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Yield Model Development

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WINTER WHEAT: A MODEL FOR THE SIMULATION OF GROWTH AND YIELD IN WINTER WHEAT

3. D. N. BAKER, D. E. SMIKA, A. L. BLACK, W. O. WILLIS, AND ARMAND BAUER

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16. Abstract This paper documents the basic ideas and constructs for a general physical/physiological process level winter wheat simulation model. It is a materials balance model which calculates daily increments of photosynthate production and respiratory losses in the crop canopy. It simulates the partitioning of the resulting dry matter to the active growing tissues in the plant each day. It simulates transpiration and the uptake of nitrogen from the soil profile. It incorporates the RHIZOS model which simulates, in two dimensions, the movement of water, roots and soluble nutrients through the soil profile. It records the time of initiation of each of the plant organs. These phenological events are calculated from temperature functions with delays resulting from physiological stress. Stress is defined mathematically as an imbalance in the metabolite supply:demand ratio. Physiological stress is also the basis for the calculation of rates of tiller and floret abortion. Thus, tillering and head differentiation are modeled as the resultants of the two processes, morphogenesis and abortion which may be occurring simultaneously.

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WINTER WHEAT

A Model for the Simulation of Growth and Yield in Winter Wheat

D. N. Baker, D. E. Smika, A. L. Black, W. O. Willis, and Armand Bauer

USDA/ARS

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ABSTRACT

This paper documents the basic ideas and constructs for a general physical/physiological process level winter wheat simulation model. It is a materials balance model which calculates daily increments of photosynthate production and respiratory losses in the crop canopy. It simulates the partitioning of the resulting dry matter to the active growing tissues in the plant each day. It simulates transpiration and the uptake of nitrogen from the soil profile. It incorporates the RHIZOS model which simulates, in two dimensions, the movement of water, roots and soluble nutrients through the soil profile. It records the time of initiation of each of the plant organs. These phenological events are calculated from temperature functions with delays resulting from physiological stress. Stress is defined mathematically as an imbalance in the metabolite supply:demand ratio. Physiological stress is also the basis for the calculation of rates of tiller and floret abortion. Thus, tillering and head differentiation are modeled as the resultants of the two processes, morphogenesis and abortion which may be occurring simultaneously.

CONTENTS

Introduction and Objectives

The WINTER WHEAT model was first described, in abstract form, in 1978 (Smika, et.al., 1978). As has been noted elsewhere (Baker, et.al., 1982, Fye et.al., 1982, Marani and Baker, 1981), the feasibility of building simulation models of plant growth and yield has recently been demonstrated and models of cotton, corn, alfalfa, soybean, peanut, sugar beet, winter wheat, rice and sorghum are now available. Such models have been developed at research locations in the US, England, Australia, the Netherlands, USSR, and Japan. 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 US (Moss, et.al., 1961, Baker and Musgrave, 1964), and that of Murata (1961) and others in Japan, Duncan, et.al., (1967) in the US, deWit (1965) in the Netherlands, and Ross (1969), and Tooming (1967) in the USSR immediately precede our work in the effort to predict growth and yield of field crops.

Our objective in developing WINTER WHEAT is to identify and assemble the factors determining winter wheat 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 winter wheat growth and yield, and, of synthesis in which these factors are assembled for rational use by agronomists and farm managers.

General Model Strategy, Characteristics Features and Rationale

Since winter wheat has tremendous ecological range, the above objective implies a general model capable of simulating crop growth over the widest possible range of climates and soils. Since different environmental factors affect different physiological and physical 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, growth, and water flow change rapidly with temperature, light intensity, and plant water status. Except for pollen dessication and organ abscission, the plant processes are continuous, so, the model must be essentially continuous. However, we have 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 cost of running the model. Length of the time steps (for various processes) must be determined mathematically, evaluating size and distribution of errors generated by using progressively longer time

steps.

WINTER WHEAT, like most crop simulators of plant growth, is a materials balance model. 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, glumes, fruit and roots. Various losses may occur as a result of insect damage and the natural plant processes, i.e. senescence and abscission in response to physiological stress. Redistribution (mining) of nitrogen within the plant is modeled. The initiation of organs on the plant occurs as a series of discrete events, with initiation 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 light interception, and, it is reduced by water stress and very low leaf nitrogen concentrations. 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. It also (at a different level of stress) reduces growth and the demand for nutrients. The supply:demand ratios for carbohydrate and nitrogen are used as indices of stress induced organ abscission. Here, we assume that the metabolite supply:demand status of the plant determines (or shifts) hormone balances which result in the abscission of organs. Thus, a severe moisture stress which interferes with photosynthesis and nutrient uptake may result in significant fruit abortion, while a mild moisture stress which reduces growth (demand) more than (supply) photosynthesis may have no effect or even a positive effect on fruit retention.

WINTER WHEAT gains its broad ecological range, i.e. its capability to simulate crops on virtually any soil type, through the incorporation of RHIZOS. RHIZOS (Lambert and Baker, 1982, Whisler et.al., 1981) is a comprehensive simulator of the soil processes, including root growth. While the WINTER WHEAT source listing included here (Appendix a) includes the RHIZOS section, a detailed description is not provided, (ref. Lambert and Baker, 1982). "RHIZOS" is the name given to a system of subroutines designed to serve as a general rhizosphere model for all crops providing the above ground sections with three parameters; an effective soil water potential used to calculate plant water potential, an estimate of metabolite sink strength in the roots, and a mineral nutrient uptake rate.

The appendix contains a source listing, a typical input data set, dictionary of terms, and a typical output listing. The source contains many comments both to make it readable and to cite everyone 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 by number of

characters and listed alphabetically for accessibility.

The Subroutines

MAIN

A simplified flowcharting of the model appears in Figure 1. A detailed flowcharting labelled MAIN Program follows. MAIN calls the subroutines and performs a few calculations pertaining mostly to input/output. First, several state variables describing the plant are initialized. Then, the initial leaf and root weights are read in interactively from the terminal (device 1). A few computations pertaining to the initial status of the plant are made, and then a number of other agronomic inputs are read from the terminal and from the data file (device 5). Soil parameters are set up and initial soil conditions are defined in the soil matrix. Then, the climate data are read in from the data file (device 5).

At this point the simulation begins, and MAIN calls the process subroutines daily. CLYMAT calls the subroutines DATE and TMPSOL. SOIL calls most of the RHIZOS subroutines. They produce soil water potentials and the amount of nitrate taken up by the plant each day.

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, in turn, calls RUTGRO, a subroutine which calculates root growth. GROWTH also calculates the carbohydrate stress and calls NITRO which calculates nitrogen stress and allocates to the various plant parts the nitrogen which has been taken up.

All morphogenetic processes, as well as records of the abortion of tillers and fruit, are handled in MORPH.

CLYMAT

Each day's maximum and minimum temperatures in degrees Celsius are provided as input to the model. CLYMAT converts rainfall data from inches to millimeters. Empirical relationships based on data collected in Mississippi over cotton are used to estimate net radiation from solar radiation, and to estimate the average temperatures during daytime and nighttime from the maximum and minimum temperature data. Note that these relationships (especially the average temperature functions) are location specific. They should be validated for each site where the model is used.

Canopy light interception is calculated in CLYMAT. The model defines interception as the product of two terms. The first is a ground cover term, simply the maximum leaf length divided by the row width. The second is a canopy light attenuation term based on leaf area index. The coefficient, 0.4, was taken from Monteith (1965). This canopy light interception model has not been validated.

Finally, CLYMAT calls TMPSOL which calculates soil profile temperatures at 2, 4, 8 and 16 inch depths from regression equations of McWhorter and Brooks (1965). These equations express soil temperature as linear functions of the running average of air temperature (over the preceding 7 days). These empirical relationships were developed by McWhorter in a fine textured clay soil in Mississippi. They do not account for soil moisture effects on soil temperature.

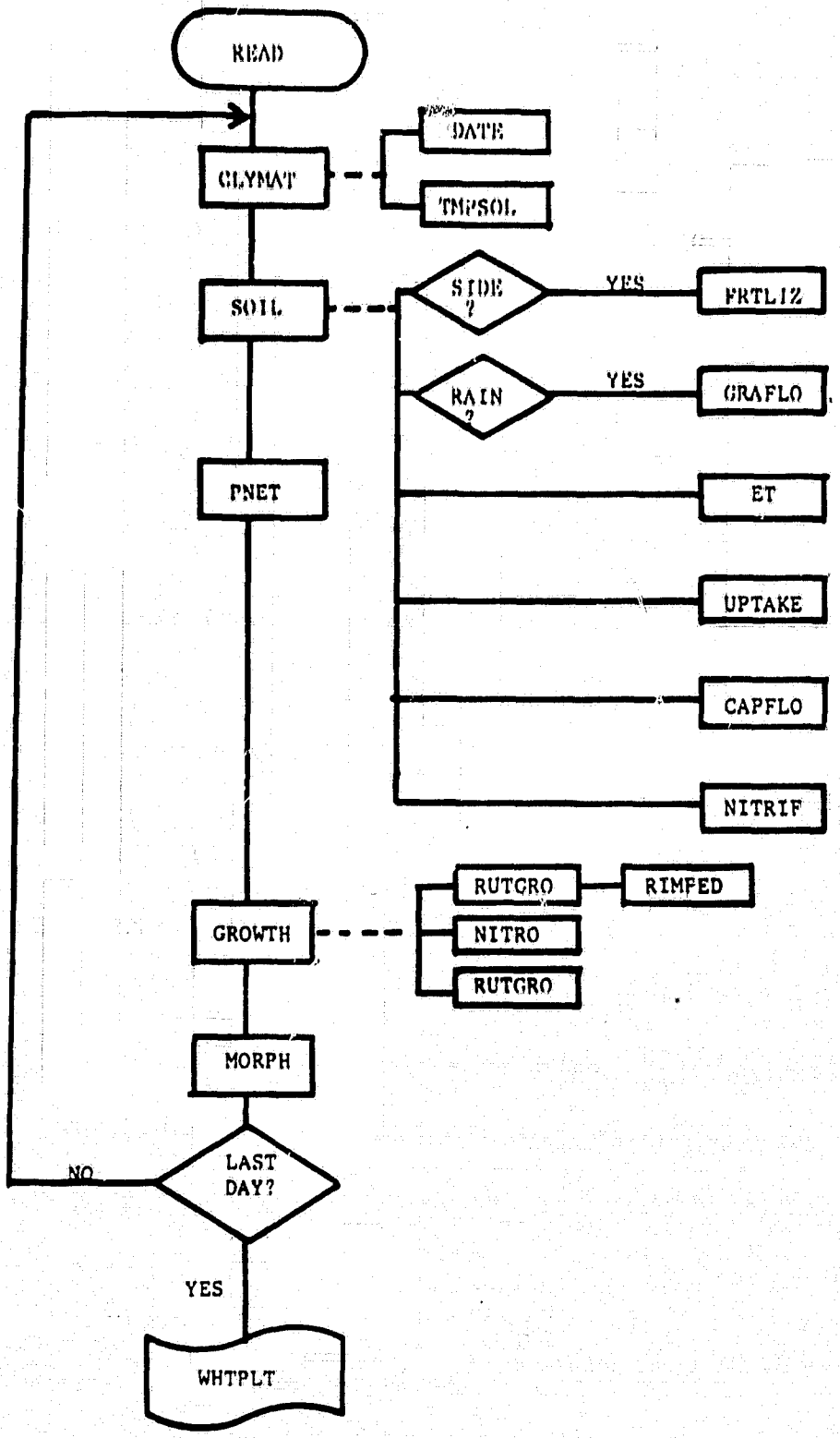
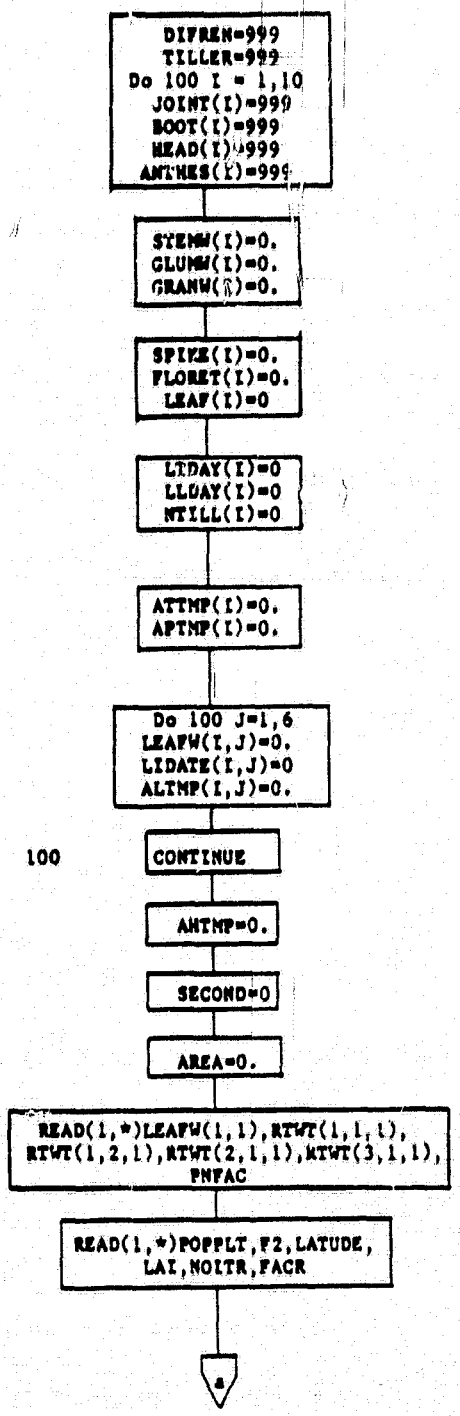


Figure 1. The subroutine structure of WINTER WHEAT.

MAIN Program

Flowchart



Notes

Initialize the variables which are set in the morphogenesis subroutine and are used to indicate state of development.

Initialize the variables where stem, glume, and grain weight for each stem are stored.

Initialize the variables where number of spikelets, florets, and leaves for each stem are stored.

Initialize the variables where day of occurance of last tiller and last leaf initiated from stem I are stored. Initialize the variable where number of tillers initiated from stem I are stored.

Initialize the variables set up to store the accumulated temperature since the initiation of the last tiller from stem I, and since the initiation of stem I.

For each leaf, variables set up to store weight, day of initiation, and accumulated temperature since initiation are set to zero.

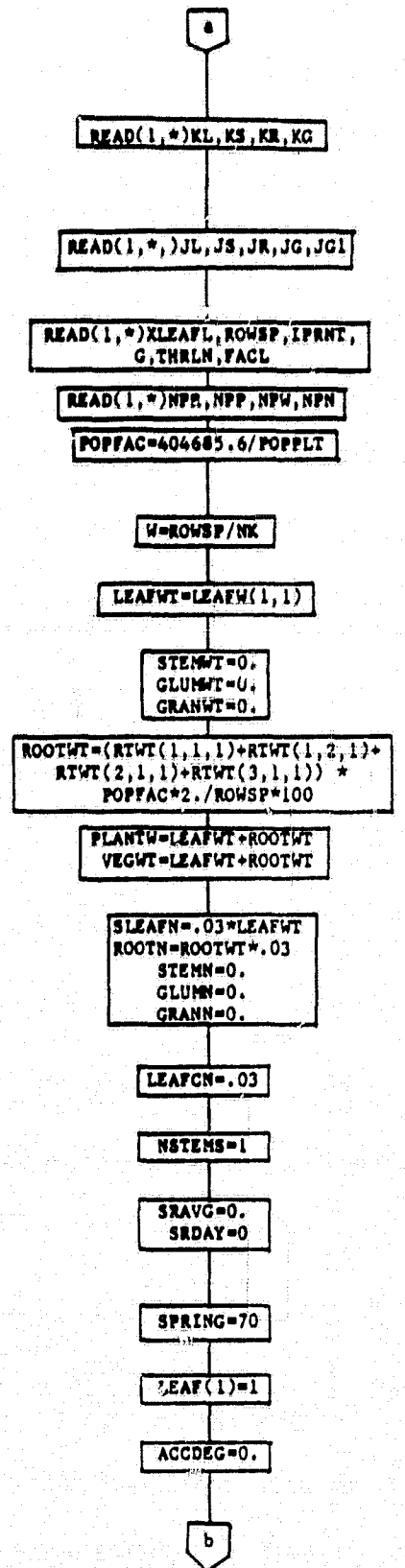
Accumulator for temperature after heading is set to zero.

