABS(K,L,M).EQ.DAY) MCODE(K,L,M) = 4
             AGEBOL(K,L,M) = AGEBOL(K,L,M) + 1
         IF(FRATIO.LT.CVB)BAGE(K,L,M) = BAGE(K,L,M) + 1
         IF(FRATIO.GE.CVB.AND.WSTRSD.GT.CM)BAGE(K,L,M) = BAGE(K,L,M) + 1
             BOLDAZ = AGEBOL(K,L,M)
             WFAC = XTR1/WSTRSD
             AT2 = AVTNOD + WFAC
             OPEN = 371.7 + AT2 * (-20.3622 + 0.304956*AT2)
C  IF GREEN BOLL IS OLD ENOUGH, MAKE IT AN OPEN BOLL.
             IF(BOLDAZ.LT.OPEN) GO TO 51
C OPEN THE BOLL
             IF(MCODE(K,L,M).EQ.2) MCODE(K,L,M) = 3
             FCODE(K,L,M)=3
             COTXX = COTXX + BOLWGT(K,L,M)
             SEEDN = SEEDN - BOLWGT(K,L,M)*SEEDN/GBOLWT
             BURRN = BURRN - BOLWGT(K,L,M)*BURRN/GBOLWT
             GBOLWT = GBOLWT - BOLWGT(K,L,M)
C GIN PERCENTAGE = GINP FROM HESKETH & LOW
             GINP = (55.00 - .6755*AVTNOD) / 100.
C ORIGINAL COEFF. WAS 50.54
C NOPEN IS NUMBER OF OPEN BOLLS
             NOPEN=NOPEN+FFRUT(K,L,M)
             IF(NOPEN.GT.0.0)GIN=(GINP+GIN)/NOPEN
C YIELD = 500 LB. BALES / ACRE OF LINT
         WB = BOLWGT(K,L,M)/FFRUT(K,L,M)
             YIELD = YIELD + (GINP*(BOLWGT(K,L,M)*.75)*POPPLT/226800.)
C K=(453.6 G/ LB) * ( 500 LB. / BALE)
C FS=FIBER STRENGTH : (G / TEX * 1/8 INCH)
             FSX = 56.603 + AVTNOD *(-2.921+0.059*AVTNOD)
             FS=(FSX+FS)/NOPEN
C FL IS FIBER LENGTH ( INCHES, 2.5% SPUN )
             FLX=1.219-.0065*AVTNOD
             FL=(FL+FLX)/NOPEN
             BOLWGT(K,L,M) = 0.
 80      CONTINUE
         GO TO 51
 90      CONTINUE
C  FCODE WRONGLY SET TO 4
         WRITE(3,1008) K,L,M
 1008 FORMAT('+++++++++++++++++++++++++ FCODE=4 AT ',3(1X,I2) )
 51          IXX = FCODE(K,L,M)
             SCODE(IXX) = SCODE(IXX) + 1
```

[illegible]

[illegible]

[illegible]

)
1
2
3
4
5
36
37
38
89
90

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      FDROPB = DPBMX
      BOLLOS = DPBMX * SUMBOL
 91   SUMBOL = SUMBOL - BOLLOS
 86   FDROP = FDROPS + FDROPB
      DO 85 IQ = 1, 450
      IF(FCODES(IQ).EQ.0) GO TO 85
      IF (FCODES(IQ).NE.1.AND.FCODES(IQ).NE.5) GO TO 81
      SQRZ = SQRZ + FRUITS(IQ)
      IF(SQAGE(IQ).LT.A31.OR.SQAGE(IQ).GT.A32) GO TO 85
      WTLOS = WTSQ(IQ) * FDROPS
      WTSQ(IQ) = WTSQ(IQ) - WTLOS
      PQFLR = PQFLR + WTLOS
      SQWT = SQWT - WTLOS
      FRUIT = FRUITS(IQ)
      FRUITS(IQ) = FRUITS(IQ) - (FRUITS(IQ)*FDROPS)
      IF(FRUITS(IQ).GT.FRUIT)FRUITS(IQ) = 0.
      SQRZ = SQRZ - (FRUIT - FRUITS(IQ))
      SQABZ = SQABZ + (FRUIT - FRUITS(IQ))
      GO TO 85
 81   IF(FCODES(IQ).EQ.2)GBZ2 = GBZ2 + FRUITS(IO)
      IF(FCODES(IQ).EQ.2.OR.FCODES(IQ).EQ.3.OR.FCODES(IQ).EQ.4)GO TO 85
      IF(BOLAGE(IQ).GE.15)GO TO 85
      WTLOS = WTBO(IQ) * FDROPB
      WTBO(IQ) = WTBO(IQ) - WTLOS
      GBLOS = GBLOS + WTLOS
      GBOLWT = GBOLWT - WTLOS
      FRUIT = FRUITS(IQ)
      FRUITS(IQ) = FRUITS(IQ) - FRUITS(IQ)*FDROPB
      GBZ2 = GBZ2 + FRUITS(IQ)
      BOLABZ = BOLABZ + FRUIT - FRUITS(IQ)
      SEEDN = SEEDN - (WTLOS/GBOLWT)*SEEDN
      BURRN = BURRN - (WTLOS/GBOLWT)*BURRN
 85   CONTINUE
      ABZ = SQABZ + BOLABZ
C  ABSCISE ALL PREFRUIT LEAVES OLDER THAN 65 DAYS.
      DO 4 J=1,NUMPFN
        IF(ISQ.GT.0) AGEPFN(J) = AGEPFN(J) + 1
        IF(AGEPFN(J).LT.70.) GO TO 4
        AREA = AREA - PFAL(J)
        PFAL(J) = 0.
        LEFABS = LEFABS + PFWL(J)
        LEAFWT = LEAFWT - PFWL(J)
        SLEAFN = SLEAFN - PFWL(J) * .02
        PFWL(J) = 0.
 4    CONTINUE
 22   POPSLF = WTSLFD * POPFAC
      IF(DAY.EQ.DAYINC)WRITE(3,1001)NUMPFN,NDLAY,CDLAYV,CDLAYF,FLOSS,
     . GBLOS,LEFABS,PQFLR,WTSLFD
 1001 FORMAT(' NUMPFN   NDLAY  CDLAYV  CDLAYF   FLOSS   GBLOS  LEFABS'
     .,'   PQFLR  WTSLFD',/,3X,I1,6X,F5.2,2X,F5.2,4X,F5.2,3X,F5.2,2X,
     .F5.2,4X,F5.2,3X,F5.2,2X,F5.2)
      RETURN
      END

      SUBROUTINE OUT(ARRAY,TTL1,TTL2,RANGE,UNITS,TOTAL,UNITST,IGO)
C  ***********************************************************
C  *                                                         *
C  *  THIS SUBROUTINE PLOTS THE SOIL SLAB AND THE DENSITIES  *
C  *  OF THE ARRAY ELEMENTS IN EACH CELL.                    *
C  *                                                         *
C  ***********************************************************
      DIMENSION ARRAY(20,20), RANGE(11)
      INTEGER*2 KHAR(20,20), KA(12)
      INTEGER TTL1(10), TTL2(10), UNITS(6), UNITST(4)
C
      COMMON /PLOTS / IDAY, NFRQ, NFRQX, NPD, NPN, NPP, NPR, NPW
C
      DATA KA/' ','0','1','2','3','4','5','6','7','8','9','*'/
      DATA KHAR/400*' '/
      DO 1 K=1, 20
      DO 1 L=1, 20
      ARAYLK = ARRAY(L,K)
      DO 2 I=1, 11
      RANGE1 = RANGE(I)
      IF(ARAYLK.LE.RANGE1) GO TO 1
 2    CONTINUE
      I = 12
 1    KHAR(L,K) = KA(I)
      IF(IGO.EQ.2) GO TO 15
      RANGE1 = RANGE(1)
      WRITE(3,100) TTL1,IDAY,TTL2,UNITS,KA(1),RANGE1,RANGE1,KA(2),
     .  RANGE(2)
 100  FORMAT(/6X,10A4,17X,'DAY ',I3/6X,10A4//6X,'UNITS - ',6A4,23X,
     . 'LEGEND'//24X,'1 1 1 1 1 1 1 1 1 1 2'/6X,'1 2 3 4 5 6 7 8 9 0 ',
     . '1 2 3 4 5 6 7 8 9 0',18X,A1,' <= ',F8.4//53X,F8.4,' < ',
     . A1,' <= ',F8.4)
      DO 14 L=1, 17, 2
      L1 = L+1
 14   WRITE(3,102)L,(KHAR(L,K),K=1,20),L1,(KHAR(L+1,K),K=1,20),
     .  RANGE((L+3)/2),KA((L+3)/2+1),RANGE((L+3)/2+1)
 102  FORMAT(1X,I2,3X,20A2/1X,I2,3X,20A2,7X,F8.4,' < ',
     .  A1,' <= ',F8.4)
      L19 = 19
      L20 = 20
      WRITE(3,104) L19,(KHAR(19,K),K=1,20),L20,(KHAR(20,K),K=1,20),
     . RANGE(11),KA(12),TOTAL,UNITST
 104  FORMAT(1X,I2,3X,20A2/1X,I2,3X,20A2,7X,F8.4,' < ',A1//
```

```
 OTAL = ',F11.4,1X,4A4)
 
 1 = RANGE(1)
 (3,200) TTL1,IDAY,TTL2,UNITS,KA(11),RANGE1,RANGE1,KA(1),
 GE(2)
 T(/6X,10A4,17X,'DAY ',I3/6X,10A4//6X,'UNITS - ',6A4,23X,
 END'//24X,'1 1 1 1 1 1 1 1 1 1 2'/6X,'1 2 3 4 5 6 7 8 9 0 ',
 2 3 4 5 6 7 8 9 0',18X,A1,' < ',E8.2//53X,E8.2,' < ',
 .' < ',E8.2)
 5 L=1, 17, 2
 L+1
 E(3,202)L,(KHAR(L,K),K=1,20),L1,(KHAR(L+1,K),K=1,20),
 NGE((L+3)/2),KA((L+1)/2+1),RANGE((L+3)/2+1)
 AT(1X,I2,3X,20A2/1X,I2,3X,20A2,7X,E8.2,' < ',
 ,' < ',E8.2)
 = 19
 = 20
 TE(3,204) L19,(KHAR(19,K),K=1,20),L20,(KHAR(20,K),K=1,20),
 ANGE(11),KA(12),TOTAL,UNITST
 MAT(1X,I2,3X,20A2/1X,I2,3X,20A2,7X,E8.2,' < ',A1//
 X,'TOTAL = ',F11.4,1X,4A4)
 .D(2,1000) IDUMI
 MAT(I4)
 URN
 )

 BROUTINE COTPLT
 ***************************************************************
                                                              *
 IS SUBROUTINE PLOTS THE COTTON PLANT WITH THE                *
 RRESPONDING SYMBOLS IN THE CORRECT LOCATIONS.                *
 QUARE-X  GREEN BOLL-*  OPEN BOLL-$  ABSCISED-O               *
                                                              *
 ***************************************************************

 NTEGER PRI(3,30), PRT(3,30,5), CHAR1(7), CHAR2(7), CHARI

 COMMON /FRUTE / FFRUT(3,30,5), MCODE(3,30,5), SQLOSS(170),
.                BOLOSS(170)
 COMMON /NUMS  / NFBR(3), NNOD(3,30), NVBRCH

 DATA CHAR1/'-X','-*','-$','-O','-X','-*','-*'/
 DATA CHAR2/'X-','*-','$-','O-','X-','*-','*-'/
 DATA CHARI/'I'/
 DATA PRT/450*' '/,PRI/90*' '/
 DO 1 K=1,NVBRCH
   NBRCH=NFBR(K)
   DO 2 L=1,NBRCH,2
     NNID  =NNOD(K,L)
     DO 3 M=1,NNID
       IF(MCODE(K,L,M).EQ.0)GO TO 2
       ICODE = MCODE(K,L,M)
       PRI(K,L) = CHARI
     PRT(K,L,M) = CHAR1(ICODE)
   CONTINUE
   DO 4 L=2,NBRCH,2
     NNID = NNOD(K,L)
     DO 5 M=1,NNID
       M2 = 6-M
       IF(MCODE(K,L,M).EQ.0) GO TO 4
       ICODE = MCODE(K,L,M)
       PRI(K,L) = CHARI
     PRT(K,L,M2) = CHAR2(ICODE)
   CONTINUE
 CONTINUE
 NBRCH = NFBR(1)
 IF(NBRCH.EQ.(NBRCH/2*2)) GO TO 20
 DO 10 L=1,NBRCH,2
   LX = NBRCH +1 - L
   LX1 = LX-1
   WRITE(3,100) PRI(1,LX),(PRT(1,LX,M),M=1,5),PRI(2,LX),
.  (PRT(2,LX,M),M=1,5),PRI(3,LX),(PRT(3,LX,M),M=1,5)
   IF(LX1.EQ.0) GO TO 6
   WRITE(3,101) (PRT(1,LX1,M),M=1,5),PRI(1,LX1),
.  (PRT(2,LX1,M),M=1,5),PRI(2,LX1),(PRT(3,LX1,M),M=1,5),
.  PRI(3,LX1)
100    FORMAT(1X,10X,A1,5A2,2X,10X,A1,5A2,2X,10X,A1,5A2)
101    FORMAT(1X,5A2,A1,10X,2X,5A2,A1,10X,2X,5A2,A1)
10   CONTINUE
     GO TO 6
20   DO 21 L=1,NBRCH,2
       LX = NBRCH + 1 - L
       LX1 = LX - 1
       WRITE(3,101) (PRT(1,LX,M),M=1,5),PRI(1,LX),
.      (PRT(2,LX,M),M=1,5),PRI(2,LX),(PRT(3,LX,M),M=1,5),
.      PRI(3,LX)
       IF(LX1.EQ.0) GO TO 6
       WRITE(3,100) PRI(1,LX1),(PRT(1,LX1,M),M=1,5),
.      PRI(2,LX1),(PRT(2,LX1,M),M=1,5),PRI(3,LX1),
.      (PRT(3,LX1,M),M=1,5)
21   CONTINUE
6    WRITE(3,102) PRI(1,1),PRI(2,1),PRI(3,1),PRI(1,1),PRI(2,1),
.    PRI(3,1),PRI(1,1),PRI(2,1),PRI(3,1)
102  FORMAT(11X,A1,22X,A1,22X,A1/11X,A1,22X,A1,22X,A1/
.    11X,A1,22X,A1,22X,A1)
      RETURN
     END
```

```
      SUBROUTINE READ
C ***********************************************************
C          SUBROUTINE READS AND CHECKS DATA                 *
C ***********************************************************
      REAL LAI, LATUDE, NPLT, NSIDE
C
      COMMON /CLIM  / CLIMAT(250,7)
      COMMON /COM1  / EMERGE, KARDS, LAI, SEASON, VARITY, YIELD
      COMMON /FERT  / APDAY, DD, DR, FERN, FNH4, FNO3, NPLT, NSIDE,
     .                OMA, RNNH4, RNNO3
      COMMON /LIGHT / DAYLNG, DAYNUM, LATUDE
      COMMON /SIZES / POPPLT, ROWSP, Z
C
      READ(1,10) KARDS
 10   FORMAT(I3)
      IF(KARDS.GT.0.AND.KARDS.LE.300) GO TO 2
      WRITE(3,11) KARDS
 11   FORMAT(' E R R O R -----  KARDS = ',I3)
C
  2   DO 3 K = 1,KARDS
      READ(1,20) (CLIMAT(K,J),J=1,7)
 20   FORMAT(3F3.0,F2.0,F5.2,F4.2,F4.0)
      IF(CLIMAT(K,1).LT.0.0.OR.CLIMAT(K,1).GE.900.)
     . WRITE(3,21) CLIMAT(K,1), K
 21   FORMAT(' E R R O R ----- RAD = ',F10.2,' K= ',I3)
      IF(CLIMAT(K,2).LT.0.0.OR.CLIMAT(K,2).GT.105.)
     . WRITE(3,22) CLIMAT(K,2), K
 22   FORMAT(' E R R O R ----- TMAX = ',F10.2,' K= ',I3)
      IF(CLIMAT(K,3).LT.0.0.OR.CLIMAT(K,3).GT.CLIMAT(K,2))
     . WRITE(3,23) CLIMAT(K,3), K
 23   FORMAT(' E R R O R ----- TMIN = ',F10.2,' K= ',I3)
      IF(CLIMAT(K,4).GT.1.)WRITE(3,24) K
 24   FORMAT(' E R R O R ----- IN RAINFALL/IRRIGATION METHOD, K=',I3)
      IF(CLIMAT(K,5).LT.0.0.OR.CLIMAT(K,5).GT.10.)
     . WRITE(3,25) CLIMAT(K,5), K
 25   FORMAT(' E R R O R ----- RAIN = ',F10.2,' K= ',I3)
      IF(CLIMAT(K,6).LT.0.0.OR.CLIMAT(K,6).GT.2.)
     . WRITE(3,26) CLIMAT(K,6), K
 26   FORMAT(' E R R O R ----- PANVAP = ',F10.2,' K= ',I3)
  3   CONTINUE
C
      READ(1,30) POPPLT, LATUDE, EMERGE, SEASON, ROWSP
      READ(1,30) NPLT, NSIDE, APDAY, VARITY
      WRITE(3,30) POPPLT, LATUDE, EMERGE, SEASON, ROWSP
      WRITE (3,30) NPLT, NSIDE, APDAY, VARITY
 30   FORMAT(5F10.2)
      RETURN
      END
```

APPENDIX B
Input Data Set

1	179						
2	674	70	48		.00	.23	122
3	651	74	45		.00	.18	123
4	741	78	53		.00	.28	124
5	531	86	59		.00	.22	125
6	354	86	63		.00	.21	126
7	579	85	66		.00	.19	127
8	455	84	67		.00	.21	128
9	494	82	52		.00	.31	129
10	516	68	45		.00	.16	130
11	537	74	49		.00	.16	131
12	656	81	54		.00	.17	132
13	715	82	59		.00	.29	133
14	575	88	62		.00	.22	134
15	740	87	70		.00	.40	135
16	786	79	54		.00	.29	136
17	704	82	54		.00	.09	137
18	544	87	64		.00	.39	138
19	776	83	61		.00	.21	139
20	397	83	61		.00	.25	140
21	693	87	64		.00	.23	141
22	457	85	66		.00	.22	142
23	354	82	61		.00	.18	143
24	645	80	53		.00	.21	144
25	525	84	63		.00	.21	145
26	356	80	58		.00	.19	146
27	886	67	41		.00	.25	147
28	777	76	44		.00	.22	148
29	769	84	54		.00	.22	149
30	673	89	61		.00	.33	150
31	708	89	60		.00	.29	151
32	718	89	65		.00	.35	152
33	651	88	66		.00	.33	153
34	721	91	65		.00	.36	154
35	430	88	67		.00	.25	155
36	555	91	67		.00	.27	156
37	397	88	65		.00	.18	157
38	428	84	66		.00	.09	158
39	668	90	64		.00	.25	159
40	646	90	72		.00	.25	160
41	504	88	71		.00	.28	161
42	465	86	69		.00	.22	162
43	394	84	69		.00	.14	163
44	525	88	70		.00	.10	164
45	630	89	69		.00	.35	165
46	579	89	71		.00	.28	166
47	365	80	56		.00	.21	167
48	196	67	60		.00	.04	168
49	285	72	59		.00	.09	169
50	286	73	58		.00	.08	170
51	109	72	65		.00	.07	171
52	618	82	63		.00	.05	172
53	722	83	59		.00	.16	173
54	424	85	64		.00	.28	174
55	669	87	64		.00	.22	175
56	373	85	66		.00	.21	176
57	554	77	65		.00	.14	177
58	719	85	60		.00	.23	178
59	641	87	65		.00	.25	179
60	741	87	65	1	.69	.31	180
61	700	89	64		.00	.22	181
62	621	90	67		.00	.33	182
63	603	88	65		.00	.22	183
64	458	86	66		.00	.24	184
65	708	88	63		.00	.19	185
66	790	89	63		.00	.35	186
67	640	90	69	1	.41	.32	187
68	200	80	70		.39	.13	188
69	478	88	69		.00	.15	189
70	600	84	65		.00	.20	190
71	641	82	60		.00	.26	191
72	139	80	67		.00	.09	192
73	282	80	67		.00	.09	193
74	232	83	67		.00	.13	194
75	498	87	68		.00	.17	195
76	624	90	71		.00	.22	196
77	395	87	69		.00	.32	197
78	311	91	68	1	.28	.13	198
79	644	92	64		.00	.07	199
80	459	91	72		.00	.34	200
81	674	93	72		.00	.32	201
82	585	91	70		.00	.25	202
83	700	92	70		.00	.31	203
84	559	89	70		.00	.24	204
85	375	87	68		.00	.26	205
86	608	89	69		.00	.28	206
87	741	91	68		.00	.34	207
88	542	92	70		.00	.27	208
89	673	92	67		.00	.29	209
90	690	91	69		.00	.33	210
91	664	91	71		.00	.26	211
92	470	90	69		.00	.21	212
93	541	90	71		.00	.24	213
94	744	93	73		.00	.30	214
95	622	93	75		.00	.26	215
96	609	91	69		.00	.29	216
97	677	94	70		.00	.35	217
98	500	85	68		.00	.27	218
99	362	84	67	1	2.00	.16	219
100	567	90	65		.00	.24	220
101	638	90	66		.00	.37	221
102	591	92	70		.00	.25	222
103	333	85	69		.00	.26	223
104	432	92	72		.00	.24	224
105	710	90	71		.00	.31	225
106	463	88	65		.00	.19	226
107	292	86	70		.00	.04	227
108	400	83	67		.00	.24	228
109	637	87	67	1	1.75	.29	229
110	424	87	68		.00	.27	230
111	580	88	66		.00	.25	231
112	687	87	66		.00	.26	232
113	429	82	63		.00	.23	233
114	634	85	58		.00	.24	234
115	549	87	68		.00	.24	235
116	297	84	66		.00	.16	236
117	663	86	63		.00	.18	237
118	524	86	65		.00	.23	238
119	613	89	68		.00	.21	239
120	515	91	70	1	1.75	.34	240
121	592	94	70		.00	.18	241
122	486	96	69		.00	.29	242
123	379	91	73		.00	.16	243
124	419	92	71		.00	.23	244
125	550	94	75		.00	.29	245
126	342	88	71		.00	.14	246
127	534	93	69		.01	.23	247
128	451	91	71		.00	.21	248
129	433	89	69		.00	.16	249
130	339	86	67	1	1.75	.14	250
131	641	89	69		.00	.22	251
132	418	89	69		.00	.23	252
133	549	89	69		.00	.24	253
134	369	88	70		.00	.14	254
135	217	86	70		.00	.13	255
136	252	85	71		.00	.14	256
137	217	78	61		.00	.10	257
138	609	72	54		.00	.19	258
139	600	76	47		.00	.23	259
140	657	77	50		.00	.22	260
141	514	75	52		.00	.24	261
142	554	80	55		.00	.17	262
143	510	84	55		.00	.19	263
144	473	88	63		.00	.16	264
145	458	92	70		.00	.14	265
146	556	93	70		.00	.26	266
147	548	93	67		.00	.24	267
148	401	92	72		.00	.21	268
149	511	88	58		.00	.24	269
150	501	89	60		.00	.19	270
151	517	86	66		.00	.25	271
152	526	89	58		.00	.21	272
153	475	87	65		.00	.22	273
154	185	85	60		.00	.00	274
155	78	72	57		.00	.10	275
156	537	67	48		.00	.15	276
157	569	71	41		.00	.20	277
158	553	76	47		.00	.16	278
159	549	77	47		.00	.20	279
160	424	79	50		.00	.17	280
161	120	75	59		.00	.11	281
162	427	83	58		.00	.06	282
163	507	84	58		.00	.20	283
164	475	83	59		.00	.18	284
165	490	83	59		.00	.19	285
166	450	84	57		.00	.18	286
167	525	71	54		.00	.28	287
168	544	67	40		.00	.20	288
169	461	77	44		.00	.12	289
170	504	81	50		.00	.16	290
171	470	82	51		.00	.12	291
172	407	79	54		.00	.25	292
173	485	65	38		.00	.13	293
174	345	65	42		.00	.11	294
175	484	72	40		.00	.10	295
176	441	78	40		.00	.12	296
177	418	80	52		.00	.16	297
178	284	79	58		.00	.14	298
179	400	72	42		.00	.20	299
180	454	70	35		.00	.17	300
181	20498.	34.	129.	170.	101.6		
182	75.	75.	28.	0.			