The variable for number of secondary roots is set to zero.

Total leaf area is set to zero.

Read in initial leaf weight, root weight, and minimum value for net photosynthesis.

Read in plant population, nitrogen availability factor, latitude, initial leaf area index, number of iterations per half day, and a root growth calibration factor.



Read the variables which give minimum levels of nitrogen in leaves, stems, roots, and glumes (reserves may be withdrawn until this concentration is reached).

Read the required nitrogen concentration for new plant growth. Values are read for leaves, stems, roots, glumes and grain.

Read initial leaf length, row spacing, gravity root factor, root growth calibration factor, leaf growth calibration factor, and some printout control variables.

Convert from plants per acre to square decimeters per plant.

Cell width is equal to row spacing divided by number of columns.

Total leaf weight is set to be the weight of the first leaf on stem one.

Total stem, glume, and grain weight for the plant is set to zero.

Plant root weight is a function of plant population, row spacing, and weight of the roots in the soil section.

Total plant weight and vegetative weight is set to be leaf weight plus root weight.

The amount of nitrogen in the leaves is set to be three percent of the leaf weight. The amount of nitrogen in the roots is set to be three percent of the root weight, and the amount of nitrogen in the stems, glumes, and grain is initialized at zero.

Leaf concentration of nitrogen is set to three percent.

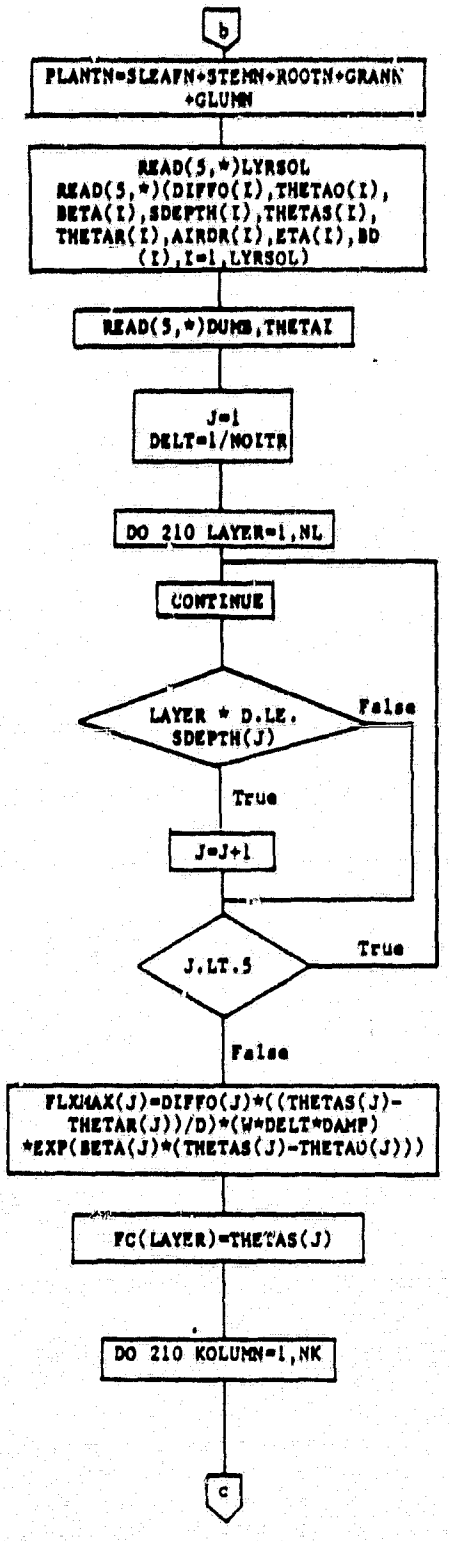
Number of stems on the plant is set to be one.

The accumulator for temperature since initiation of the last seconday root, and the day the last secondary root was initiated, are set to zero.

Spring is arbitrarily set to begin on the seventieth day that the average temperature is at or above 4°C.

The number of leaves on stem one is set at one.

The temperature accumulator for the simulation is set to zero.



Total plant nitrogen is set to be the sum of the nitrogen in the plant parts.

Read the number of soil horizons of different characteristics, and read values for the variables which define the soil characteristics.

Read the initial value for the volume of water at the bottom boundary.

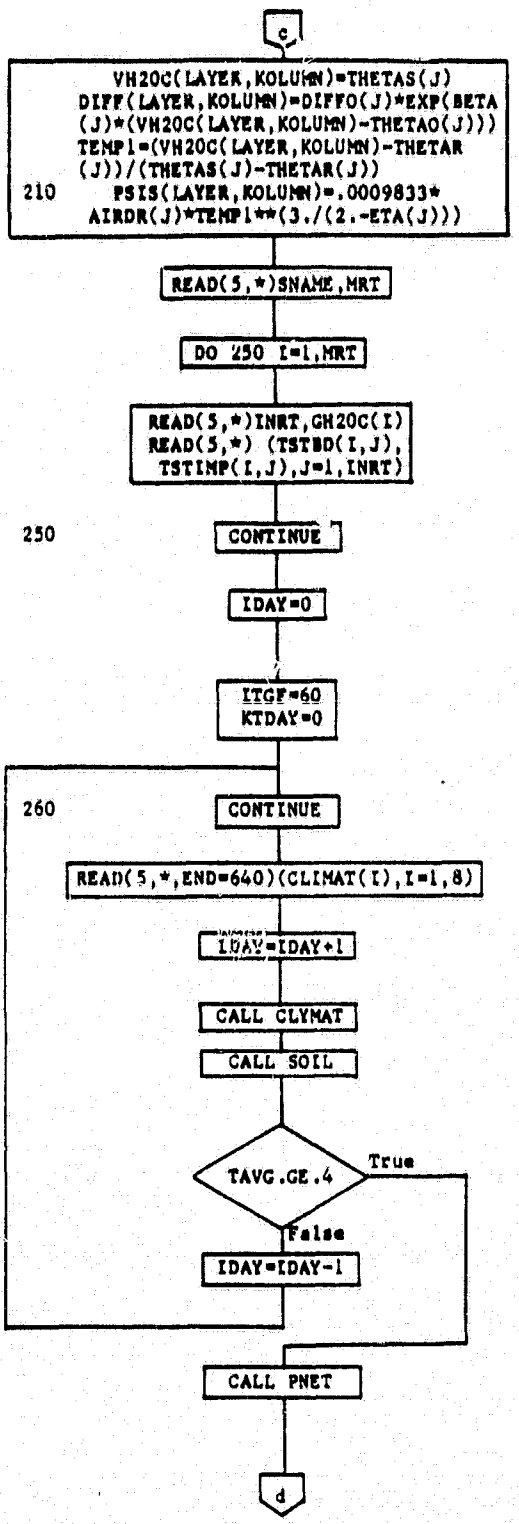
Initialise the counter for number of soil horizons and set the increment.

Do for each of the layers.

Determine the maximum flow of water for each soil horizon.

Set the initial field capacity for water content for each layer in the soil profile.

Do for each column in the soil profile.



Set the initial value for volumetric water content, soil water diffusivity, and soil water potential for each soil cell.

Read the name of the soil type and the number of tables that apply, then write these values to the printer.

Read in the tables that relate soil type and their resistance to root growth. Write these tables out to the printer.

The counter for the number of days with average temperature at or above 4°C is set to zero.

The time for grain fill and the number of days since anthesis began are initialized.

Read in the daily climate data.

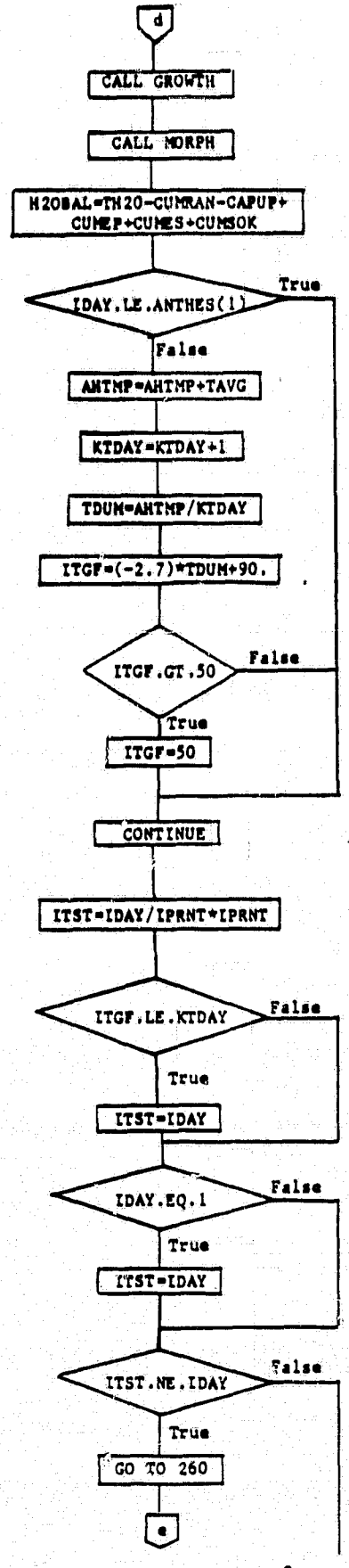
Increment the day counter.

Call the CLYMAT subroutine.

Call the SOIL subroutine.

If the average temperature is below 4°C then do not count this day in the simulation, and skip the routines that deal with other then soil processes.

Call the PNET subroutine to calculate photosynthesis.



Call the GROWTH subroutine to distribute the photosynthate.

Call the MORPH subroutine to determine the stage of growth.

Calculate the water balance.

If you have reached the beginning of ANTHESIS, then calculate the required time for grain filling.

The average daily temperature since ANTHESIS began is accumulated.

The number of days since ANTHESIS began is incremented.

Calculate the average temperature since ANTHESIS began.

Determine the time for grain filling which is a function of temperature.

Limit the time for grain filling to be a maximum of 50 days.

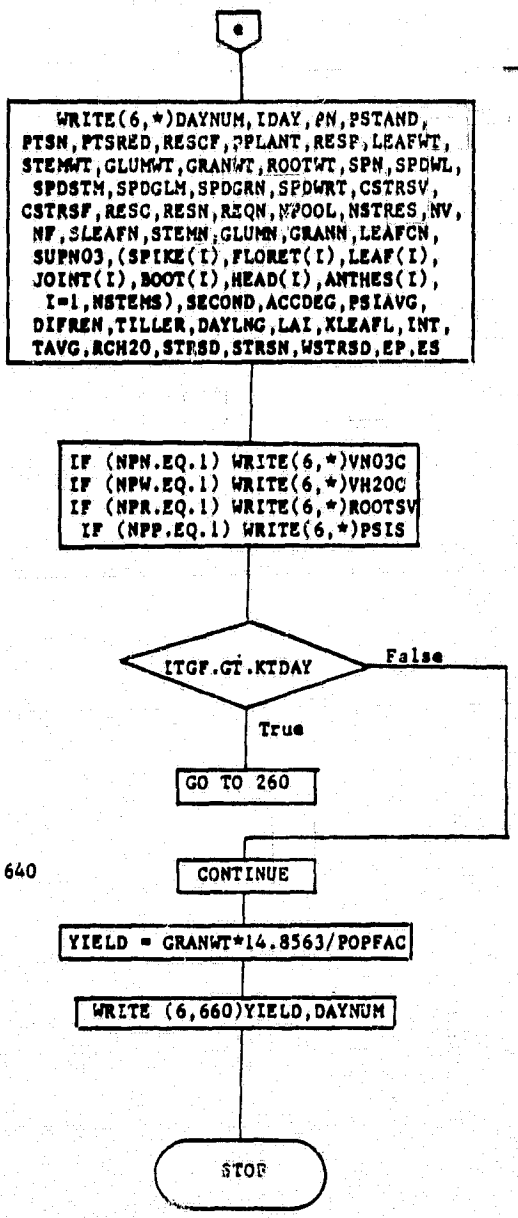
Determine if it is time for a printout of results.

If time for grain filling is satisfied, then print the results.

If it is the first day of the simulation, then print the results.

If the results are not to be printed, then go to the beginning of the daily loop.

MAIN Continued



Print the results which allows the user of the model to track the plant as to the stage of development, growth rates, problem areas, etc.

Write out the plots of nitrogen, volumetric water content, root weight, and soil water potential for the soil section as requested.

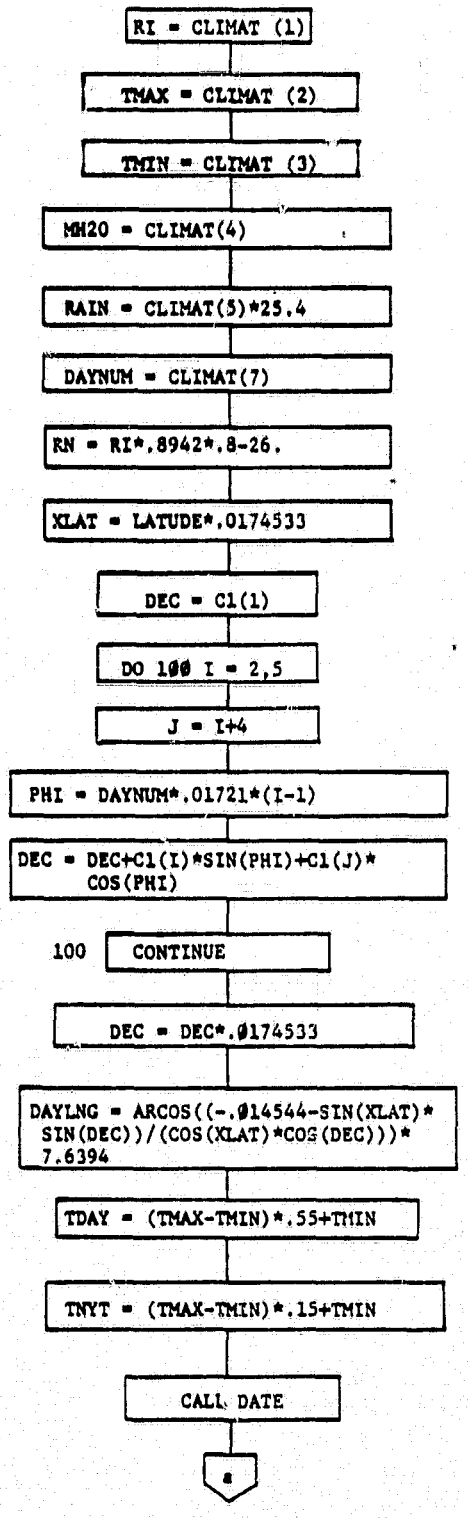
If we have not reached the last day of the simulation, then go to the beginning of the daily loop.

Determine yield in bushels per acre.

Write out the yield.

CLYMAT Subroutine

Flowchart



Notes

RI is daily radiation in Langley's.

TMAX is maximum daily temperature (°C).

TMIN is minimum daily temperature (°C).

MH20 is set to 1 if Rain is actually irrigation.

Rainfall (or irrigation) is converted to millimeters.

DAYNUM is the Julian day.