APPENDIX C
Dictionary of Terms

```
************      DICTIONARY OF TERMS FOR GOSSYM      ************

A1     - CALIBRATION  PARAMETER
A21    - CALIBRATION  PARAMETER
A22    - CALIBRATION  PARAMETER
A31    - CALIBRATION PARAMETER
A32    - CALIBRATION PARAMETER
ABSDAY - ABSCISSION DAY
ABZ    - TOTAL ABSCISSED FRUIT
ADJDUM - ADJUSTED DUMMY VARIABLE TO ACCOUNT FOR ACTUAL SOIL WATER LOSS.
ADJES  - AN OPERATION ON SOIL EVAPORATION FOR CALCULATING FLOW
       - OF WATER UP.
AGE    - (K,L,M) - AGE OF EACH NODE
AGEBOL - AGE OF BOLL
AGENOD - AGE OF NODE
AGEPFN - AGE OF PREFRUITING NODE
AGETOP - AVERAGE AGE OF TOP THREE MAINSTEM NODES
ALPHA  - A CONSTANT, DEPENDENT ON HYDRAULIC PROPERTIES OF THE SOIL,
AMAX1  - FORTRAN FUNCTION TO FIND MAXIMUM VALUE
AMIN1  - FORTRAN FUNCTION TO FIND MINIMUM VALUE.
APDAY  - APPLICATION DAY
AREA   - TOTAL LEAF AREA
AT     - RUNNING AVERAGE TEMPERATURE AT VEGETATIVE BRANCH NODE
AT2    - ADJUSTED AVERAGE TEMPERATURE OF NODE
AVGPSI - THE SOIL WATER POTENTIAL EFFECTING PHOTOSYNTHESIS
AVGT   - (K,L,M) - RUNNING AVERAGE TEMPERATURE OF EACH NODE
AVGTI  - AVERGE TIME INTERVAL BETWEEN MAINSTEM NODES
AVTEMP - RUNNING AVERAGE TEMPERATURE
AVTNOD - AVERAGE TEMPERATURE OF NODE
AVTPFN - AVERAGE TEMPERATURE OF PREFRUITING NODE
BAGE   - BOLL AGE, AFFECTED BY MOISTURE STRESS
BLOOM  - TIME INTERVAL FROM SQUARE INITIATION TO POLLINATION
BLUM   - CUMULATIVE NUMBER OF BLOOMS
BMAIN  - MAINTENANCE RSPIRATION
BOLABZ - BOLLS ABSCISED
BOLAGE - AGE OF BOLLS
BOLDAZ - BOLL AGE
BOLL1  - BOLL NITROGEN REQUIREMENT FOR GROWTH
BOLLS  - TOTAL NUMBER OF BOLLS ON THE PLANT (GREEN + OPEN BOLLS).
BOLOSS - BOLL LOSS
BOLWGT - (K,L,M) - BOLL WEIGHT
BRANCH - NUMBER OF BRANCHES ON THE PLANT. (VEGETATIVE + FRUTING)
BSUM   - SUM OF BOLLS
BURADD - BURR1 + BURMIN
BURCN  - AVERAGE NITROGEN CONCENTRATION IN BURRS
BURMIN - BURR NITROGEN REQUIREMENT FOR GROWTH (MINIMUM)
BURR   - POTENTIAL NITROGEN STORAGE IN  BURRS
BURR1  - BURR NITROGEN REQUIREMENT FOR GROWTH
BURRN  - BURR NITROGEN
CALAVG - FACTOR OF REGRESSION EQUATION FOR CALCULATING FRACTION OF
       - TIME PLANT. IS ABOVE -7.0 BARS.
CALMAX - FACTOR OF REGRESSION EQUATION FOR CALCULATING FRACTION OF
       - TIME PLANT. IS ABOVE -7.0 BARS.
CALTSD - FACTOR OF REGRESSION EQUATION FOR CALCULATING FRACTION OF
       - TIME PLANT. IS ABOVE -7.0 BARS. (DAY).
CALTSN - FACTOR OF REGRESSION EQUATION FOR CALCULATING FRACTION OF
       - TIME PLANT. IS ABOVE -7.0 BARS. (NIGHT).
CAPSCA - VECTOR OF BREAK POINTS FOR GRAPHICAL INTERPRETATION OF
         VOLUMETRIC WATER CONTENT.
CAPUP  - CUMULATIVE CAPILLARY UPTAKE OF WATER ACROSS BOTTOM OF PROFILE,
         MM.
CBL    - MAXIMUM AGE AT WHICH BOLL CAN BE MARKED FOR ABSCISSION
CD     - CARBOHDRATE DEMAND
CDLAYF - DELAY IN FRUITING NODE FORMATION DUE TO CHO STRESS
CDLAYV - CARBOHYDRATE DELAYS IN VEGETATIVE BRANCHES.
CH2OX  - EXCESS CARBOHYDRATE RESULTING FROM INADEQUATE N SUPPLY
         FOR TISSUE GROWTH.
CHAR1  - FRUIT SYMBOL IN OUTPUT MAP
CHAR2  - FRUIT SYMBOL IN OUTPUT MAP
CHARI  - 'I'
CL     - CALIBRATION  PARAMETER
CLIMAT - (DAY,1) - SOLAR RADIATION DAILY TOTAL (LY/DAY)
CLIMAT - (DAY,2) - MAXIMUM DAILY TEMPERATURE. DEG F.
CLIMAT - (DAY,3) - MINIMUM DAILY TEMPERATURE. DEG F.
CLIMAT - (DAY,4) - METHOD OF WATER APPLICATION. 0=RAINFAL,1=IRRIGATION
CLIMAT - (DAY,5) - AMOUNT OF WATER IRRIGATED OR RAINFALL. INCHES.
CLIMAT - (DAY,6) - JULIAN DAY NUMBER.
CLIMAT - (II,K) EQUALS CLIMAT(I,K)
CM     - CALIBRATION PARAMETER
CO2    - CO2 FERTILIZATION SWITCH (ON OR OFF)
COND   - UNSATURATED HYDRAULIC CONDUCTIVITY, IN CM/DAY.
CONSCA - VECTOR OF BREAK POINTS FOR GRAPHICAL INTERPRETATION OF
         VOLUMETRIC WATER CONTENT IN CC PER CC SOIL.
COTXX  - WEIGHT OF OPEN BOLLS
COUNT  - COUNTER OF SQUARES AND BOLLS WHICH CAN BE ABSCISSED
CPF    - MODEL CALIBRATION FACTOR
CPOOL  - CH2O POOL
CSQ    - MODEL CALIBRATION FACTOR
CSTRES - RATIO OF CARBOHYDRATE SUPPLY TO DEMAND FOR GROWTH
CUMEP  - CUMULATIVE TRANSPIRATION, MM.
CUMES  - CUMULATIVE SOIL EVAPORATION, MM.
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CUMRAN - CUMULATIVE RAINFALL, MM.
CUMSOK - CUMULATIVE SOAK THROUGH, MM.
CVB - MODEL CALIBRATION FACTOR
CZD - MODEL CALIBRATION FACTOR
CZN - COEFFICIENT FOR CALCULATING HEIGHT GROWTH
D - DEPTH (VERTICAL) OF EACH SOIL CELL, IN CM.
DACNT - NUMBER OF DAYS/MONTH
DAL - CHANGE IN AREA OF LEAF K,L,M
DAMP - DAMPING FACTOR TO APPROXIMATE LINEARIZATION OF EXPONENTIAL DECAY RESPONSE.
DAY - CALENDAR DAYS FROM EMERGENCE
DAYABS - DAY OF ABSCISSION
DAYINC - DAYS BETWEEN OUTPUTS
DAYL1 - FRACTION OF 24 HOUR PERIOD IN DAYLIGHT
DAYL2 - FRACTION OF 24 HOUR PERIOD IN NIGHT
DAYLNG - DAY LENGTH, IN HOURS.