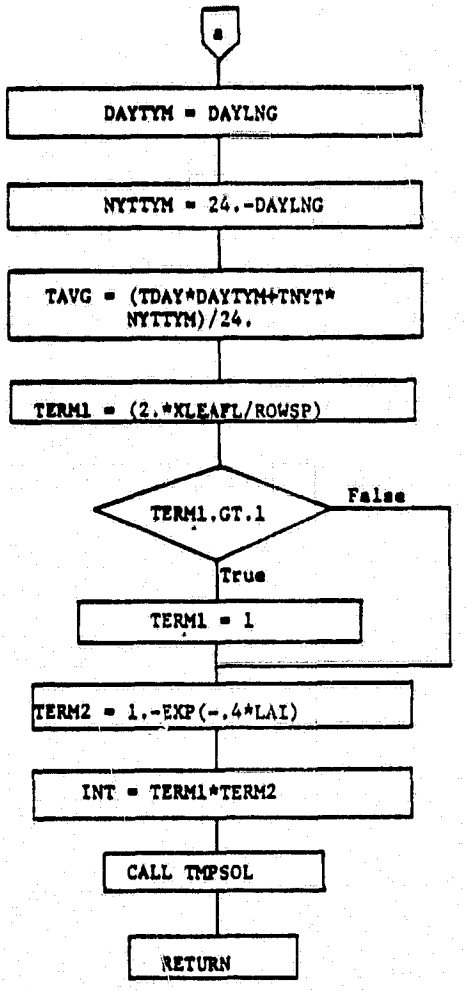
Solar radiation is converted to watts/meter**2.

Day length is calculated as a function of latitude and Julian day.

Average daytime temperature is calculated as a function of the maximum and minimum daily temperatures.

Average nighttime temperature is calculated as a function of the maximum and minimum daily temperatures.

Call the DATE subroutine to convert Julian date to calendar date.



The variable DAYTYM is set to be the number of daylight hours in the 24-hour day.

The variable NYTTYM is set to the number of hours from sunset to sunrise.

The average daily temperature is calculated.

The percentage of light intercepted is determined as a function of row-spacing, length of the largest leaf on the plant, and leaf area index.

Call the TMPSOL subroutine to calculate soil temperatures.

SOIL

The reader is referred to Lambert and Baker (1982), Marani and Baker (1981) and Whisler et.al. (1981) for detailed descriptions of the subroutines called from SOIL. However, a brief statement of function is offered here. In general, the purposes of the RHIZOS section of WINTER WHEAT 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 above ground 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, two meters being the depth. This section is one cm thick and it is assumed to be longitudinally representative of the row. It is subdivided into a 6x20 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. If fertilizer is to be added on a given day, FRTLIZ is called.

If rainfall or irrigation occurs, GRAFLO is called which distributes the water vertically in the profile. Ammonium ions are assumed to be adsorbed on soil colloids and to be stationary. Nitrate nitrogen, on the other hand, is assumed to be in solution and to move 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, then, 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 in those cells containing roots. The amount taken from any given cell depends on the amount and age distribution (permeability) of the roots in the cell.

Redistribution of water within the soil profile occurs in CAPFLO. Again, nitrate nitrogen moves with the moving soil water.

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

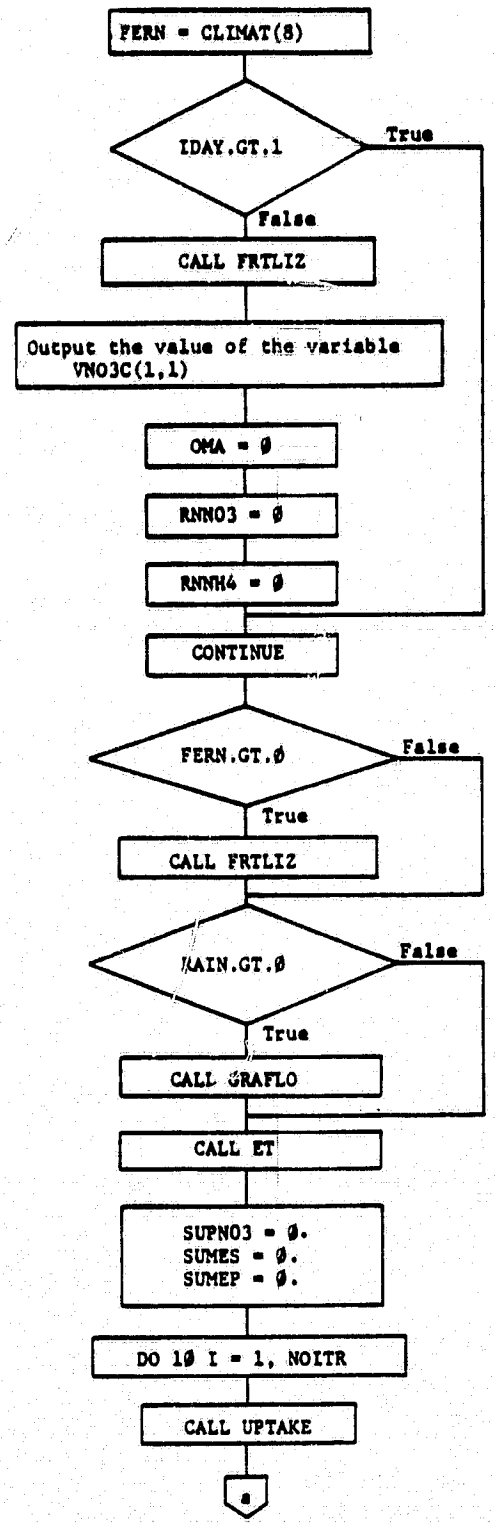
PNET

As noted earlier, WINTER WHEAT 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, being the dry weight of the grain.

In a review of the subject of canopy photosynthesis (Baker, et.al., 1978a) a number of factors were considered in the choice of approach to the problem of estimating canopy photosynthesis.

SOIL Subroutine

Flowchart



Notes

CLIMAT(8) is the amount of fertilizer to be applied today.

On the first day of the simulation, call the fertilizer subroutine to add nitrogen found in the organic matter, and to add residual nitrate and ammonium to the profile.

After the first day, the organic matter and residual nitrate and ammonium variables are set to zero.

If fertilizer is to be applied then call the fertilizer subroutine (FRTLIZ).

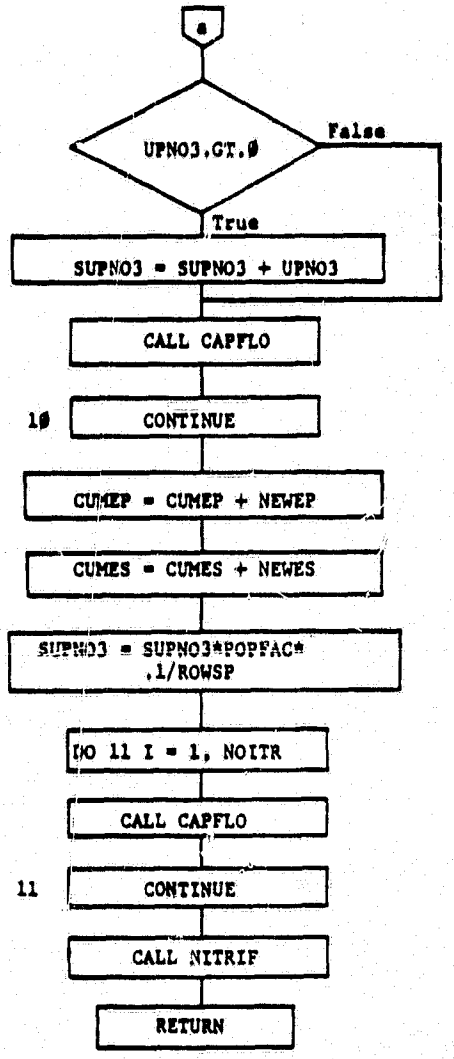
If rain or irrigation occurred, then call the gravitational flow subroutine (GRAFLO).

Call the evapotranspiration subroutine (ET).

Initialize the accumulators for uptake of nitrate, evaporation from the soil, and transpiration from the plant for the day.

Iterate NOITR (an input parameter) times during the daytime.

Call the uptake subroutine (UPTAKE).



Accumulate the nitrate taken up by the roots during the day.

Call CAPFLO to redistribute water and nitrate in response to potential gradients caused by the withdrawal of water.

Add periodic transpiration to the accumulator.

Add periodic evaporation from the soil to the accumulator.

Convert nitrate uptake to units of grams per plant.

Iterate NOITR (an input parameter) times during the night.

Call CAPFLO to redistribute soil water during the night.

Do the nitrification processes.

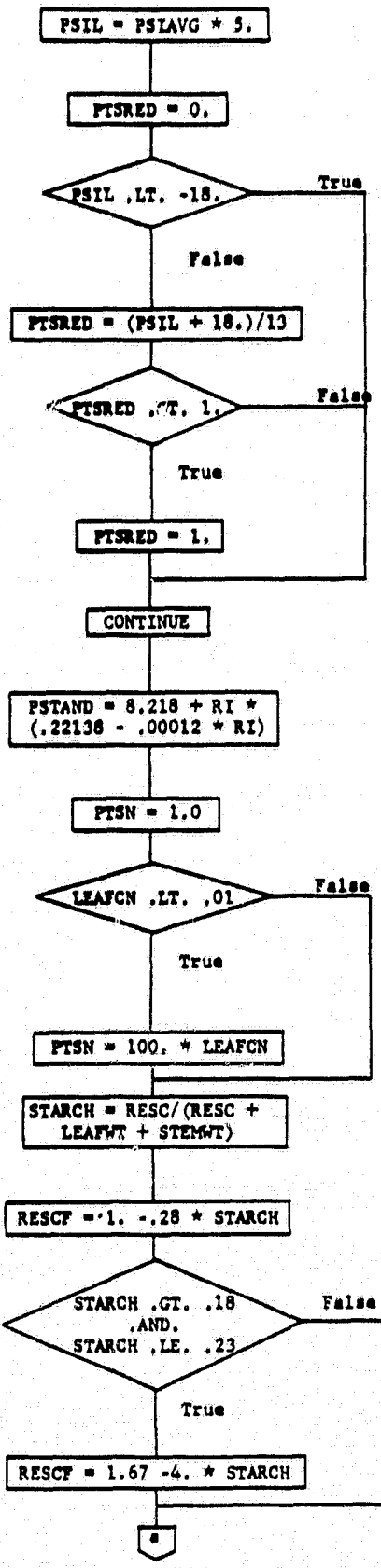
The static models of Monsi and Saeki (1953), deWit (1965), Duncan, et.al., (1967), and Tooming, (1967) consider the leaf as the basic photosynthetic element. They treat an exceedingly complex subject requiring a vast amount of input data describing the physical location, the climate and the angular orientation of each leaf element in the canopy. This information must be provided continuously throughout the day. In order to accurately estimate total canopy performance they also require the age, the developmental history and the current nitritional 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 the crop modeler with 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. Secondly, they do not correctly account for 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, they assume a horizontally uniform distribution of leaves which is not appropriate in a row crop.

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

A detailed flow chart of PNET is presented on pages 17 and 18. The model does not contain a mechanism for the calculation of leaf water potential from environmental inputs, and so it (PSIL) is simply set equal to five times the water potential in the rooted portion of the soil profile. The next several statements, down to line 10, compute a water stress reduction factor for photosynthesis. The reduction factor (PTSRED) is a linear function of leaf water potential taken directly from Figure 1 of Lawlor (1976). We believe that the data base for PTSRED must be confirmed in experiments at various stages of development in crops grown under natural light and with various patterns of water stress development.

Next, canopy photosynthesis, on a ground area basis, is calculated. In 1977, Baker, Parsons, Phene, Lambert and McKinion (unpublished) collected a set of canopy aparent photosynthesis and respiration data in the winter winter wheat cultivar, Scout, under abundant soil moisture and fertility conditions. Measurements were made at several stages of development in the crop. The measurements were made in SPAR units (Phene et.al., 1978) via the closed system technique. Apparent photosynthesis was recorded continuously, throughout the season, at fifteen minute intervals, along with incident PAR, canopy light interception and canopy air temperature. Respiration was measured in



Leaf water potential is set to be five times the average soil water potential.

Photosynthesis reduction factor for moisture stress is initialized at zero.

If leaf water potential is less then -18 bars then PTSRED remains at zero.

The reduction factor is a linear function of the leaf water potential.

If this reduction factor is calculated to be greater than one then it is set to one.

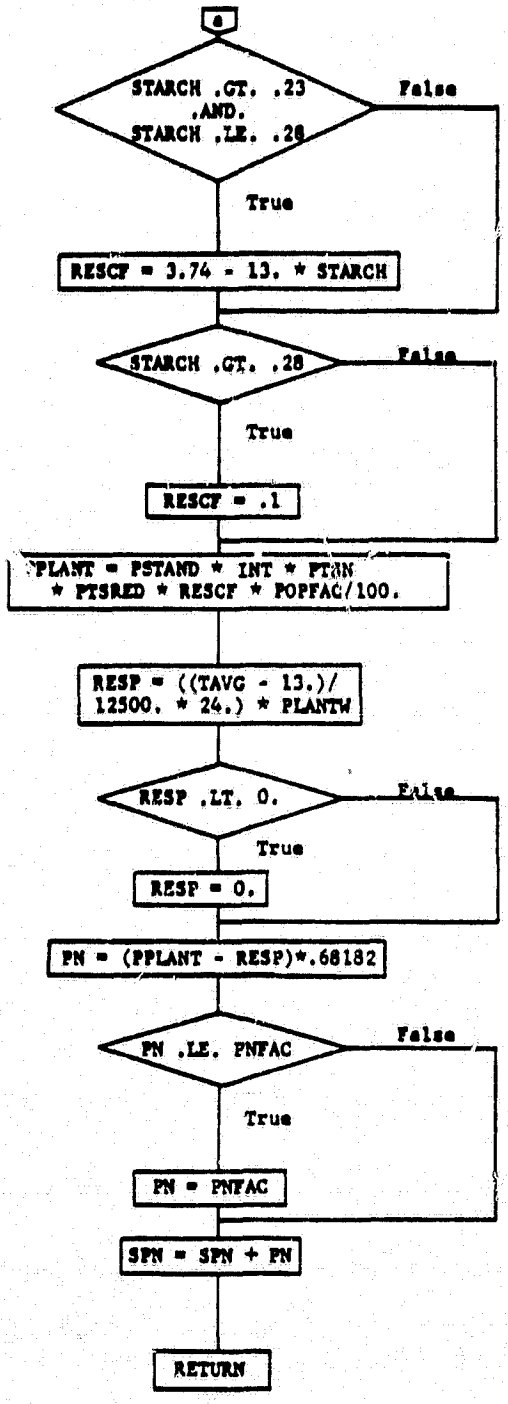
Potential canopy photosynthesis is a function of solar radiation.

Photosynthesis reduction factor for nitrogen stress is initialized at one.

If leaf concentration is less than one percent, then the photosynthesis reduction factor due to nitrogen stress is set to be 100 times the leaf concentration of nitrogen.

Calculate the fraction of plant weight which is starch.

Calculate photosynthesis reduction factor for starch leafloading feedback as a function of leaf carbohydrate level.



Gross photosynthesis is a function of intercepted light, plant population, and the calculated reduction factors.

Respiration loss is calculated as a function of temperature and plant weight.

If the respiration loss is calculated to be less than zero then it is set to zero.

Net photosynthesis is set to be gross photosynthesis minus respiration loss multiplied by a factor to convert grams of CO_2 to grams of CH_2O.

If net photosynthesis is less than the minimum amount, then it is set to the minimum (arbitrarily assigned) value.

Net photosynthesis is totaled for the season.

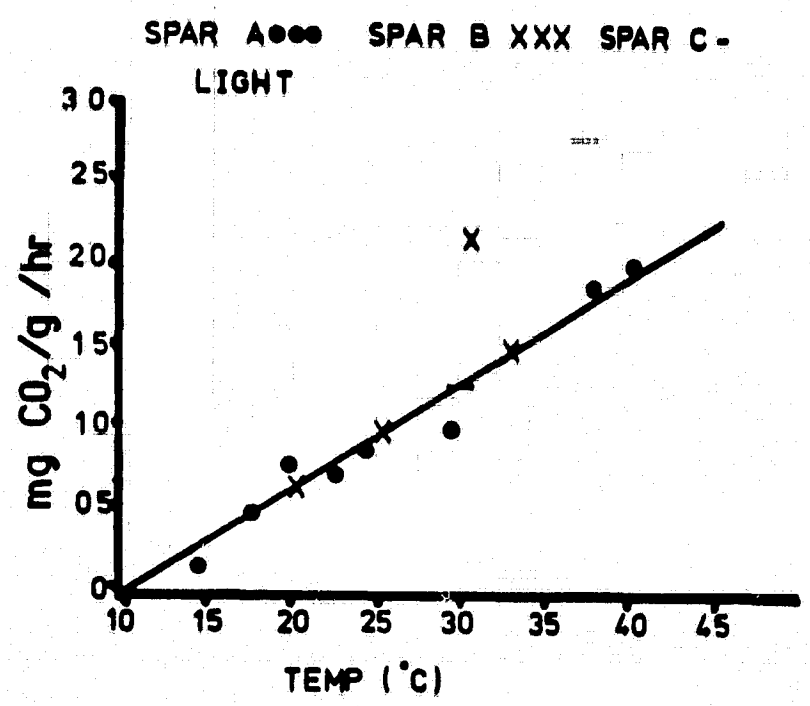
the same SPAR crops as was photosynthesis. The respiration data are presented in Figure 2. Two techniques were used in these measurements. In the first, (Figure 2a) the chamber was quickly darkened after a period of photosynthesis. In the second, (Figure 2b) the chamber was kept dark for a period of about 18 hours prior to and during the respiration measurements. Rate of increase in canopy CO_2 was measured after 25 to 30 minutes' accomodation to a new temperature level. Unlike the results with cotton, (Baker et.al., 1972) we found no difference in rate of canopy respiration whether preceded by a period of rapid photosynthesis or not. The senesced SPAR C data points were deleted. The light and dark data sets were combined and fitted to provide the respiration function in the code. This technique may be criticized since it is, in fact, a respiration measurement made in the dark being used to represent respiration in the light, c.f. Chollet and Ogren (1975). Although we believe any quantitative error will be relatively small, this estimate of the respiratory loss in the light will probably be on the high side. Canvin (1970) presents evidence that dark respiration may be reduced in the presence of light. There appeared to be no change in photosynthetic efficiency during the season until the beginning of senescence. The data were collected on crops in three SPAR units maintained at three temperature regimes (c.f. Table 1). So, the crops matured at different rates. The effect of senescence on canopy photosynthesis is shown in Figure 3. There was no significant senescence effect in chamber B through days 114, 116, and 117, nor was any senescence in A noticeable through days 126, 127, and 128. Appropriate dark respiration values from the above measurements were added to these (fifteen minute) apparent photosynthesis values, and, the data were pooled and fitted to obtain a composite canopy light response curve with 258 15-minute data points. An R^2 value of 0.89 was obtained. This curve was used, with 15-minute average solar radiation data throughout the daylight periods in 36 representative days over the season to produce the daily total data presented in Figure 4. The data range from completely clear days to completely and heavily overcast days. The equation for this curve is used to calculate daily photosynthate production (PSTAND) from daily total solar radiation in WINTER WHEAT. Next, a photosynthesis reduction factor for nitrogen stress is calculated. At the time of the development of this model, no data base for this was available to us, and so, we arbitrarily reduce photosynthesis for leaf nitrogen concentrations below one percent by the leaf concentration multiplied by 100. In future versions of WINTER WHEAT an experimental data base for this will be developed.

The following section of PNET develops a photosynthesis reduction factor for starch buildup in the leaves. Again, no data base for this in winter wheat was available to us. Therefore the data and logic of Holt, et.al. (1975) in their alfalfa model, SIMED, are used.

Next, the photosynthate yield (PSTAND) is reduced by the above reduction factors, adjusted for canopy light interception (INT), and put on a per plant basis.

In the next several statements, canopy respiration is calculated.

Net photosynthesis, PN, is calculated as the difference between photosynthesis and respiration multiplied by a factor to convert the



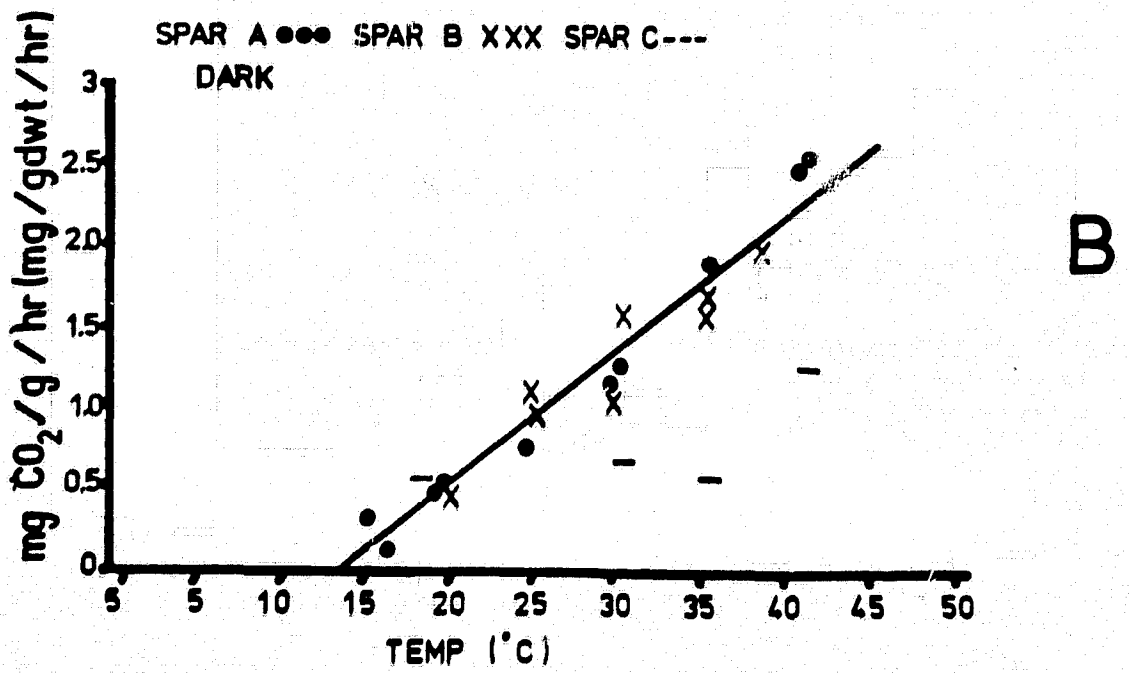


Figure 2. Canopy respiration rates (in mg. CO_2/gram dry plant weight/hour) vs. air temperature immediately after exposure to bright light (A) and after exposure to long periods of darkness (B).

Table 1. SPAR Unit Temperature Control Program.

Julian Day	Average SPAR Air Temperature °C		
	SPAR UNIT		
	A	B	C
6-12	2.7	5.3	9.8
13-19	4.6	7.2	10.1
20-26	4.9	7.1	12.8
27-33	4.6	9.7	12.8
34-40	7.2	10.2	15.6
41-47	7.2	12.8	18.3
48-54	7.2	12.9	18.4
55-61	10.0	15.5	21.1
62-68	10.0	15.6	23.9
69-75	10.1	18.0	23.5
76-82	12.6	18.0	25.8
83-89	13.1	18.3	25.8
90-96	15.9	21.2	29.3
97-103	16.0	23.9	29.4
104-110	18.2	23.9	29.3
111-117	18.2	23.8	28.8
118-124	17.9	24.1	29.3
125-131	19.0	23.8	28.7
132-138	18.0	23.9	27.4*
139-145	16.8	23.8	
146-152	17.2	23.9	
153-159	17.1	23.8	

*Terminated after day 137

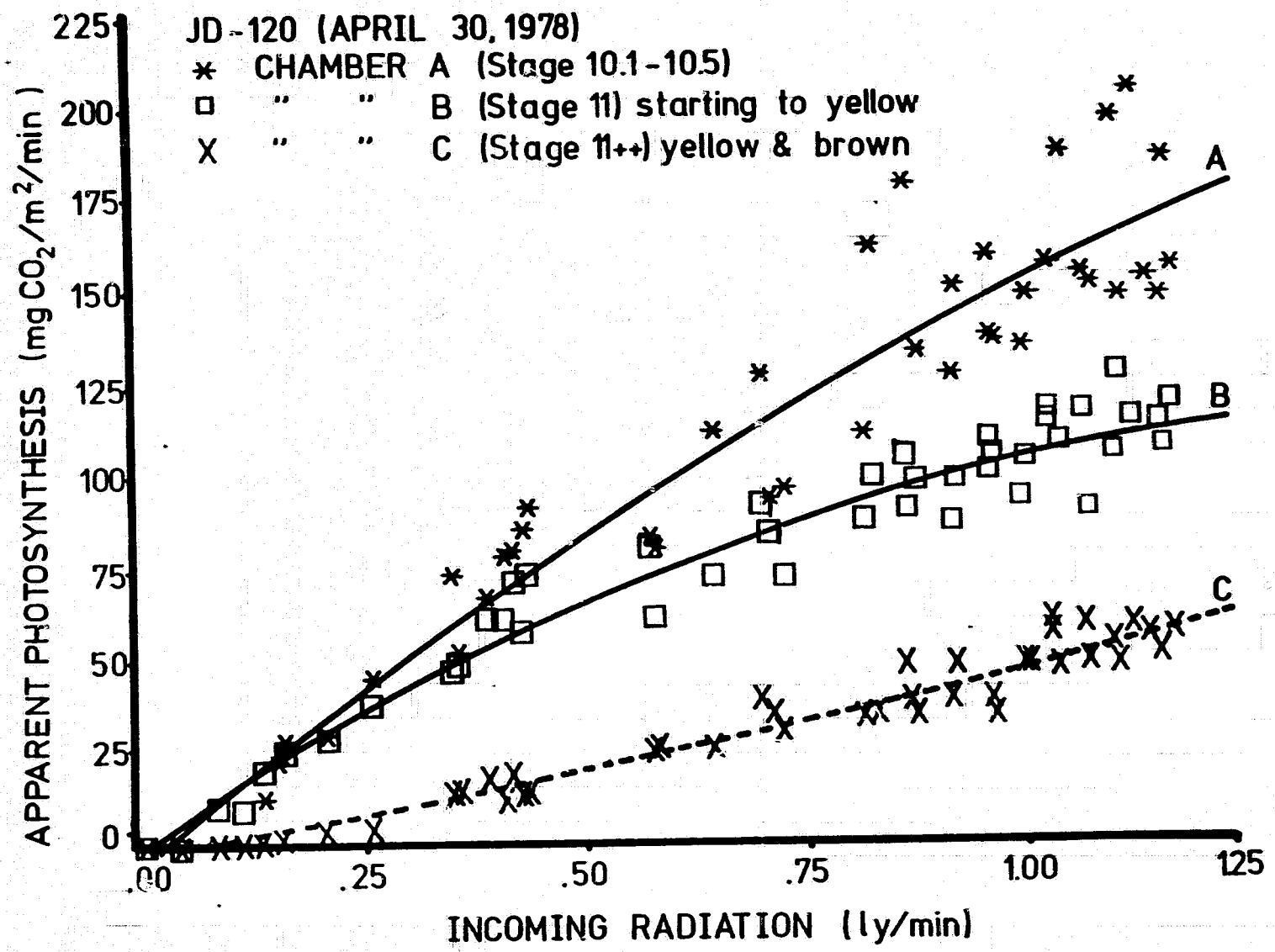


Figure 3. Apparent canopy photosynthesis vs. solar radiation flux density in three SPAR crops differing in maturity.

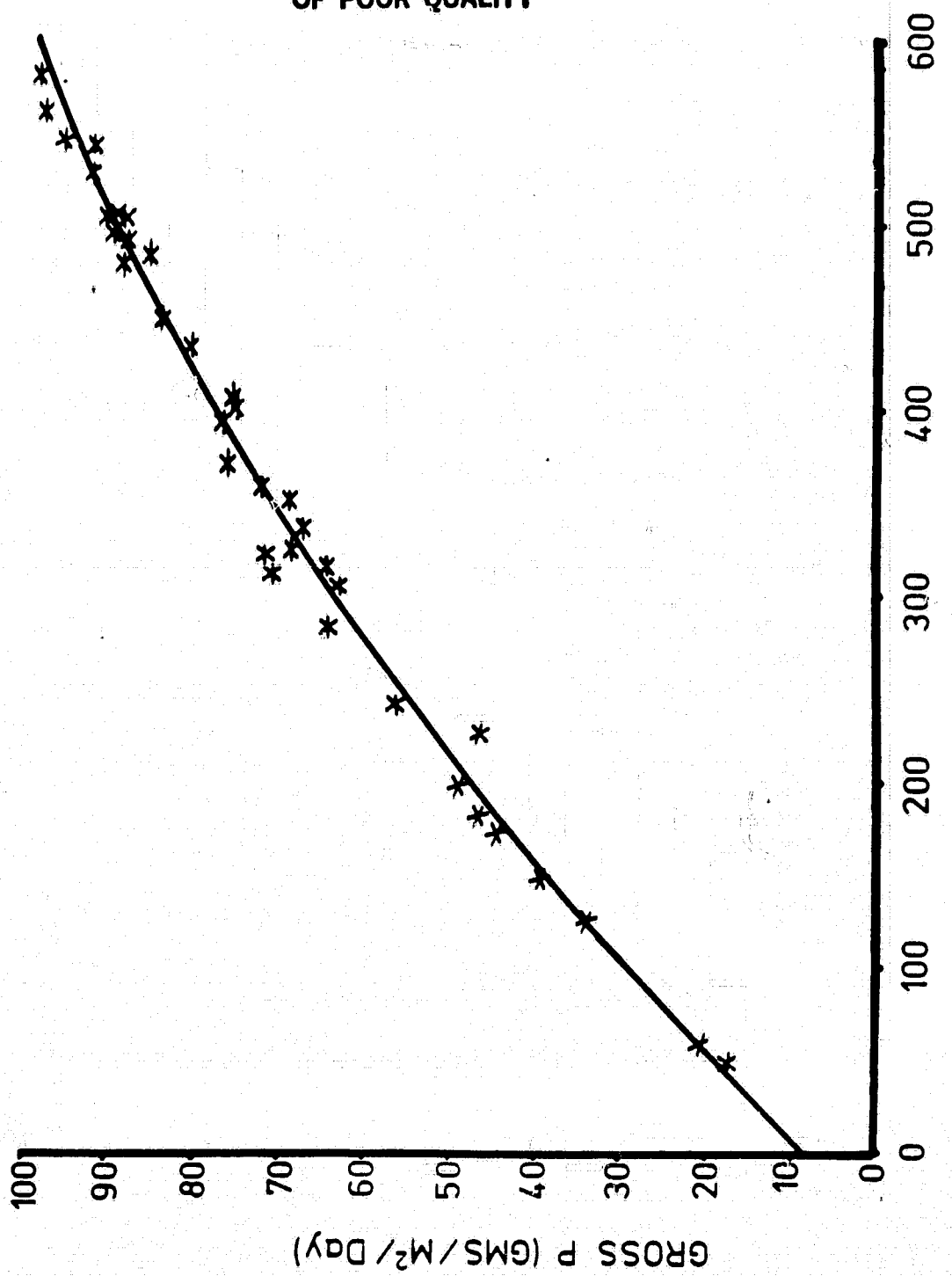


Figure 4. Daily total canopy photosynthesis vs. daily total solar radiation.

CO_2 to CH_2O. It represents dry matter production per plant per day. A very small minimum limit ensures some growth in the very early seedling stages.

Finally, the day's increment of net photosynthate production is accumulated for diagnostic purposes in the materials balance.