DAYNUM - DAY NUMBER OF THE YEAR, IN JULIAN DAYS.
DAYTYM - DAYLIGHT FRACTION OF 24 HOUR DAY
DAYWTF - TEMPERATURE DEPENDENT FACTOR FOR CONVERTING LEAF AREA TO LEAF WEIGHT DURING THE DAY
DAZE - DAY OF MONTH
DBLUM - BLOOMS MADE IN THE LAST SEVEN DAYS
DBOLLD - CUMULATIVE CARBOHYDRATE NOT USED IN BOLL GROWTH DUE TO DAY TIME WATER STRESS.
DBOLLN - CUMULATIVE CARBOHYDRATE NOT USED IN BOLL GROWTH DUE TO NIGHT TIME WATER STRESS.
DD - DISTANCE BELOW SOIL SURFACE WHERE BANDED FERTILIZER IS PLACED, IN INCHES.
DEAD - TOTAL WEIGHT OF DEAD TISSUE LOST.
DEL - SLOPE OF SATURATION VAPOR PRESSURE CURVE AT MEAN AIR SOIL SURFACE, IN MM/DAY.
DELAY - DELAY IN FRUITING NODE FORMATION (DAYS)
DELT - INCREMENT OF TIME OVER WHICH UPTAKE AND CAPILLARY FLOW IS SIMULATED, IN DAYS.
DIFF - DIFFUSIVITY OF SOIL, IN CM BAR/DAY.
DIFSCA - VECTOR OF BREAK POINTS FOR GRAPHICAL INTERPRETATION OF SOIL WATER DIFFUSIVITY, IN CM**2 PER DAY.
DIFUNI - VECTOR USED TO WRITE UNITS OF SOIL WATER DIFFUSIVITY.
DLEAFD - CUMULATIVE CARBOHYDRATE NOT USED IN LEAF GROWTH DUE TO DAY TIME WATER STRESS.
DLEAFN - CUMULATIVE CARBOHYDRATE NOT USED IN LEAF GROWTH DUE TO DAY TIME WATER STRESS.
DNIT - NITRIFICATION OF NH4
DNMIN - AMOUNT OF MINERALIZED ORGANIC NITROGEN IN MG N/CM**3.
DPBMX - MAXIMUM PERMISSIBLE BOLL DROP
DPN - CHANGE IN PHOTOSYNTHESIS DUE TO MOISTURE STRESS
DPSIDT - DERIVATIVE OF WATER POTENTIAL WITH RESPECT TO MOISTURE CONTENT, IN BARS/CC/CC.
DPSMX - MAXIMUM PERMISSIBLE SQUARE DROP
DR - DISTANCE TO RIGHT OF ROW WHERE BANDED FERTILIZER IS PLACED, IN INCHES.
DRAD - ARRAY OF DAILY RADIATION AMOUNTS NOT INTERCEPTED BY PLANTS, IN LANGLEYS.
DROOT - MOISTURE ADJUSTMENT FOR POTENTIAL DAY TIME ROOT GROWTH
DSITES - DIFFERENCE IN SITES
DSTEMD - CUMULATIVE CARBOHYDRATE NOT USED IN STEM GROWTH DUE TO DAY TIME WATER STRESS.
DSTEMN - CUMULATIVE CARBOHYDRATE NOT USED IN STEM GROWTH DUE TO NIGHT TIME WATER STRESS.
DTAH - ARRAY OF DAILY MAXIMUM (HIGH) AIR TEMPERATURES, IN DEG F.
DTAL - ARRAY OF DAILY MINIMUM (LOW) AIR TEMPERATURES, IN DEG F.
DTAVG(J)-THE AVERAGE DAY TIME TEMPERATURE FOR J DAYS AGO.
DTOP - MOISTURE STRESS ADJUSTMENT FOR POTENTIAL DAY TIME TOP GROWTH
DUMAY - DUMMY ARRAY USED FOR LOCAL DIMENSIONED VARIABLES
DUMAY1 - DUMMY ARRAY USED FOR LOCAL DIMENSIONED VARIABLES.
DUMMY0 - DUMMY ARRAY TO SET ASIDE CORE
DUMY01 - TEMPERATURE FACTOR IN BOLL GROWTH IN DAY TIME
DUMY02 - TEMPERATURE FACTOR IN BOLL GROWTH IN DAY TIME
DUMY03 - TEMPERATURE FACTOR IN BOLL GROWTH IN DAY TIME
DUMY04 - TEMPERATURE FACTOR IN PREFRUITING LEAF GROWTH IN DAY TIME
DUMY05 - TEMPERATURE FACTOR IN PREFRUITING LEAF GROWTH IN NIGHT TIME
DUMY06 - TEMPERATURE FACTOR IN SQUARE GROWTH
DUMY07 - TEMPERATURE FACTOR IN BOLL GROWTH DURING NIGHT TIME
DUMY08 - TEMPERATURE FACTOR IN BOLL GROWTH DURING NIGHT TIME
DUMY09 - TEMPERATURE FACTOR IN BOLL GROWTH DURING NIGHT TIME
DUMY10 - DUMMY VARIABLE, USED TO REDUCE CPU TIME.
DWBOLL - (K,L,M) ACTUAL CHANGE IN WEIGHT OF BOLL K,L,M
DWL - (K,L,M) ACTUAL CHANGE IN WEIGHT OF LEAF K,L,M
DWRT - ACTUAL INCREMENT OF ROOT WEIGHT FOR A GIVEN CELL, IN GM/CELL/DAY.
DWSQ - ACTUAL GROWTH OF THE SQUARES
DWSTM - AMOUNT OF CARBOHYDRATE ALLOCATED TO STEM GROWTH
DZ - CHANGE IN PLANT HEIGHT IN TOP INTERNODE
DZ2 - CHANGE IN PLANT HEIGHT IN NEXT TO TOP INTERNODE
E - TOTAL EVAPORATIVE LOSS FROM CROP.
EMERGE - DAY OF EMERGENCE
EO - POTENTIAL EVAPORATION RATE ABOVE THE PLANT CANOPY, IN MM/DAY.
EP - EVAPORATION RATE FROM PLANT LEAVES, TRANSPIRATION, IN MM/DAY.
ES - EVAPORATION FROM SOIL SURFACE, IN MM/DAY.
ESO - POTENTIAL EVAPORATION RATE BELOW PLANT CANOPY AT THE SOIL SURFACE IN MM/DAY.
ESX - EVAPORATION RATE FROM THE SOIL SURFACE DURING STAGE 2 EVAPORATION ON A DAY WHEN P LESS THAN SESII, IN MM/DAY.
EXC - AMOUNT OF NITROGEN AVAILABLE FOR LEAF RESERVES
F2 - RESERVE NITROGEN AVAILABILITY COEFFICIENT
FC - FIELD CAPACITY OF SOIL, CM**3/CM**3.

FCODE - (K,L,M,) FRUIT CODE (1=SQUARE, 2=GREEN BOLL, 3=OPEN BOLL, 4=ABSCISED, 5=SQUARE MARKED FOR ABSCISION, 6=BOLL MARKED FOR ABSCISION, 7=BOLL OF AGE SUSCEPTIBLE TO ABSCISSION)
FDROPB - FRACTION OF BOLLS TO BE DROPPED FROM EACH NODE
FDROPS - FRUIT DROPPED AS SQUARE
FDROP - FRACTION OF BOLLS AND SQUARES TO BE DROPPED
FERN - FERTILIZER NITROGEN APPLIED, IN LBS N/ACRE.
FFRUT - FRACTION OF FRUIT REMAINING AT A NODE
FL - AVERAGE FIBER LENGTH
FLDCAP - FIELD CAPACITY OF BOTTOM SOIL LAYER, CM**3/CM**3.
FLOSS - FRUIT LOSS
FLX - FIBER STRENGTH OF BOLL
FMIN - MINERALIZATION FUNTION OF SOIL ORGANIC NITROGEN
FNH4 - FRACTION OF FERTILIZER NITROGEN WHICH IS AMMONIUM, DIMENSIONLESS.
FNICN - FLUX OF NITROGEN INTO THE CELL, NET, IN MG N/CELL.
FNIT - NITRIFICATION OF NH4
FNL - FLUX OF NITROGEN TO THE LEFT OUT OF THE CELL, MG N/CELL.
FNO3 - FRACTION OF FERTILIZER NITROGEN WHICH IS NITRATE, DIMENSIONLESS
FNU - FLUX OF NITROGEN UPWARD OUT OF THE CELL, MG N/CELL.
FRATIO - RATIO OF GREEN BOLLS WEIGHT TO TOTAL PLANT WEIGHT
FRUITS - FRACTION OF FRUIT REMAINING AT A SITE
FS - FIBER STRENGTH
FSTRES - PHYSIOLOGICAL STRESS AFFECTING FRUITING
FSX - FIBER STRENGTH OF BOLL
FWICN - FLUX OF WATER INTO THE CELL, NET, IN CM**3/CELL.
FWL - FLUX OF WATER TO THE LEFT OUT OF THE CELL, IN CM**3/CELL.
FWU - FLUX OF WATER UPWARD OUT OF THE CELL, CM**3/CELL.
G - WEIGHTING FACTOR FOR GEOTROPISM (THE PREFERENCE OF ROOTS TO GROW DOWNWARD).
GAMMA - CONSTANT OF THE WET AND DRY BULB PSYCHROMETER EQUATION, IN MB/DEG C.
GBLOS - GREEN BOLLS LOST
GBOLWT - GREEN BOLL WEIGHT
GBZ2 - GREEN BOLLS PAST ABSCISSION AGE
GIN - AVERAGE GIN PERCENTAGE FOR PLANT
GINP - GIN PERCENTAGE FOR BOLL
GSUBR - GROWTH RESPIRATION COEFFICIENT
H2OBAL - WATER BALANCE.
H2OUNT - VECTOR USED TO WRITE UNITS OF TOTAL WATER IN THE PROFILE.
H2OUPT - UPTAKE OF WATER IN CM**3
I - INDEX (DAILY) USED IN MANIPULATING DAILY WEATHER VARIABLES.
IBLUM - SWITCH ON DAY OF FIRST BLOOM
IDAY - NUMBER OF DAYS SINCE EMERGENCE.
- VIEWED SUFFICIENTLY
IFLOSS - INTEGER NUMBER OF FRUIT TO BE LOST
IGO - SWITCHING VARIABLE TO DETERMINE WHETHER LEGEND IS WRITTEN
- IN FIXED DECIMAL FORM OR EXPONENTIAL FORM.
IH - HOUR OF THE DAY, FROM MIDNIGHT.
IH9 - NINE HOURS FROM THE CURRENT TIME.
II - AN INDEX FOR WEATHER DATA.