GROWTH

This subroutine calculates potential and actual daily increments of growth of each of the organs on the plant. The data base is mainly from papers by Sofield et.al. (1974) and Friend et.al. (1962). Root growth is handled in RUTGRO, a 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 day time and night time (WSTRSD AND WSTRSN) water stress parameters referred to 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 the potential growth increments of all the plant organs. Plant attributes used in this calculation include organ weights and ages (since initiation). When a better organ data base is available, potential growth will be calculated for day and night time 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. Its function is to estimate the nitrogen required to assimilate the amount of carbon just estimated for each of the organs. These nitrogen requirements are summed for the vegetative parts and the fruiting parts and the sums are used in the denominators of nitrogen supply/demand ratios to estimate the maximum fractions of the carbohydrate uptake potentials that can actually be assimilated, considering the nitrogen limitations. This, then, is a reduced or refined estimate of potential organ growth increments.

c) a carbohydrate supply/demand ratio is calculated as follows:

$$CPOOL = PN + RESC$$

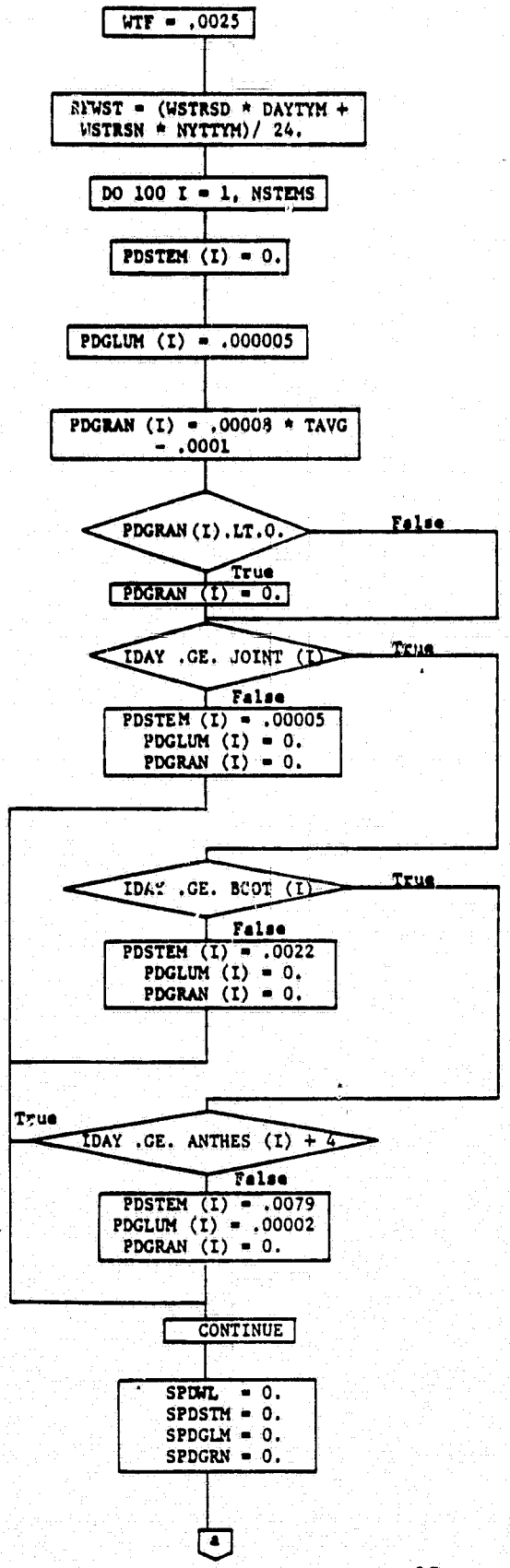
$$CSTRES = CPOOL/CD$$

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

d) actual growth of each organ on the plant, then, is calculated as the product of potential growth multiplied by CSTRES. This partitions photosynthate to each organ on the plant in proportion to its contribution to total demand, except that grain will receive their full requirement first if sufficient carbohydrate is available for grain growth. Anything beyond that is partitioned to the vegetative parts, including roots.

GROWTH is flowcharted on pages 25 to 30. The water stress terms,

GROWTH Subroutine



WTF is the factor to convert leaf area in cm**2 to weight in grams.

Determine the water stress factor for reduction of potential growth.

Do for all the stems on the plant.

Initialize the potential change in stem weight for each stem. (Heading Stage)

Initialize the potential change in glume weight for each stem. (Heading Stage)

The potential change in grain weight is a function of temperature. (Heading Stage)

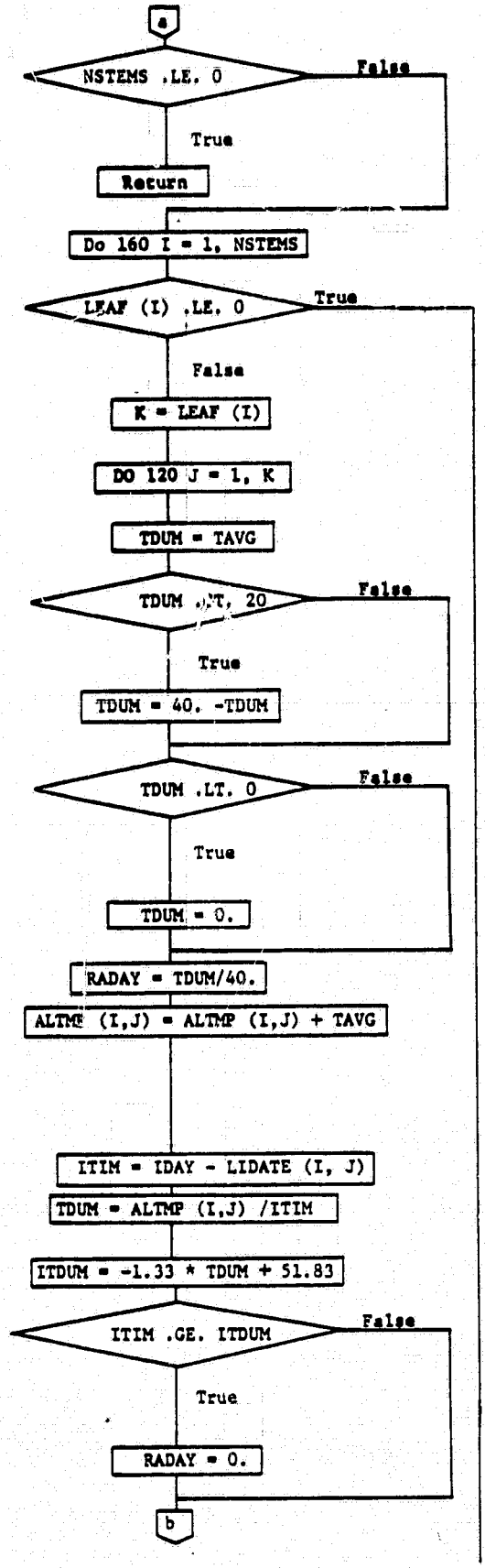
If the potential change in grain weight is calculated to be less than zero, then set it to zero.

Set potentials for stem, glume, and grain growth prior to jointing.

Set potentials for stem, glume, and grain growth during jointing.

Set potentials for stem, glume and grain growth during boot stage through anthesis.

Zero the accumulators for weight change potentials.



If there are no stems, then get out of the growth routine.

Do for each stem on the plant.

If a stem has no leaves, then skip leaf growth routine.

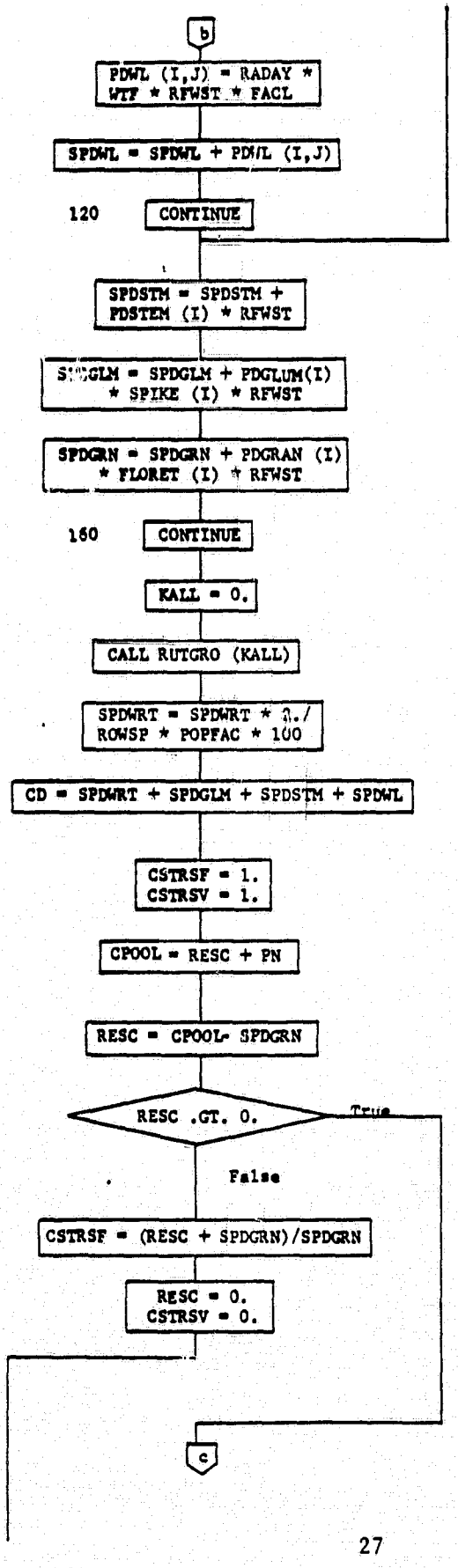
Do for each leaf on the stem.

Potential change in leaf area is a function of temperature with max potential change occuring at 20°C. The relationship is linear with no potential growth below 0°C or above 40°C.

The average temperature is added to the temperature accumulator for each leaf (accumulated since the leaf was initiated).

Determine the age of each leaf.

Calculate the average temperature of each leaf since its initiation.



Potential change in leaf weight is a function of potential change in leaf area, area to weight factor, water stress factor, and an input growth coefficient.

Calculate potential change in leaf weight for the plant (total).

Calculate potential change in stem weight for the plant (total).

Calculate potential change in glume weight for the plant (total).

Calculate potential change in grain weight for the plant (total).

Call RUTGRO subroutine to get potential change in root weight.

Convert potential change in root weight to be in units of grams per plant.

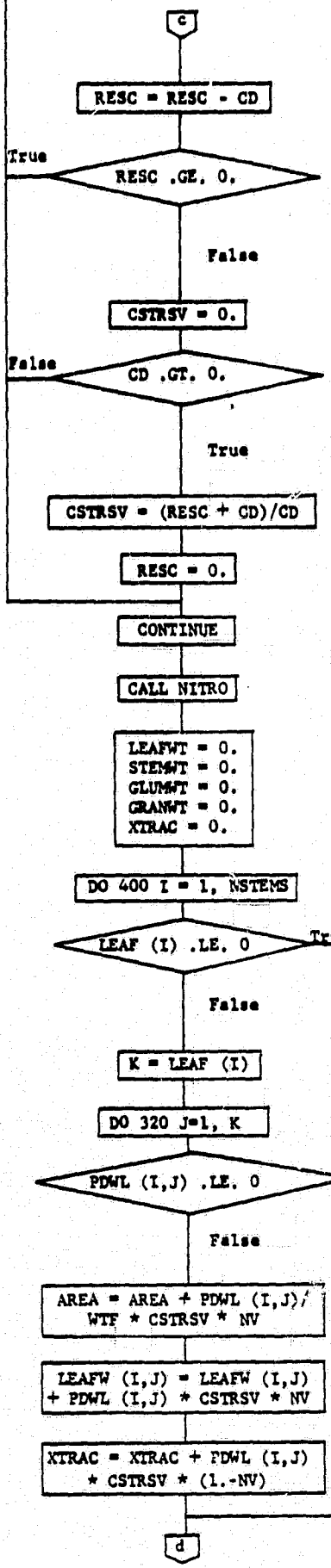
Total potential change in weight of all plant parts except grain to determine carbohydrate demand for these parts.

Initalize the carbohydrate stress factors at 1 (no stress).

Calculate total available carbohydrate as being reserve from IDAY-1 plus the photosynthate produced on IDAY.

Subtract carbohydrate needed for maximum potential grain growth from the carbohydrate available.

If no carbohydrate remains for growth of other plant parts, set the reserve carbohydrate variable to zero, the carbohydrate stress factor for vegetative parts to zero, and recalculate the carbohydrate stress factor for grain growth based upon available carbohydrate.



Subtract the carbohydrate needed for growth of plant parts other than grain from available carbohydrate.

If the available carbohydrate is insufficient to meet demand, then use the remaining carbohydrate for growth, calculate a carbohydrate stress factor for vegetative growth and set the carbohydrate reserve to zero.

Call the NITRO subroutine to allocate nitrogen for growth.

Set the variables used to total the weight for the leaves, stems, glumes, and grain on the plant to zero. Zero the variable used to accumulate the extra carbohydrate.

Do for all the stems on the plant.

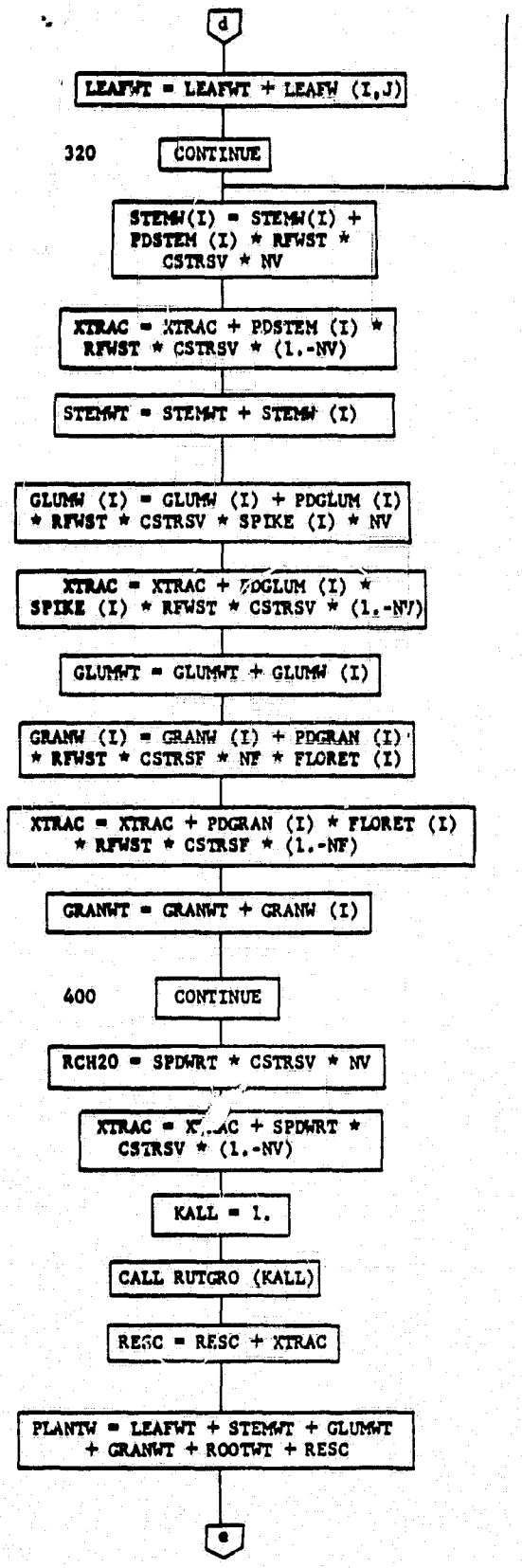
For each leaf on stem I;

if there is a potential for change in leaf weight;

determine change in area of leaf J on stem I and add to accumulator of total leaf area for plant.

Determine the weight of leaf J on stem I.

Accumulate the extra carbohydrate which was needed for growth but was not used because of nitrogen stress.



Accumulate the weight of leaves on plant.

Determine weight of stem I by adding change in stem weight to the accumulator.

Accumulate the extra carbohydrate which was needed for stem growth but not used because of nitrogen stress.

Accumulate the total weight of all stems on plant.

Determine weight of glumes on stem I by adding change in glume weight to the accumulator.

Accumulate the extra carbohydrate which was needed for glume growth but not used because of nitrogen stress.

Accumulate the total weight of all glumes on plant.

Determine the weight of grain of stem I by adding grain weight to the accumulator.

Accumulate the extra carbohydrate which was needed for grain growth but not used because of nitrogen stress.