ILG - TRIGGER TO DETERMINE WHETHER F OR E FORMAT IS USED TO WRITE LEGEND.
IMGKOL - IMAGE KOLUMN
INT - FRACTION OF SOLAR RADIATION INTERCEPTED BY CROP DIMENSIONLESS
IQ - NODE NUMBER.
IRC - INDEX FOR WEIGHING ROOT GROWTH TO THE RIGHT IN RESPONSE
- TO WATER POTENTIAL.
ISQ - SWITCH TURNED ON BY FIRST SQUARE
ISR - HOUR OF SUNRISE. MIDNIGHT IS 0.
ISS - HOUR OF SUNSET.
ISS1 - HOUR OF SUNSET PLUS ONE.
ITER - ITERATION WITHIN A HALF DAY.
IXX - INDEX FCODE
IYR - YEAR/4
J - INDEX (DAILY) USED IN MANIPULATING DAILY WEATHER (IN MAIN)
J - INDEX PREFRUITING NODE NUMBER (IN PLTMAP)
JM1 - AN INDEX FOR SOIL TEMPERATURE.
JNUM - NUMBER OF PREFRUITING NODES
K - VEGETATIVE BRANCH NUMBER
K1 - PART OF OPERATION FOR CALCULATION OF WATER FLOW
K2 - PART OF OPERATION FOR CALCULATION OF WATER FLOW
KA - ARRAY OF CHARACTERS AVAILABLE TO PRINT ON THE MAP.
KALL - VARIABLE USED TO CALL RUTGRO AND CALCULATE ACTUAL OR POTENTIAL ROOT GROWTH
KARDS - NUMBER OF INPUT DATA CARDS
KHAR - CHARACTERS PRINTED ON THE MAP.
KINT - NUMBER OF UNSHADED SOIL KOLUNMS.
KL1 - COLUMN TO LEFT OF SOURCE OF ROOT GROWTH
KOLUMN - COLUMN OF SOIL IN THE PROFILE, 1 TO NK.
KOUNT - COUNTER OF FRUIT SUSCEPTIBLE TO ABSCISSION
KR - FURTHEST COLUMN TO RIGHT CONTAINING ROOTS.
KR1 - COLUMN TO RIGHT OF SOURCE CELL OF ROOT GROWTH
KRL - COLUMN COUNTER FOR THE LAYER
L - MAINSTEM NODE NUMBER
L1 - LAYER + 1.
L2 - LAYER + 2.
LAGE - LEAF AGE AFFECTED BY MOISTURE STRESS
LAI - LEAF AREA INDEX
LAMDAC - ALBEDO OF CROP, DIMENSIONLESS.
LAMDAS - ALBEDO OF SOIL, DIMENSIONLESS.
LAMDA - TOTAL ALBEDO OF CROP AND SOIL, DIMENSIONLESS.
LAREA - (K,L,M) AREA OF LEAF K,L,M
LATUDE - LATITUDE
LAYER - LAYER OF SOIL IN THE PROFILE, 1 TO NL.
LC - K - 1

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LCODE  - (K,L,M) - LEAF CODE ( 1=PRESENT, 4=ABSCISED)
LD1    -  LAYER BELOW SOURCE CELL OF ROOT GROWTH
LDC    - INDEX FOR WEIGHING ROOT GROWTH DOWNWARD IN RESPONSE TO
       - WATER POTENTIAL
LEAFCN - LEAF NITROGEN CONCENTRATION
LEAFR1 - LEAF NITROGEN REQUIREMENT FOR GROWTH
LEAFRS - LEAF RESERVES
LEAFR  - POTENTIAL NITROGEN STORAGE IN  LEAVES
LEAFW  - (K,L,M) WEIGHT OF LEAF K,L,M
LEAFWT - LEAF WEIGHT (G)
LEFABS - WEIGHT OF LEAVES ABSCISSED
LMAX   - PEAK LEAF AREA INDEX.
LOSSQR - SQUARE LOSS
LR     - DEEPEST LAYER CONTAINING ROOTS
LRT    - DEEPEST LAYER CONTAINING ROOTS BEFORE THE DAYS ROOT GROWTH
LYTRES - LIGHT RESPIRATION
M      - FRUITING BRANCH NODE NUMBER
MAXMIN - TMAX - TMIN
MCODE  - CONDITION CODE FOR FRUIT
MEM    - A MARKER OF LOCATION OF LAST OPERATION IN THE FRUIT MATRIX
MEMSTR - A MARKER OF THE PLACE OF LAST OPERATION IN FRUIT MATRIX
MH20   - METHOD OF WATER APPLICATION.
MO     - MONTH
MVBRCH - NUMBER OF VEGETATIVE BRANCHES (INCLUDING MAINSTEM) AS OF
         THE END OF THE LAST ITERATION.
N      - INDEX VARIABLE.
NAPDAY - NITROGEN APPLICATION DAY
NBRCH  - NUMBER OF FRUITING BRANCH
NDAYS  - LENGTH OF SEASON TO BE SIMULATED
NEWBR  - VEGETATIVE BRANCH NODE NUMBER OF LATEST FRUITING BRANCH
NEWDAY - VARIABLE USED TO STOP THE ACUMMULATION OF SOIL AND PLANT
         WATER LOSS AFTER THE LAST ITERATION OF THE DAY.
NEWEP  - ADJUSTED EVAPORATION RATE FROM PLANT LEAVES, ( IN MM/DAY)
         DUE TO LACK OF SOIL MOISTURE.
NEWES  - ADJUSTED EVAPORATION FROM SOIL SURFACE, (IN MM/DAY.) DUE TO
         LACK OF SOIL MOISTURE.
NEWNOD - NUMBER OF NEWEST NODE ON FRUITING BRANCH
NF     - FACTOR FOR LIMITING FRUIT GROWTH IN RESPONSE TO N SHORTAGE.
NFBR   - (K) - NUMBER OF FRUITING BRANCHES ON THE VEGETATIVE BRANCH
NFBRCH - NUMBER OF THE FRUITING BRANCH
NFRQ   - FREQUENCY OF OUTPUT DESIRED, IN DAYS.
NFRQX  - DAY ON WHICH FIRST OUTPUT DESIRED.
NITUNT - VECTOR USED TO WRITE UNITS OF TOTAL NITRATE IN THE PROFILE.
NK     - NUMBER OF COLUMNS IN THE PROFILE.
NKES   - NUMBER OF COLUMNS IN WHICH SOIL EVAPORATION OCCURS
NKH    - HALF THE NUMBER OF COLUMNS IN THE PROFILE.
NKHP1  - HALF THE NUMBER OF COLUMNS PLUS ONE.
NKHP2  - HALF THE NUMBER OF COLUMNS PLUS TWO.
NKK    - COLUMN, MIRRORED ABOUT CENTER LINE OF PROFILE.
NL     - NUMBER OF LAYERS OF SOIL IN THE PROFILE.
NLR    - NUMBER OF LAYERS CONTAINING ROOTS
NNID   - NODE NUMBER ON FRUITING BRANCH
NNOD   - (M) - NUMBER OF NODES ON THE FRUITING BRANCH
NODES  - TOTAL NUMBER OF BRANCHES ON THE PLANT (VEGETATIVE + FRUITING).
NOITR  - NUMBER OF ITERATIONS DURING 1/2 DAY (DAY TIME OR NIGHT TIME).
NOPEN  - NUMBER OF OPEN BOLLS
NOWGO  - DECISION VARIABLE.
NPC    - SWITCH COMMANDING OUTPUT OF PLANT DIAGRAM
NPD    - TRIGGER TO DETERMINE IF 'MAP' OF DIFFUSIVITY PRINTED DURING
         EXECUTION.
NPLT   - NITROGEN AT PLANTING
NPN    - TRIGGER TO DETERMINE IF 'MAP' OF NITRATE CONTENT PRINTED
         DURING EXECUTION.
NPOOL  - NITROGEN POOL (AVAILABLE)
NPP    - TRIGGER TO DETERMINE IF 'MAP' OF WATER POTENTIAL PRINTED
         DURING EXECUTION.
NPR    - TRIGGER TO DETERMINE IF 'MAP' OF ROOTS IS PRINTED DURING
         EXECUTION.
NPW    - TRIGGER TO DETERMINE IF 'MAP' OF WATER CONTENT IS PRINTED
         DURING EXECUTION.
NROOT  - MOISTURE ADJUSTMENT FOR POTENTIAL NIGHT TIME ROOT GROWTH.
NSHORT - N WHICH IS REMOVED FROM LEAF RESERVES.
NSIDE  - NITROGEN SIDE DRESSING
NSTRES - NITROGEN STRESS
NTOP   - MOISTURE ADJUSTMENT FOR POTENTIAL NIGHT TIME TOP GROWTH
NUMPFN - NUMBER OF PREFRUITING NODES
NV     - FACTOR FOR LIMITING VEGETATIVE GROWTH IN RESPONSE
         NITROGEN STRESS.
NVBRCH - NUMBER OF VEGETATIVE BRANCHES
NYTTYM - NIGHT TIME FRACTION OF 24 HOUR DAY
NYTWTF - TEMPERATURE DEPENDENT FACTOR FOR CONVERTING LEAF AREA TO
          LEAF WEIGHT DURING THE NIGHT
OBZ    - OPEN BOLLS
OMA    - ORGANIC MATTER ADDED TO THE PLOW ZONE AT BEGINNING OF
         SEASON, IN LBS/ACRE.
OPEN   - TIME INTERVAL FROM BLOOM TO BOLL OPENING
P      - RAINFALL (LOCAL VARIABLE), IN MM/DAY.
PARTD  - FRACTION OF CH2O BUDGETED TO VEGETATIVE WHICH GOES TO ROOT
         DURING THE DAY
PARTN  - FRACTION OF CH2O BUDGETED TO VEGETATIVE WHICH GOES TO ROOT
         DURING THE NIGHT
PDADAY - (K,L,M) POTENTIAL CHANGE IN AREA DURING DAY TIME
PDANYT - (K,L,M)     "        "    "    "     "    NIGHT TIME
         FRUITING BRANCHES.
PDBOLL - CHANGE IN BOLL WEIGHT DUE TO GROWTH
PDLEAF - CHANGE IN LEAF WEIGHT DUE TO GROWTH
PDRES  - POTENTIAL CHANGE IN PLANT NITROGEN RESERVES
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PDROOT - CHANGE IN ROOT WEIGHT DUE TO GROWTH
PDSQ - TOTAL POTENTIAL SQUARE GROWTH IN WEIGHT AFTER ACCOUNTING FOR CSTRES BUT NOT FOR NSTRES
PDSTEM - CHANGE IN STEM WEIGHT DUE TO GROWTH
PDSTMD - POTENTIAL STEM GROWTH DURING THE DAY
PDSTMN - POTENTIAL STEM GROWTH DURING THE NIGHT
PDWBON - POTENTIAL CHANGE IN WEIGHT OF BOLL DURING THE NIGHT
PDWBOD - POTENTIAL CHANGE IN WEIGHT OF BOLL DURING THE DAY
PDWLD - POTENTIAL CHANGE IN WEIGHT OF THE LEAF DURING THE DAY
PDWLN - POTENTIAL CHANGE IN WEIGHT OF THE LEAF DURING THE NIGHT
PDWSQ - (K,L,M) - POTENTIAL CHANGE IN WEIGHT OF SQUARE
PFAL - AREA OF PREFRUITING NODE LEAF
PFAREA - AREA OF LEAF AT PREFRUITING NODE
PFDAL - THE CHANGE IN AREA OF A PREFRUITING NODE LEAF.
PFDWL - THE CHANGE IN WEIGHT OF A PREFRUITING NODE LEAF.
PFDWLD - PREFRUITING NODE CHANGE IN WEIGHT OF LEAF
PFDWLN - PREFRUITING NODE CHANGE IN WEIGHT OF LEAF DURING NIGHT
PFWL - WEIGHT OF PREFRUITING NODE LEAF
PIN - PIN HEAD SQUARES TO BE LOST TODAY
PINDEX - INDEX PHOTOSYNTHESIS RATE UNDER WELL WATERED CONDITIONS
PINHED - PINHEAD SQUARES TO BE LOST IN MAP OUTPUT
PLANTW - PLANT WEIGHT IN GRMS.
PLANTN - TOTAL NITROGEN CONTENT OF PLANT
PLTN - TOTAL NITROGEN CONTENT OF PLANT
PNET - TODAY'S NET PHOTOSYNTHATE YIELD
POLINA - POLLINATION TRIGGER
POLOSS - BOLLS TO BE LOST DUE TO BLOOM STICKING BY RAIN
POLYNA - POLLINATION TRIGGER
POPFAC - POPULATION FACTOR
POPPLT - PLANT POPULATION, IN PLANTS/ACRE.
POPSLF - ROOTS SLOUGHED PER PLANT
PPLANT - GROSS PHOTOSYNTHATE PRODUCED PER PLANT TODAY
PQFLR - WEIGHT LOST FROM FRUIT DUE TO PETAL SHED AFTER BLOOMING
PRI - PRINT CHARACTER 'I', INTERNODES
PRT - PRINT CHARACTER FOR FRUITING NODES.
PSIAVG - AVERAGE WATER POTENTIAL OF ROOT ZONE, IN BARS.
PSIL - MINIMUM LEAF WATER POTENTIAL FOR THE DAY
PSILIN - MINIMUM LEAF WATER POTENTIAL FOR THE DAY IN WELL WATERED SOIL
PSIMAX - MAXIMUM WATER POTENTIAL IN PROFILE OCCUPIED BY ROOTS, IN BARS
PSINUM - THE NUMBER OF CELLS OF WHICH PSIAVG IS CALCULATED WATER POTENTIAL IN BARS.
PSITOT - TOTAL OF PSI
PSIUNI - VECTOR USED TO WRITE UNITS OF SOIL WATER POTENTIAL.
PSTAND - GROSS DAILY PHOTOSYNTHATE PRODUCTION (MG CO2/DM**2/DAY)
PTS - PPLANT - LYTRES - BMAIN IN LANGLEYS/DAY.
RADAY - RATE OF AREA GROWTH DURING DAY TIME
RADL1 - RAD LAGGED BY ONE WEEK.
RAIN - RAINFALL OR IRRIGATION, IN MM/DAY.
RANGE1 - ARRAY OF 11 NUMBERS TERMINATING THE RANGE OF EACH OF THE 10 CHARACTERS USED ON THE MAP.
RANGE - ARRAY OF 11 NUMBERS TERMINATING THE RANGE OF EACH OF THE 10 CHARACTERS USED ON THE MAP.
RANYT - RATE OF LEAF AREA GROWTH DURING NIGHT TIME
RATIO - ROOT : SHOOT RATIO
RCH2O - ROOT CARBOHYDRATE SUPPLY PER PLANT, IN GM/PLANT.
RCHOSS - ROOT CARBOHYDRATE FOR SOIL SLAB, (100 CM**2), IN GM/100 CM**2.
RECDAT - HOURLY TEMPERATURES OF THE SOIL LAYER, IN DEG C.
REQ1 - TOTAL NITROGEN REQUIREMENT FOR GROWTH
REQV - (NITROGEN) REQUIREMENT FOR VEGETATIVE GROWTH
RESC - RESERVE CARBOHYDRATE
RESN - RESERVE NITROGEN
RFEP - REDUCTION FACTOR FOR TRANSPIRATION DUE TO WATER STRESS ON CROP, DIMENSIONLESS.
RFEPD - REDUCTION FACTOR FOR TRANSPIRATION DUE TO MOISTURE STRESS DUE TO DAY TIME WATER STRESS.
RFEPN - REDUCTION FACTOR FOR TRANSPIRATION DUE TO MOISTURE STRESS DUE TO NIGHT TIME WATER STRESS.
RGCF - ROOT GROWTH CORRECTION FACTOR, DIMENSIONLESS.
RI - INCIDENT SOLAR RADIATION, IN CAL/CM**2/DAY.
RN - NET RADIATION, IN WATTS/M**2.
RNNH4 - RESIDUAL NITROGEN AS AMMONIUM IN SOIL AT BEGINNING OF SEASON, IN LBS/ACRE.
RNNO3 - RESIDUAL NITROGEN AS NITRATE IN SOIL AT BEGINNING OF SEASON, IN LBS/ACRE.
RNO - NET RADIATION ABOVE THE CANOPY, IN MM/DAY.
RNS - NET RADIATION AT THE SOIL SURFACE BELOW THE CANOPY, IN MM/DAY.
ROOSCA - VECTOR OF BREAK POINTS FOR GRAPHICAL INTERPRETATION OF ROOT WEIGHT DENSITY.
ROOTCN - AVERAGE NITROGEN CONCENTRATION IN ROOTS
ROOTN - TOTAL ROOT NITROGEN
ROOTR - POTENTIAL NITROGEN STORAGE IN ROOTS
ROOTR1 - ROOT NITROGEN REQUIREMENT FOR GROWTH
ROOTRS - ROOT RESERVES
ROOTSV - ARRAY OF TOTAL DRY ROOT WEIGHT IN EACH SOIL CELL.
ROOTS - DRY WEIGHT OF ALL LIVING ROOTS IN PROFILE, IN GRAMS.
ROOTWT - DRY WEIGHT OF ALL LIVING ROOTS PER PLANT
ROOTXP - ROOT GROWTH EXPONENT
ROOUNT - VECTOR USED TO WRITE UNITS OF TOTAL ROOT WEIGHT IN THE PROFILE.
ROOUNI - VECTOR USED TO WRITE UNITS OF ROOT WEIGHT DENSITY.
ROWSP - ROWS SPACING
RS - SOLAR RADIATION
RSUBL - LIGHT RESPIRATION COEFFICIENT (FRACTION OF GROSS - PHOTOSYNTATE PRODUCTION)
RSUBO - MAINTENANCE RESPIRATION COEFFICIENT

RTP1 - PARTITIONING COEFFICIENT FOR MOVING ROOT MATERIAL FROM ONE AGE CLASS TO ANOTHER
RTP2 - PARTITIONING COEFFICIENT FOR MOVING ROOT MATERIAL FROM ONE AGE CLASS TO ANOTHER.
RTWT - ARRAY OF ROOT WEIGHTS BY CELL AND BY AGE CLASS, IN GMS.
RTWTCU - ROOT WEIGHT CAPABLE OF WATER UPTAKE, IN GM DM/CELL.
RTWTCG - WEIGHT OF ROOTS CAPABLE OF GROWTH, IN GMS/CELL.
SBLUM - CUMULATIVE SUM OF NUMBER OF BLOOMS
SBOLLD - CARBOHYDRATE NOT USED IN BOLL GROWTH DUE TO DAY TIME WATER STRESS, ACUMULATED DURING DAYS WITH MOISTURE STRESS
SBOLLN - CARBOHYDRATE NOT USED IN BOLL GROWTH DUE TO NIGHT TIME WATER STRESS, ACUMULATED DURING DAYS WITH MOISTURE STRESS
SBOLL - CUMMULATIVE AMOUNT OF CARBOHYDRATE ALLOCATED TO BOLL GROWTH
SCDLAY - SUM OF CARBOHYDRATE DELAYS
SCODE - SUM OF IXX CODES TO THIS POINT IN THE MATRIX
SDWBOL - AMOUNT OF CARBOHYDRATE ALLOCATED TO BOLL GROWTH
SDWLEF - AMOUNT OF CARBOHYDRATE ALLOCATED TO LEAF GROWTH
SDWSQR - AMOUNT OF CARBOHYDRATE ALLOCATED TO SQUARE GROWTH
SEASON - LENGTH OF SEASON TO BE SIMULATED
SEDADD - ADDITIONAL NITROGEN REQUIRED FOR SEED GROWTH
SEEDCN - AVERAGE NITROGEN CONCENTRATION IN SEEDS
SEEDN - SEED NITROGEN
SEEDR1 - SEED NITROGEN REQUIREMENT FOR GROWTH
SEEDR - POTENTIAL NITROGEN STORAGE IN SEEDS
SESI - CUMULATIVE EVAPORATION FROM THE SOIL SURFACE DURING STAGE 1, IN MM.
SESII - CUMULATIVE EVAPORATION FROM THE SOIL SURFACE DURING STAGE 2, IN MM.
SFLOSS - SUM OF FRUIT TO BE LOST
SH - ACCUMULATOR FOR UPTH20 WITHIN THE PROFILE.
SHRTD - SUM OF HOURLY TEMPERATURES DURING THE DAY TIME, IN DEG C.
SHRTN - SUM OF HOURLY TEMPERATURES DURING THE NIGHT TIME, IN DEG C.
SITES - TOTAL FRUITING SITES
SITEZ - TOTAL FRUITING SITES
SLEAF - CUMULATIVE AMOUNT OF CARBOHYDRATE ALLOCATED TO LEAF GROWTH.
SLEAFN - TOTAL LEAF NITROGEN
SLEFD - CARBOHYDRATE NOT USED IN LEAF GROWTH DUE TO DAY TIME WATER STRESS, ACUMULATED DURING DAYS WITH MOISTURE STRESS
SLF - SLOUGHING FACTOR, FRACTION OF BOTH YOUNG AND OLD ROOTS WHICH ARE SLOUGHED EACH DAY, IN 1/DAYS.
SN - ACCUMULATOR FOR UPNO3C WITHIN THE PROFILE.
SOAKN - NITROGEN SOAKING INTO CELL I FROM ABOVE, IN MG N/CM**2.
SOAKW - WATER SOAKING INTO CELL I FROM ABOVE, IN CM**3/CM**2.