Accumulate the total weight of all grain on the plant.

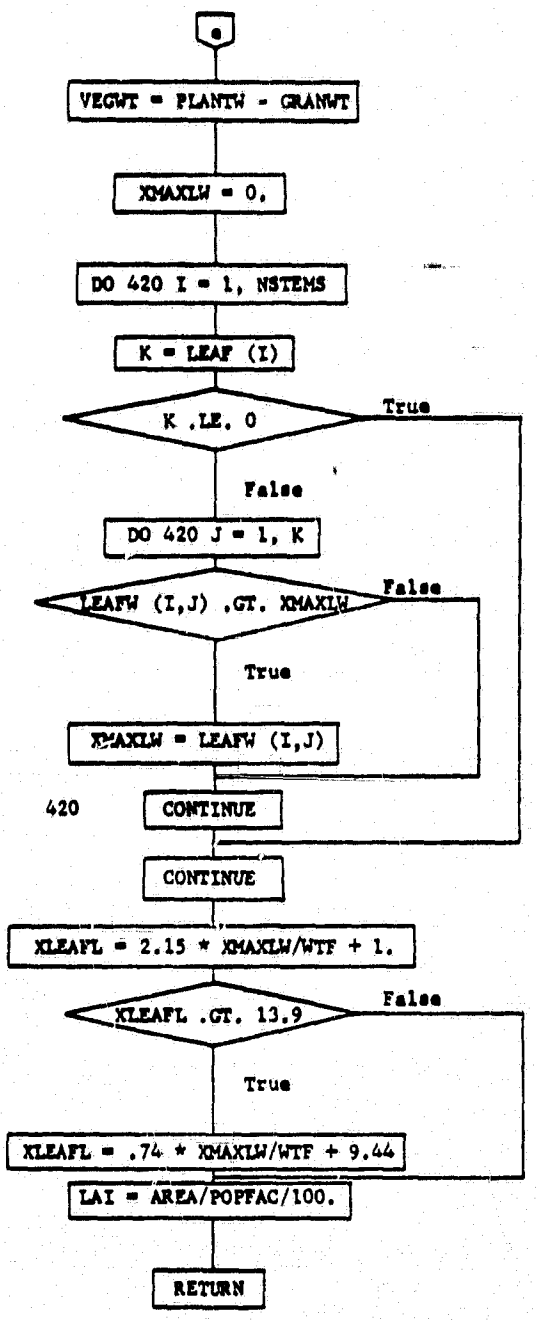
Determine the amount of carbohydrate going to the roots of the plant.

Accumulate the extra carbohydrate which was allocated for root growth, but not used because of nitrogen stress.

Call the RUTGRO subroutine to grow the roots.

The extra carbohydrate is added to reserve carbohydrate.

Total plant weight is weight of individual plant parts plus the reserve carbohydrate which is mainly stored in the leaves.



Vegetative weight is plant weight minus grain weight.

Initialize the variable which is used to store the weight of the largest leaf on the plant.

Do for all the stems on the plant.

Do for all the leaves on stem I.

If the weight of leaf J on stem I is more than the maximum weight of any leaf to this point, then set the maximum leaf weight to be the weight of leaf J on stem I.

Use maximum leaf weight to determine maximum leaf length.

Determine leaf area index for the plant.

defined in subroutine RUTGRO, for daytime and nighttime, and, day and night average temperatures are brought in from MAIN.

Referring to the flow charts on page 25, the first statement defines a specific leaf weight term from unpublished data of Smika. The second statement forms a water stress factor from water stress data (WSTRSD and WSTRSN) data brought in from RUTGRO via MAIN. These data represent the fraction of the day and night time periods during which the leaf water potential is estimated to be above -7 bars. The remaining statements on page 25 calculate or define the potential dry matter accumulation increments in the stems, glumes and grain. The values for stems and glumes have been chosen arbitrarily. The values for the grain are taken from Sofield et.al. (1974). These are first defined for the heading stage. Then, they are successively defined for the jointing, booting and anthesis (plus 4 days) stages.

The statements on page 26 and down to statement 120 on page 27 define the potential growth increment of each leaf on each stem as functions of temperature and water stress. The data base, both for leaf growth rate and the length of the leaf growth period is from Friend et.al. (1962). They did not record leaf growth per se. The temperature responses represent total above ground vegetative growth rates. Their experiments were done with Marquis wheat (Triticum aestivum) under artificial light (up to a maximum of 2500 f.c.), and their data extend only to 30 C.. We believe that values derived from this data set may be low representations of "potential", i.e. not limited by carbohydrate supply, growth. Certainly these data need to be confirmed in further experiments. However, we have used the Friend et.al. data only to construct the shape of a temperature response. Actual amounts of leaf growth appear to be reasonable. First, leaf area growth is calculated. Then, the length of the leaf growth period is calculated as a function of running (since leaf initiation) average temperature. Finally, a potential leaf weight increment is calculated from the potential area growth increment, the specific leaf weight factor and the water stress reduction factor. These potential leaf growth increments are then accumulated.

Next potential growth increments for stems, glumes and grain are adjusted for water stress and accumulated. Then, (middle of page 27) RUTGRO is called, where the potential change in root weight in each of the RHIZOS cells is computed as a function of soil temperature and accumulated.

This potential total root growth increment is added to the total of growth increments for stems, leaves, and glumes to produce a total carbohydrate demand (CD) for vegetative growth. Then, the carbohydrate pool is calculated as the sum of today's photosynthate production plus reserves carried over from yesterday.

Next, the supply:demand ratio for grain growth is calculated. The following logic allows carbohydrate shortage to terminate vegetative growth entirely in favor of grain growth. First, the reserve pool is decremented by the amount needed for grain growth. If this completely depletes the reserves, then, reserves are set to zero, the supply:demand ratio for vegetative growth is zeroed, and, the supply:demand ratio for fruit growth is defined less than one. If, however, reserves are not depleted by grain growth, they are

decremented by the amount needed for vegetative growth. If they are still not depleted, full vegetative growth occurs. If they are depleted, a supply:demand ratio for vegetative growth less than one is calculated.

Next, NITRO is called and in an analogous way, nitrogen supply:demand ratios for grain and vegetative growth are calculated.

After return from NITRO, (middle of page 28 through page 29) actual dry matter growth of each organ on the plant in calculated. In each case, three steps are taken. First, the new organ size is defined as the old value plus today's increment, which is equal to the potential growth increment multiplied by the supply:demand ratios for carbohydrate and nitrogen. Next, if nitrogen was limiting, some carbohydrate is left over, (XTRAC). This is accumulated and added to reserve. Finally, the total weights of the various categories of organs are accumulated.

After RUTGRO is called for the actual incrementing of root dry matter, total plant weight and vegetative weight are calculated. Maximum leaf length is calculated for use in the estimation of canopy ground cover (INT), and LAI is calculated.

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 above ground plant parts.

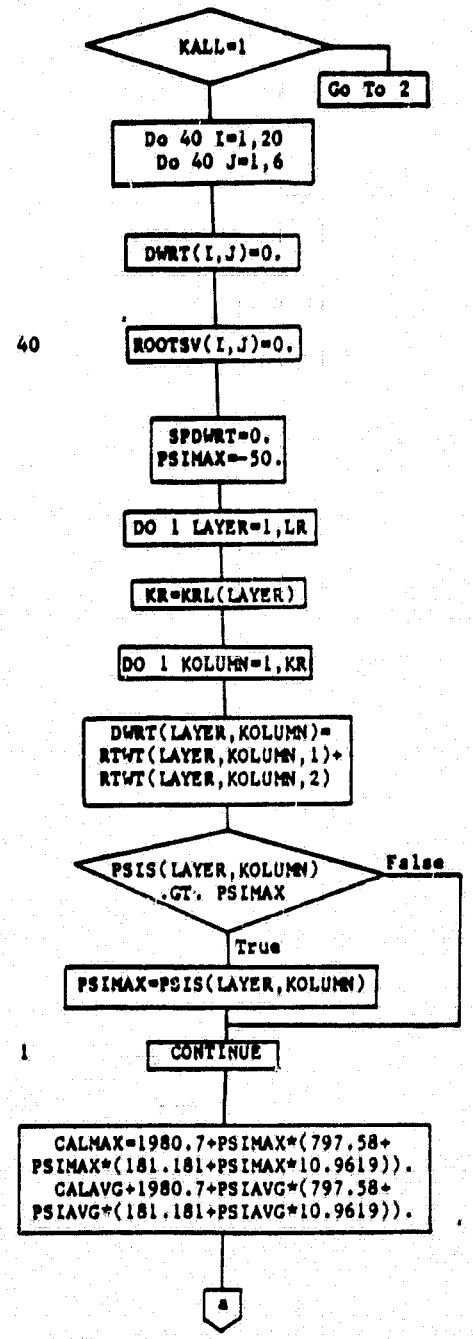
A more detailed description of this subroutine is presented by Lambert and Baker (1982) in their discussion of RHIZOS. The parts directly affecting above ground processes will be outlined here for readability of the present discussion of WINTER WHEAT as a whole. Flow charts are presented on pages 33-44.

The water stress parameters (WSTRSD and WSTRSN) 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 from about -3 bars (full turgor). The exact cutoff varies with species and we presume it varies with conditioning. The plants approach zero enlargement asymptotically, reaching zero at or before -12 bars leaf water potential. Baker et. al. (1982) have chosen thresholds ranging from -3 to -12 bars and found that a -7 bar threshold works best for estimating growth in cotton. This analysis has yet to be repeated for winter wheat.

Model strategy is to assume that above -7 bars leaf water potential there is no restriction to growth of above ground plant parts and below that threshold no growth occurs, since the asymptote is approached sharply in Boyer's data. A regression model expressing cotton leaf water potential (PSIL) as a function of soil water potential (PSIS), net radiation (RN) and temperature (TA), where water potentials are in bars, temperature is in Celsius, and net radiation is in watts/m^2 was used to calculate PSIL values at ten minute intervals for all combinations of the weather and soil water potential conditions in Table 2. Daily time courses of a typical data set are given in Figure 5 along with the net radiation and air temperature values used.

RUTGRO Subroutine



On the second time RUTGRO is called each day skip to statement 2.

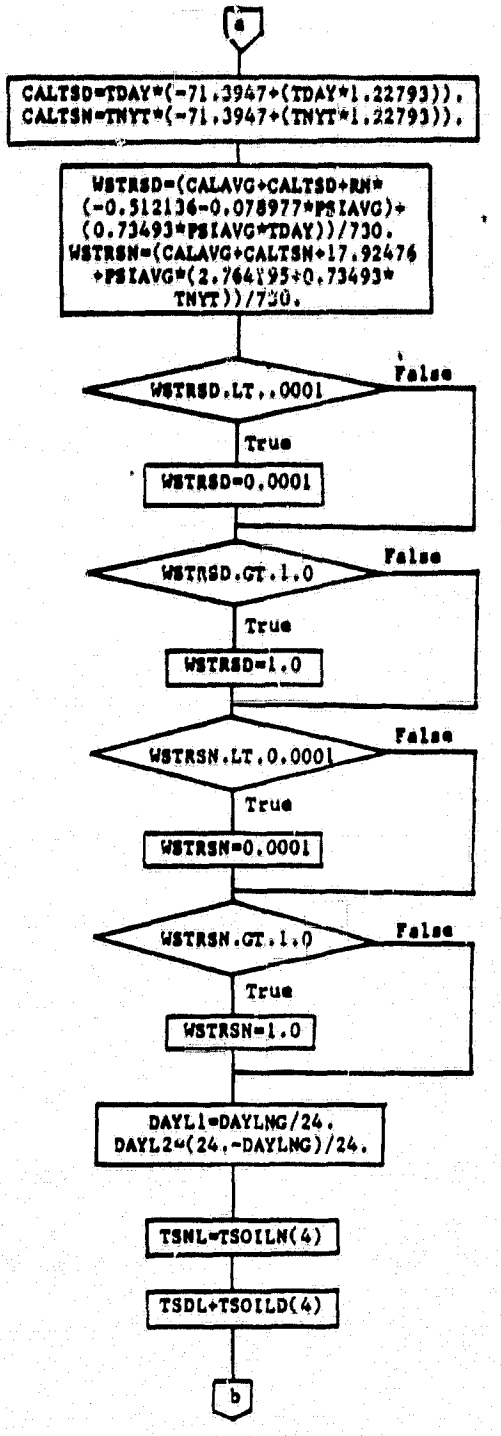
Initialize the arrays DWRT and ROOTSV each day.

Initialize 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 3 days old) plus those in age class 2 (between 3 and 12 days).

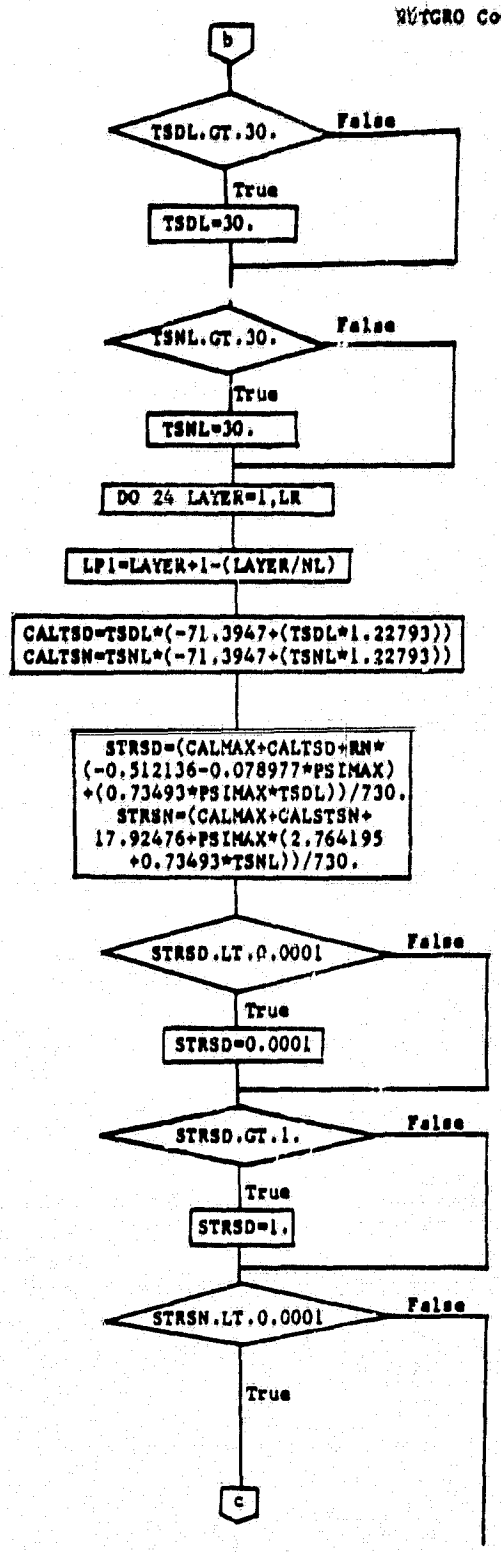
By repeating this comparison over all soil cells occupied by roots, the maximum soil water potential in the root-occupied region will be found. Note that PSIS(Ψ_s) is negative.



Limits .001 .LT. WSTRSD .LT. 1.

Limits .0001 .LT. WSTRSN .LT 1.