SPDWBO - TOTAL POTENTIAL CHANGE IN WEIGHT OF BOLLS
SPDWL - TOTAL POTENTIAL CHANGE IN WEIGHT OF LEAVES
SPDWLD - TOTAL POTENTIAL LEAF GROWTH DURING THE DAY
SPDWLN - TOTAL POTENTIAL LEAF GROWTH DURING THE NIGHT
SPDWRD - TOTAL POTENTIAL ROOT GROWTH DURING THE DAY
SPDWRN - TOTAL POTENTIAL ROOT GROWTH DURING THE NIGHT
SPDWRT - SUM OF POTENTIAL DELTA WEIGHT OF ROOTS OVER ALL CELLS, GMS.
SPDWSQ - SUM OF POTENTIAL WEIGHT GAINS BY SQUARES
SPN - SUM OF PHOTOSYNTHATE PRODUCED TO DATE.
SQABZ - SQUARES ABSCISED
SQAGE - SQUARE AGE
SQRLOS - SQUARE LOSS
SQRWT - WEIGHT OF SQUARES.
SQRZ - SQUARES
SQSUM - SUM OF SQUARES
SQUAR - CUMULATIVE AMOUNT OF CARBOHYDRATE ALLOCATED TO SQUARE GROWTH.
SQWT - TOTAL WEIGHT OF SQUARES ON PLANT
SRAD - WEEKLY SUM OF SOLAR RADIATION, IN LANGLEYS
SRWP - SUM OF RECIPROCAL WATER POTENTIALS, IN 1/BARS.
SSTEM - CUMULATIVE AMOUNT OF CARBOHYDRATE ALLOCATED TO STEM GROWTH.
SSTEMN - CARBOHYDRATE NOT USED IN STEM GROWTH DUE TO WATER STRESS,
SSTEMD - CARBOHYDRATE NOT USED IN STEM GROWTH DUE TO DAY TIME WATER STRESS ACCUMULATED DURING THE DAYS WITH MOISTURE STRESS
SSTEMN - CARBOHYDRATE NOT USED IN STEM GROWTH DUE TO NIGHT TIME WATER STRESS ACCUMULATED DURING THE DAYS WITH MOISTURE STRESS
STEMCN - AVERAGE NITROGEN CONCENTRATION IN STEMS
STEMN - TOTAL STEM NITROGEN
STEMR - POTENTIAL NITROGEN STORAGE IN STEMS
STEMR1 - STEM REQUIREMENT FOR VEGETATIVE GROWTH
STEMRS - STEM RESERVES
STEMWT - STEM WEIGHT.
STRESN - FRACTION OF NIGHT TIME DURING WHICH PLANT IS NOT UNDER MOISTURE STRESS.
STRESD - FRACTION OF DAY LENGTH DURING WHICH PLANT IS NOT UNDER MOISTURE STRESS.
SUMBOL - TOTAL NUMBER OF BOLLS
SUMFRU - TOTAL NUMBER OF FRUIT
SUMSQR - TOTAL NUMBER OF SQUARES
SUPF - SUM OF UPTAKE FACTORS OF THE CELLS, IN GM CM/DAY.
SUPNO3 - SUPPLY OF NITRATE TO PLANTS FROM SOIL, IN MG/DAY.
SWINGH - HALF THE DIFFERENCE BETWEEN THE MAXIMUM AND MINIMUM TEMPERATURES.
SWINGT - DIFFERENTIAL TEMPERATURE OF THE SOIL LAYER FOR THE DAY,
SWINGY - DIFFERENTIAL TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
T - TIME (DAYS FROM EMERGENCE TO FIRST SQUARE)
T16H - MAXIMUM (HIGH) TEMPERATURE AT 16-INCH DEPTH, IN DEG F.
T16L - MINIMUM (LOW) TEMPERATURE AT 16-INCH DEPTH, IN DEG F.
T24 - DIFFERENCE BETWEEN TEMPERATURES AT 2 AND 4 INCHES.
T2H - MAXIMUM (HIGH) TEMPERATURE AT 2-INCH DEPTH, IN DEG F.
T2L - MINIMUM (LOW) TEMPERATURE AT 2-INCH DEPTH, IN DEG F.
T48 - DIFFERENCE BETWEEN TEMPERATURES AT 2 AND 4 INCHES.
T4H - MAXIMUM (HIGH) TEMPERATURE AT 4-INCH DEPTH, IN DEG F.
T4L - MINIMUM (LOW) TEMPERATURE AT 4-INCH DEPTH, IN DEG F.

T816 - VARIABLE FOR USE IN INTERPOLATION AND EXTRAPOLATION
T8H - MAXIMUM (HIGH) TEMPERATURE AT 8-INCH DEPTH, IN DEG F.
T8L - MINIMUM (LOW) TEMPERATURE AT 8-INCH DEPTH, IN DEG F.
TAVG - DAILY AVERAGE TEMPERATURE, IN DEG C.
TAVM1 - AVERAGE TEMPERATURE MINUS 1 DEG, IN DEG C.
TD - DRY BULB TEMPERATURE, IN DEG C.
TDAY - AVERAGE DAY TIME TEMPERATURE.
TFACSQ - TEMPERATURE FACTOR FOR SQUARE GROWTH
TFASQ - TEMPERATURE FOR SQUARE GROWTH, IN DEG C.
TH2O - TOTAL WATER IN THE PROFILE, MM.
THRLN - THRESHOLD WEIGHT TO GIVE LENGTH OF ROOTS REACHING OPPOSITE BOUNDARIES OF CELL FROM WHICH GROWTH ORIGINATED, IN GMS.
TI - TIME INTERVAL BETWEEN NODES
TMAX - MAXIMUM TEMPERATURE DURING THE DAY, IN DEG C.
TMEANT - MEAN TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
TMEAN - MEAN TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
TMIN - MINIMUM TEMPERATURE DURING THE DAY, IN DEG C.
TMINT - MINIMUM AIR TEMPERATURE TOMORROW, DEG C.
TNNH4 - TOTAL AMMONIUM IN PROFILE, MG. N.
TNNO3 - TOTAL NITRATE IN THE PROFILE, MG N.
TNYT - AVERAGE NIGHTTIME TEMPERATURE.
TOTAL - TOTAL OF CONTENTS OF THE CELLS IN THE PROFILE.
TOTNUP - TOTAL NITROGEN UPTAKE
TPDWLN - TOTAL POTENTIAL CHANGE IN WEIGHT OF LEAVES AT NIGHT
TPDWLD - TOTAL POTENTIAL CHANGE IN WEIGHT OF LEAVES DURING THE DAY
TRANSP - TRANSPIRATION RATE, IN MM/DAY.
TSDL - TEMPERATURE OF SOIL LAYER DURING DAY TIME
TSMN - ARRAY OF MINIMUM SOIL TEMPERATURES FOR THE DAY, BY LAYER, IN DEG C.
TSMX - ARRAY OF MAXIMUM SOIL TEMPERATURES FOR THE DAY, BY LAYER, IN DEG C.
TSNL - TEMPERATURE OF SOIL LAYER DURING NIGHTIME.
TSNL - TEMPERATURE OF SOIL LAYER DURING THE NIGHT.
TSOAK - TOTAL WATER SOAKING THROUGH BOTTOM OF PROFILE, MM.
TSOILD - AVERAGE TEMPERATURE OF THE LAYER DURING DAY TIME, IN DEG C.
TSOILN - AVERAGE TEMPERATURE OF THE LAYER DURING NIGHT TIME, IN DEG C.
TSOLAV - AVERAGE TEMPERATURE OF THE LAYER OVER 24 HOURS, IN DEG C.
TSQ - TIME OF FIRST SQUARE
TTL0 - TITLE USED FOR GRAPHICAL OUTPUT.
TTL1 - LINE 1 OF TITLE OF MAP.
TTL2 - LINE 2 OF TITLE OF MAP.
TTL3 - LINE 3 OF TITLE OF MAP.
TTL4 - LINE 4 OF TITLE OF MAP.
TTL5 - LINE 5 OF TITLE OF MAP.
TTL6 - LINE 6 OF TITLE OF MAP.
TTL1R - LINE 1 OF TITLE OF MAP
TTL2R - LINE 2 OF TITLE OF MAP
TW - WET BULB TEMPERATURE, IN DEG C.
U - UPPER LIMIT OF CUMULATIVE EVAPORATION FROM SOIL DURING STAGE 1 DRYING, IN MM.
UNITST - UNITS OF TOTAL
UNITS - PHYSICAL UNITS OF ARRAY VARIABLE.
UPF - UPTAKE FACTOR USED TO APPORTION WATER UPTAKE AMONG CELLS, IN GM CM/DAY.
UPNO3 - UPTAKE OF NITRATE FROM THE CELL, IN MG N/DAY.
UPNO3C - UPTAKE OF NO3 FROM CELL, MG N/DAY.
UPNO3I - UPTAKE OF NO3 FROM IMAGE CELL, MG N/DAY.
UPTH2O - UPTAKE OF WATER FROM THE CELL, IN CM**3/DAY.
VARITY - VARIETY SWITCH, 1 = HIGH PLAINS, 0 = DELTA
VDELAY - DELAY IN FORMING NEW VEGETATIVE BRANCH NODES DUE TO - PHYSIOLOGICAL STRESS
VEGWT - WEIGHT OF VEGETATIVE PARTS
VH20C - VOLUMETRIC WATER CONTENT OF A CELL, IN CM**3/CM**3.
VH2UNI - VECTOR USED TO WRITE UNITS OF VOLUMETRIC WATER CONTENT.
VNC - VOLUMETRIC ORGANIC NITROGEN CONTENT OF THE CELL IN MG. /CM**3
VNH4C - VOLUMETRIC NITROGEN CONTENT AS AMMONIUM IN SOIL, IN MG N/CC SOIL.
VNO3C - VOLUMETRIC NITROGEN CONTENT AS NITRATE, MG N/CC SOIL.
VNOSCA - VECTOR OF BREAK POINTS FOR GRAPHICAL INTERPRETATION OF VOLUMETRIC NITRATE CONTENT IN MG N PER CC SOIL.
VNOUNI - VECTOR USED TO WRITE UNITS OF VOLUMETRIC NITRATE CONTENT.
VP - SATURATION VAPOR PRESSURE FUNCTION OF AIR TEMPERATURE, YIELDS MB.
VPA - SATURATION VAPOR PRESSURE AT WET BULB TEMPERATURE, IN MB.
VPO - SATURATION VAPOR PRESSURE AT DRY BULB TEMPERATURE, IN MB.
VSTRES - VEGETATIVE STRESS - METABOLITE SUPPLY DEMAND RATIO FOR VEGETATIVE GROWTH
W - WIDTH OF EACH SOIL CELL, IN CM.
WATTSM - INCIDENT RADIATION IN WATTS/SQ M.
WFACT - MOISTURE FACTOR AFFECTING BOLL OPENING.
WFMIN - ACTUAL SOIL MOISTURE CONTENT EXPRESSED AS A FRACTION OF FIELD CAPACITY.
WFNIT - MOISTURE FACTOR AFFECTING NITRIFICATION.
WSTRS - WATER STRESS
WSTRSD - WATER STRESS DAY. FRACTION OF DAY TIME PERIOD DURING WHICH LEAF IS TURGID ENOUGH (ABOVE -7 BARS) FOR GROWTH
WSTRSN - WATER STRESS NIGHT. SAME AS ABOVE
WTAVGF - AVERAGE TEMPERATURE FOR THE LAST 7 DAYS IN FARENHEIT.
WTAVG - AVERAGE TEMPERATURE FOR THE LAST 7 DAYS.
WTBO - (IQ) ARRAY OF BOLL DRY WEIGHT.
WTBSLF - WEIGHT TO BE SLOUGHED
WTLOS - WEIGHT LOST
WTSLFD - TOTAL ROOT WEIGHT SLOUGHED
WTSQ - WEIGHT OF SQUARE
XTR1 - MODEL CALIBRATION FACTOR
XTR2 - MODEL CALIBRATION FACTOR
XTR3 - MODEL CALIBRATION FACTOR

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XTR4    - MODEL CALIBRATION FACTOR
XTRAC   - EXTRA CARBOHYDRATE
XTRAN   - EXTRA NITROGEN
XTRES   - INDEX OF CHO STRESS
XXWT    - TOTAL (OPEN + GREEN) BOLL WEIGHT
YIELD   - YIELD OF 500 LB. BALES / ACRE
YKGSHA  - YIELD IN KG / HA.
YKGSHA  - YIELD IN LB / A.
YR      - YEAR
Z       - PLANT HEIGHT IN CM.
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APPENDIX D
Troubleshooting

Usually the first GOSSYM output item a ser looks at is the predicted final yield. he user will examine this figure in terms f its "reasonableness" or will compare it /ith a known yield level in a validation ffort. If the user determines that the yield rediction is incorrect, a systematic meth- d of identifying the source of the error hould be followed. A troubleshooting ;uide for GOSSYM is presented in Figure \. It begins with the components of yield, pen boll weights, and open boll numbers.

First, however, the user should exam- ne the input data. The model can tolerate airly large (ten percent or so) errors in :limate data as long as the errors are ran- lomly distributed in time and they vary requently about the true value. Because he model integrates over time, however, systematic climate errors of one percent :an be expected to cause very significant errors in model predictions.

Referring to Figure A, an error in yield may be caused by an error either in the mature boll weight or in the number of open bolls on the plant at the end of the season.

Error in boll weight is most likely a result of an error in the simulation of primary productivity (PNET) during the boll-fill period. This error could be caused either by an error in the photosynthesis reduction term for water stress (PTSRED), or it may be caused by an error in the estimate of leaf water potential (PSIL) which, in turn, can result from errors in the estimate of the water potential in the rooted portion of the soil matrix (AVGPSI). This error is usually caused by an error in the root system extent or distribution.

Referring again to PNET, error may also be caused by error in the simulation of plant height development, which can be caused by error in mainstem node initiation. Usually, however, this error will cause major problems in other sectors also, and it will be easily identified. A more subtle cause of error in canopy light interception and photosynthesis is the simulation of the decline in leaf area (LAI) as the canopy senesces during boll fill. The error in LAI may, of course, be partly due to an error in leaf initiation, which will show up first as an error in fruiting site production.

Still referring to Figure A, an error in the number of open bolls at harvest can be caused by errors in the simulation of boll opening or by errors in the rate of production of blooms (boll initiation). Note, however, that the model does not simulate the effects of harvest aid chemicals. If they were used, the effect can be simulated simply by continuing the simulation later into the fall.

Boll initiation errors may result from an error in estimating the time from square initiation to bloom, by insect damage (to either the squares or bolls), or simply by earlier error in simulating square initiation rates. The first things to check here are that first square and first bloom occurred at the proper time.

After squaring has begun, error in fruiting site formation rate can be caused by bad temperature data or, possibly, (for the variety involved) an incorrect morphogenetic rate-temperature response function. More likely, however, the problem will be in the rate of mainstem node formation. Both fruiting branch and mainstem node formation rates are affected by metabolic stresses (imbalances in the supply:demand ratios) of available carbohydrates and nitrogen. Improper carbohydrate supply problems can be caused by an error in the simulation of photosynthesis (see above). An improper estimate of the carbohydrate or nitrogen demand can be caused by an error in the number of green bolls on the simulator plant. Nitrogen supply problems are usually caused by error in the transpiration rate or in the withdrawal of water from portions of the soil matrix not containing nitrogen.

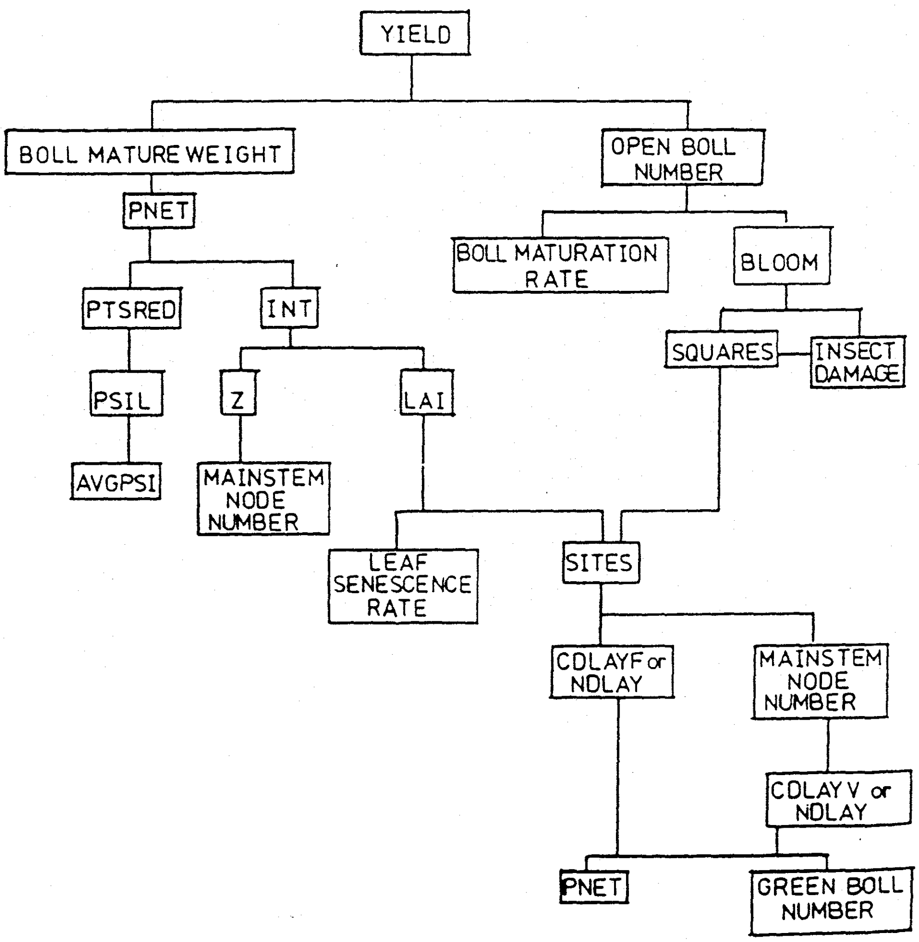

Figure A. Trouble shooting diagram.

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A major simulation effort of the nature of GOSSYM involves several people in addition to the authors. We have attempted to credit scientists whose data we have used in the narrative and source listing. Others who have contributed to this total effort include Ben Alexander who did the initial programming and Juan Landivar who compiled the dictionary and helped to test the model. V. R. Reddy, Bob Fye, and Avi Marani also contributed to the validation of GOSSYM. Frank Whisler and Basil Acock have been critically helpful in many aspects of the simulation, including review of this manuscript. Lawrence Harvey also critically reviewed the manuscript. Many other colleagues have made comments that have been either directly or indirectly of benefit to the development of GOSSYM over the last ten years. We appreciate the help of all those named and unnamed scientists, programmers, graduate students, and combinations thereof who have contributed to this total effort.

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SOUTH CAROLINA AGRICULTURAL EXPERIMENT STATION,
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Variety file ID (left to right numbering)

1	2	3	4	5
First Squaring* Adjustment to date of occurrence	Adjustment to specific leaf weight LEAFWT*		Adjustment to root weight in N-deficient soil PDWRT*	
Adjustment to (day/night) root/ shoot ratio 6	Adjustment to fruiting site initiation xms/fbn TI* 7	CDLAYF B_0 constant 8	CDALYF B_1 constant 9	CDLAYF B_2 constant 10
Early FLOSS 11	First BLOOM* Adjustment to date of occurrence from FSQ	Late FLOSS	DEHIScence* Adjustment to date of occurrence from	Adjustment to main stem node initiation MS TI*
Max fraction of square to abscisse DPSMX constant 16	Maximum fraction of boll to abscisse DPBMX constant	FLOSS Switch constant	Adjustment due to stress day/eve_lfstres* leaf_growth_water_stress	Adjust the boll safe days AGEABZ
PSILIN LF leaf_growth_water_stress constant	PSILIN DZ stem_growt_water_stress constant	NDLAY constant		CDLAYV B_1 constant
21	Minimum LAI affected by boll temperature MIN LAI BOLTMP	Adjustment to vegetative node initiation VEG NODE PFTI*	Adjustment to leaf area expansion DURATION*	Adjustment to leaf age LF AGEFAC
Adjustment to C-allocation of <35 d stems STEM C- 26	Adjustment to C-allocation of >35 d stems STEM C-ALLOC*	Maximum boll size MAX BSIZE genetic potential, g	LL VNO_3C RUTGRO constant	
31	CDLAYV B_2 constant			Adjustment to plant evap. RFEP*
Adjustment to leaf age DROPLF 36	< 35 d PDSTMD (N) constant	Adjustment to initial pre-fruiting leaf area PFLfArea*	Adjustment to initial main stem leaf area XMSLfArea*	Adjustment to initial fruiting leaf area FBLfArea*
Adjustment to initial plant height due to EPI DZ at initiation* 41	Adjustment to internode elongation DURATION*	Adjustment to photosynthesist due to EPI	Adjustment to plant height DZ*	
46	Adjustment to stem height XMNODLTH* NUMPFN < 5	Adjustment to stem height XMNODLTH*	Adjustment to stem height XMNODLTH*	Adjustment to pre-fruiting leaf weight PFDALD/N*
Adjustment to leaf weight 51 PDAMLD/N*		Adjustment to square wt PDWSQ* potential_sqr_growth	Adjustment to photosynthesis PSTAND*	Adjustment to boll weight PDWBOD/N*

*Calibration parameters using KR Reddy's new equations.
All calibration parameters denoted as constant cannot be changed.