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

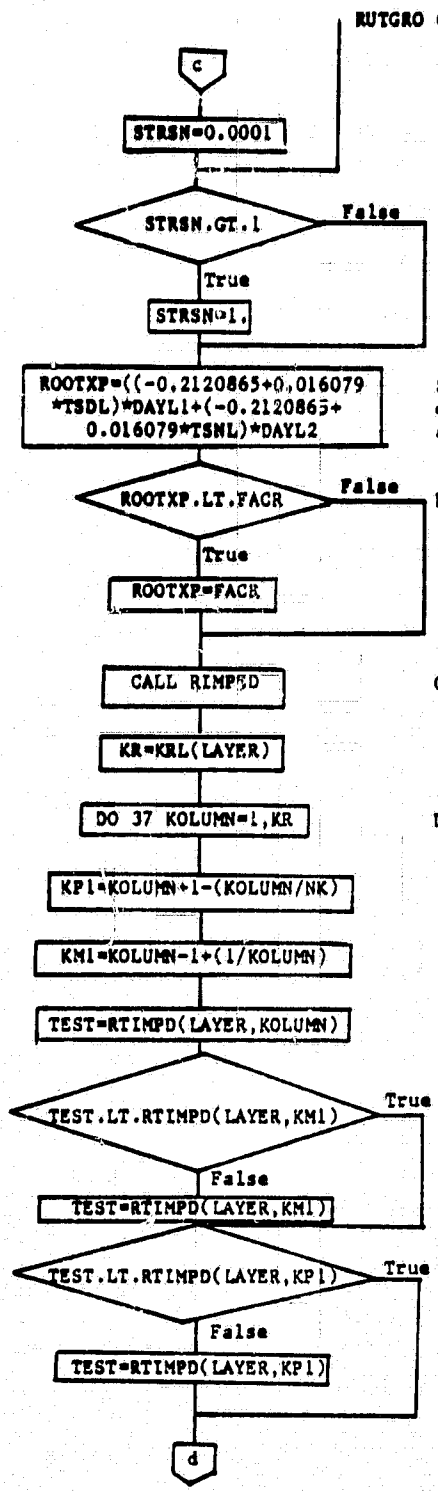


Limit TSDL and TSNL to a maximum of 30° C.

Traverses all layers occupied by roots.

Limits .0001 .LT. STRSD .LT. 1.

Limits .0001 .LT. STRSN .LT. 1.

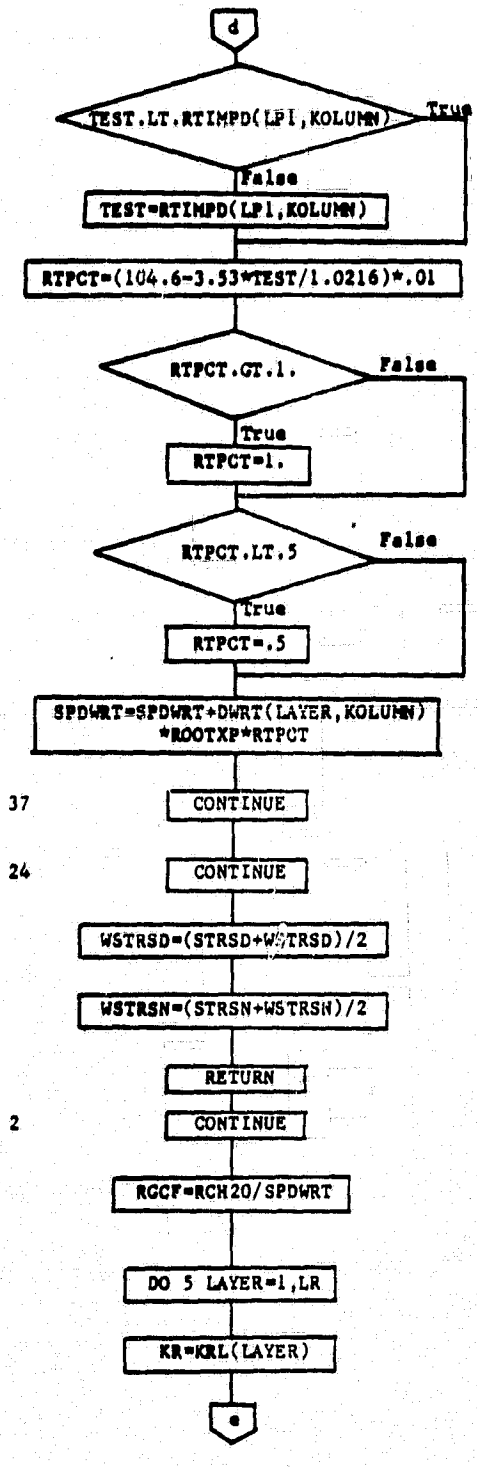


Specific root growth rate within soil cell, dependent on daylength, layer temperature, and water stress based on PSIMAX.

Limit ROOTXP to an input minimum amount.

Call the RIMPED subroutine.

Do for all the columns containing roots.

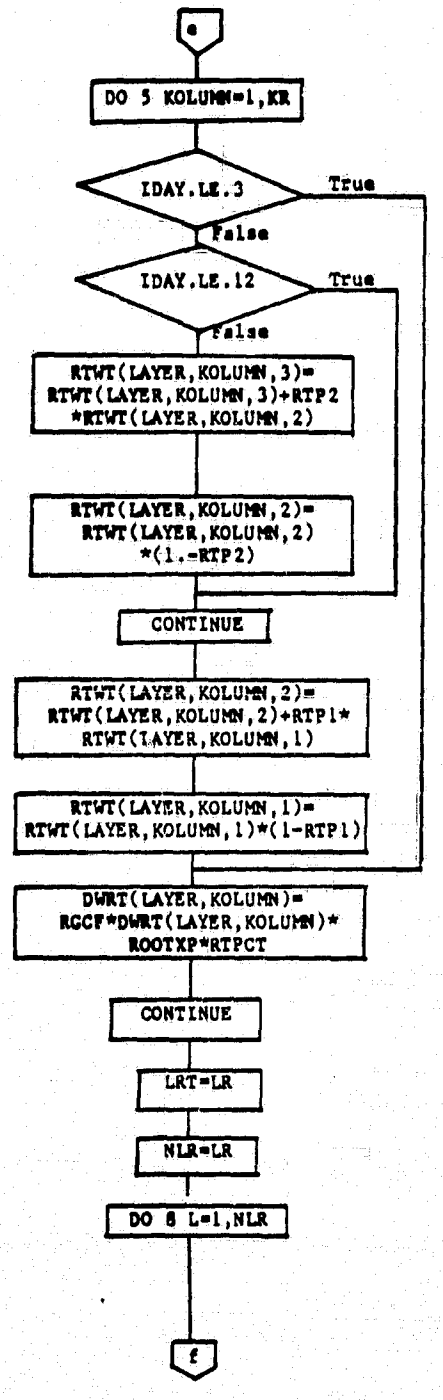


Sum potential root growth over the entire profile.

Calculate the day and night water stress terms.

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

Covers all soil cells occupied by roots.



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

If 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 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 1/3.

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

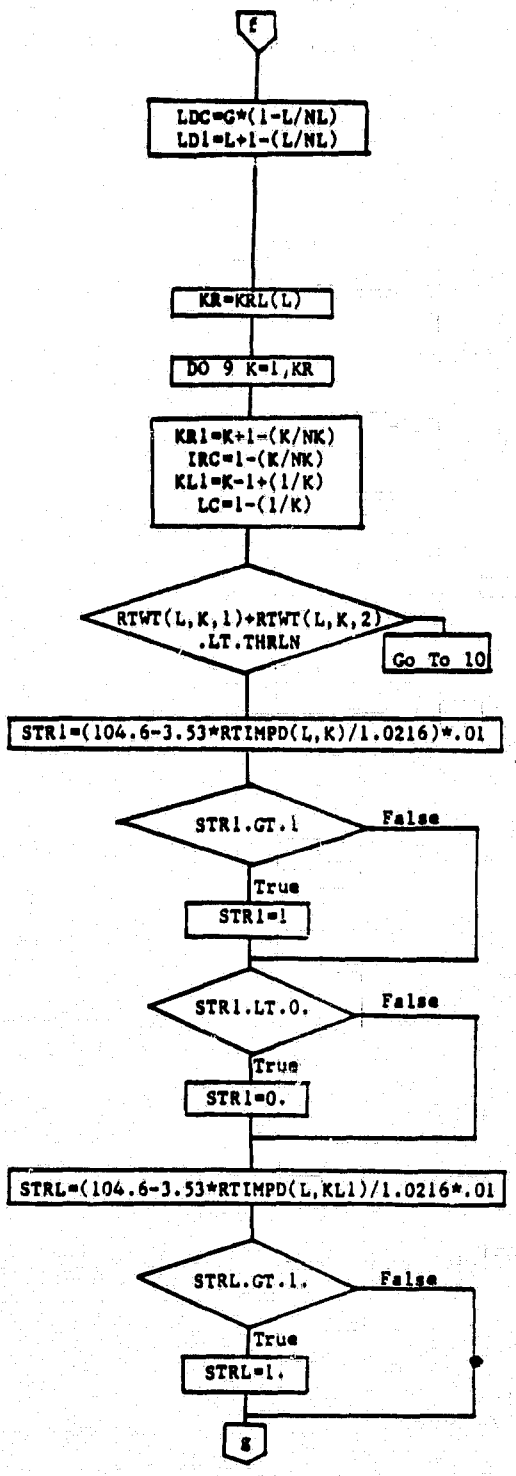
The actual root weight increase in the soil cell. Note that DWRT=RCH2O.

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 may 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

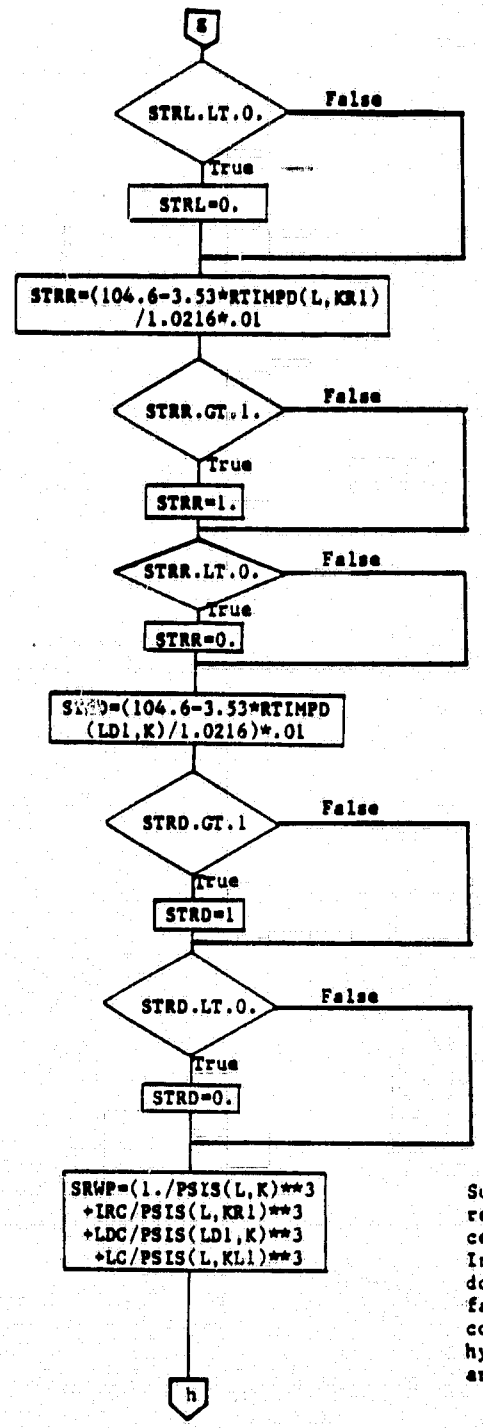


Number of "Layer down" (below) for use in SRWP equations below.
=L+1 1 .LE. L .LT. NL
=L L = NL
The effect of LDC and LD1 in the SRW and subsequent statements is to prohibit roots from growing onto the bottom of the root zone.

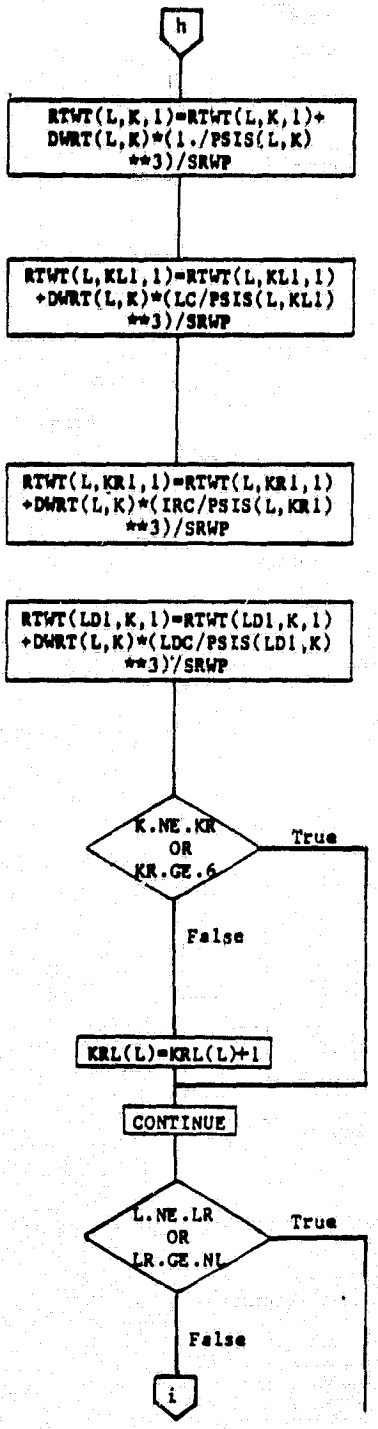
The number of columns occupied by roots in layer L.

Covers all cells occupied by roots.

If 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 to the cell itself, leftward, downward, and rightward. Weighting factors based on water potential of considered cell. Approach is strictly a hypothesis. 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 occurring 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 lefthand cell. Note that if K=1, LC=0 and the boundary condition of no growth across the plane under the row is satisfied.

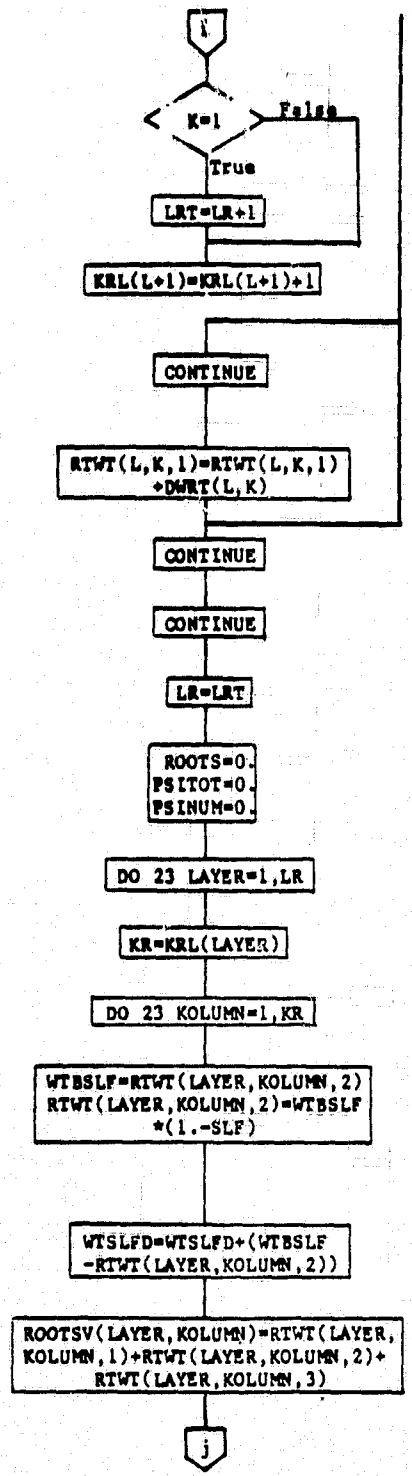
To the current young root weight in the cell to the right of cell L, K is added the fraction of the root growth occurring from the cell L, K into the righthand cell. Note that if K=NK, IRC=0 and the boundary condition of no growth across the plane under the next row is satisfied.

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 geotropic effects. If L=NL, LDC=0 and the boundary condition of no growth across the bottom of the lower boundary 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 plane, 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.



Downward growth from the lowest layer occupied by roots increases 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=1) 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.

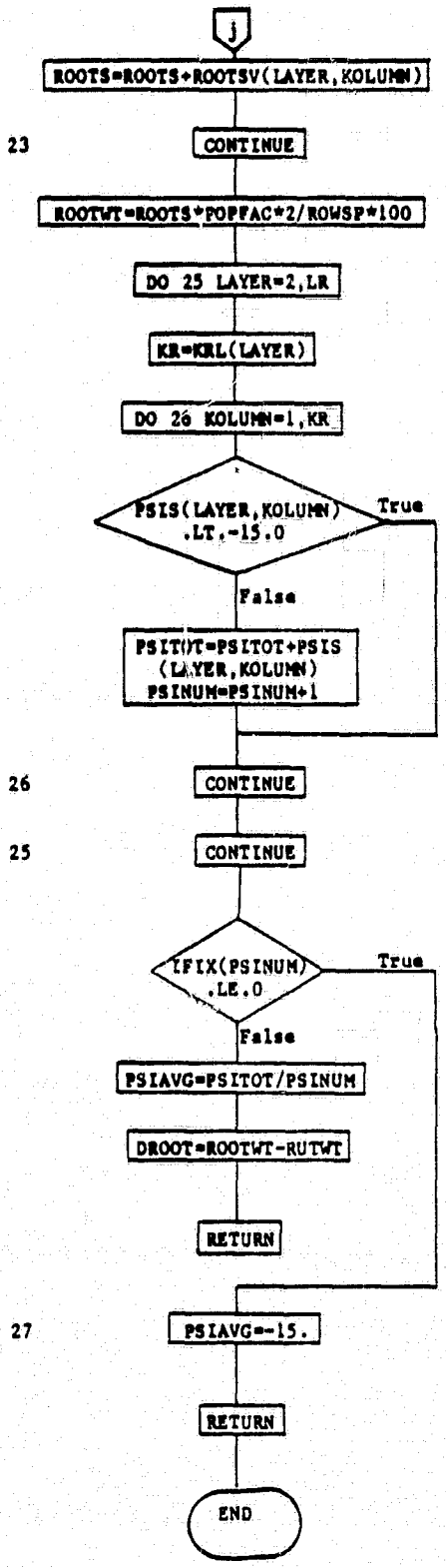
Initializes these variables.

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 of 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 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.

End of RUTGRO subroutine.

Table 2. Typical Daily Patterns.

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.

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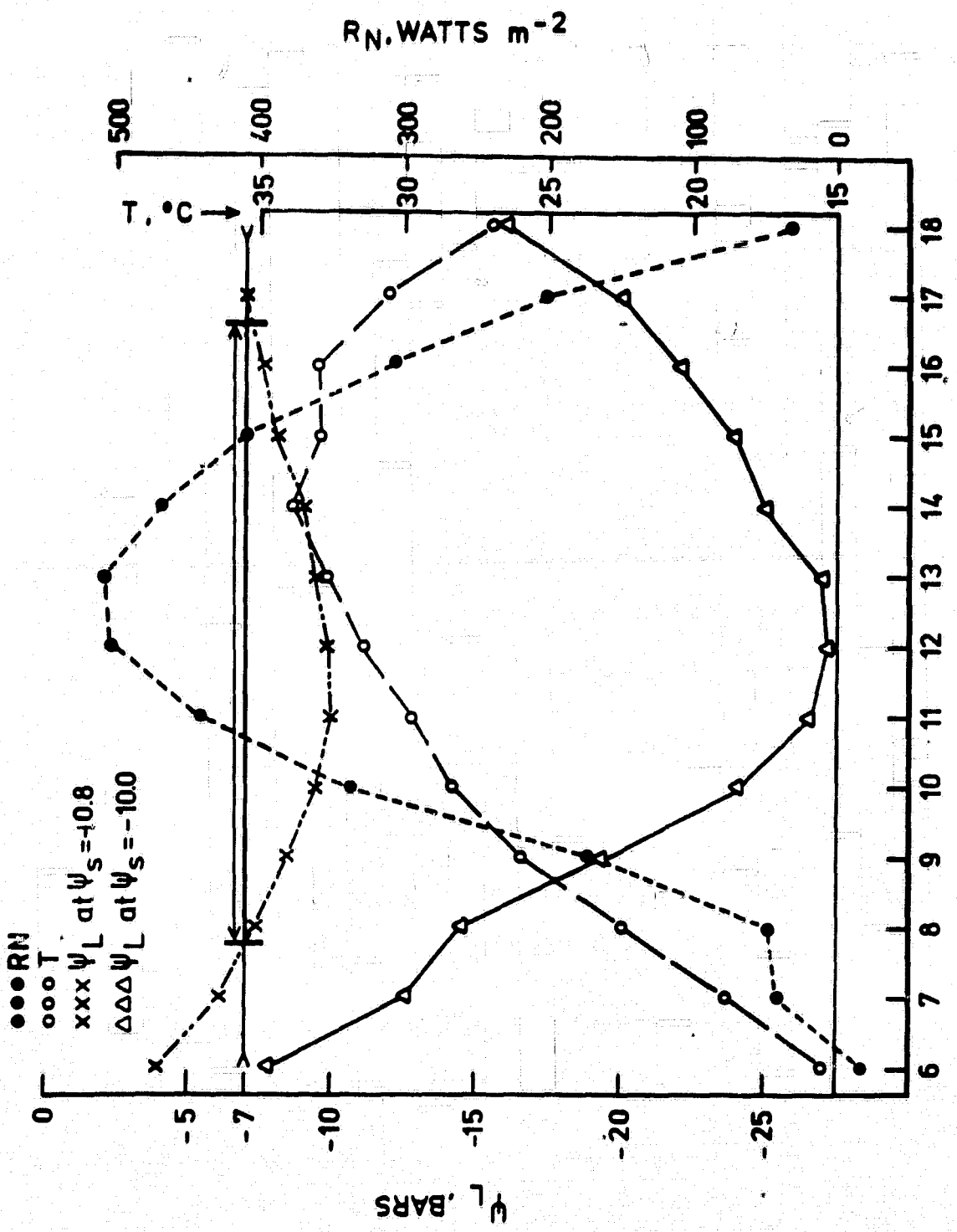


Figure 5. Typical daily time courses of net radiation, air temperature and leaf water potential at soil water potentials of -0.8 and -10.0 bar.

Finally the number of minutes (±10) during the day and night time periods when leaf water potential exceeded -7 bars was computed. This vector was then fitted via a stepwise regression to comparable vectors for daily average net radiation, average temperature, and soil suction. Day and night time water stress terms WSTRSD and WSTRSN respectively, are calculated using the average soil suction in the rooted portion of the profile. While this data base and procedure are used in the present WINTER WHEAT model, we emphasize that a data base from winter wheat, and, possibly a more mechanistic model would be more appropriate.

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 an age category capable of growth. Good data on the effects of temperature and carbohydrate supply on root growth rates in winter wheat were not available, and so cotton data (GOSSYM, Baker et.al., 1982) have been used. Thus, the ROOTXP parameter is obtained by the same function as for young cotton bolls. Subsequent work by Whisler et.al.,(1977) working with GOSSYM, in which they 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. (1982) have shown the ROOTXP term must be multiplied by factors of five or six to simulate field crops. Clearly this is an unacceptably crude guess as to the potential dry matter accretion rates in winter wheat roots. Controlled environment research on winter wheat roots is indicated.

After 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) thus,

PDWRT = RTWTCG*ROOTXP.

Then, these are summed over the whole root system to form a total (SPDWRT).

Finally the model returns to RUTGRO from GROWTH where an increment of carbohydrate actually to be allotted to the root system is determined. This dry matter is partitioned to each part of the root system in proportion to its contribution to total demand,

RGCF = RCH2O/SPDWRT.

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 is involved in the partitioning of metabolites in the plant. The supply, on a particular day, consists of the increment of nitrogen brought in through the root system (UPTAKE) plus mobilizable reserves. Three types of constants pertaining to NITRO are read in from the keyboard when operating from a computer terminal. These are a nitrogen reserve

mobilization factor (F2), "K" factors representing the minimum percentage of tissue dry matter occurring as nitrogen after all reserves have been withdrawn, and "J" factors representing the minimum nitrogen concentration of new dry matter added to organs. F2 is arbitrarily set at 0.5. Usually "K" factors for leaves, stems, roots and glumes are all set at 0.01, and all "J" factors for leaves, stems, roots, glumes and grain are set at 0.03. Obviously, these values are arbitrarily chosen and need to be verified experimentally.

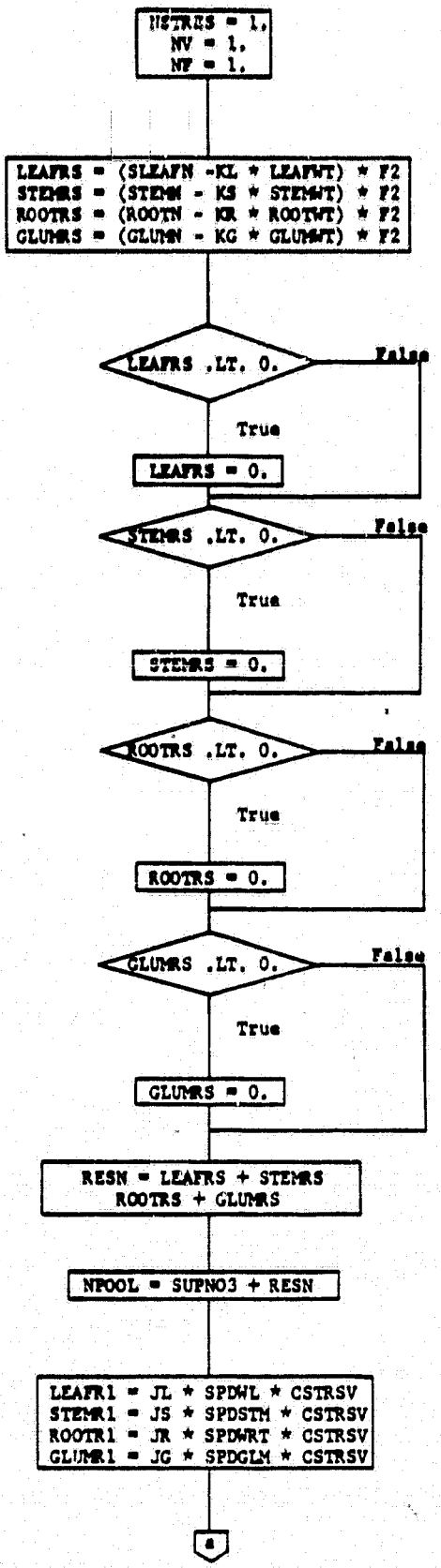
NITRO is flow charted on pages 49-51. Organ weights and nitrogen contents are brought in. Also brought in (from GROWTH) are potential growth increments. The nitrogen supply:demand ratios are initialized, and, reserves are calculated as the difference between the tissue nitrogen content and the content it could go down to if all reserves were withdrawn. Reserves in the various classes of organs are added to get a total reserve (RESN). The pool of available nitrogen (NPOOL) is defined as the sum of the reserve plus today's increment of uptake. Next, The nitrogen required for new growth in each class of organs is calculated as the product of the minimum necessary concentration multiplied by the carbohydrate limited potential growth increment, and, a total nitrogen requirement (REQN + GRANR1) is calculated. If the nitrogen required for growth of all organs is greater than the pool, stress factors are calculated as follows: if the pool is large enough for full grain growth, the vegetative growth stress factor is defined as the difference between the total pool and the grain growth requirement, all divided by the vegetative growth requirement, and the stress term for fruit growth (NF) remains one. If, however, the grain growth requirement is greater than the pool, NF is defined as the pool divided by the grain requirement, and NV is set to zero.

Next, the nitrogen contents of each of the classes of organs is updated and a total plant nitrogen content is calculated. If more nitrogen was taken up than was used in structural growth, the extra N is stored in the various vegetative structures in proportion to their fraction of the total vegetative dry weight. If there was a deficit of nitrogen (required over what was taken up), the deficit amount is withdrawn from reserves (negative addition of XTRAN).

Finally, the leaf nitrogen concentration is calculated for use in MORPH.

MORPH

This subroutine simulates plant morphogenesis. It handles system timing and the abortion of tillers and fruit in response to physiological stresses. It records, daily, the census of organs on the plant and their maturity status. MORPH is flowcharted on pages 52-64. The timing of discrete morphological events is based on the accumulation of heat units (ACCDEG) defined as centigrade degree days above zero. The following are the morphological event (heat unit) criteria: begin tillering (100); begin head differentiation (315); begin jointing (750); begin booting (1090); begin heading (1200) and, anthesis (1300). The data base for these heat units is from experiments by Baker et.al.,(1978b). Their experiments were done in SPAR units with Scout (Triticum vulgare) winter wheat. The data are presented in Figure 6. These data describe the phenology of three crops maintained



Nitrogen stress factor is initialized at 1 (No stress).
Nitrogen stress factor for vegetative growth is initialized at 1.
Nitrogen stress factor for fruit growth is initialized at 1.

The nitrogen reserves for each plant part (leaves, stems, roots, glumes) are calculated as a function of total nitrogen in each part, minimum fraction of the weight of each part that is nitrogen, total weight of each part, and an availiability factor.

If leaf reserves are calculated to be less than zero, then they are set to zero.

If stem reserves are calculated to be less than zero, then they are set to zero.

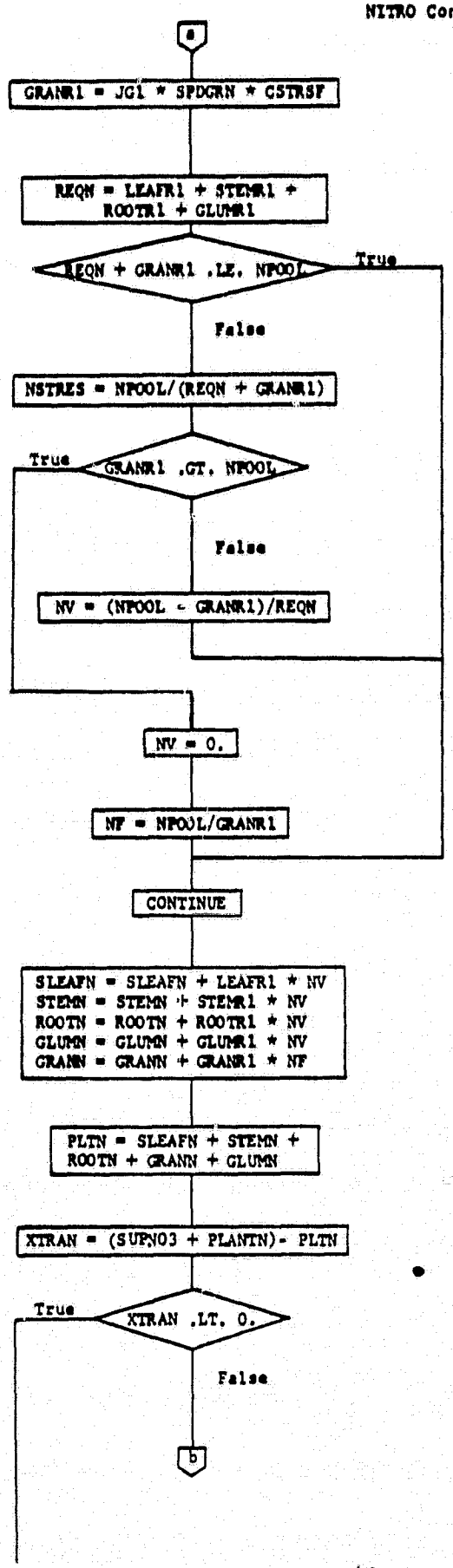
If root reserves are calculated be less than zero, then they are set to zero.

If glume reserves are calculated to be less than zero, then they are set to zero.

Find the total nitrogen reserve for the plant.

The nitrogen available for todays growth is NPOOL.

Calculate the nitrogen required for new growth in each class of vegetative organs as a function of the minimum N concentration associated with actively growing tissue, the maximum potential growth, and the vegetative carbohydrate stress factor.



Nitrogen required for grain growth is a function of minimum N concentration, maximum potential growth, and carbohydrate stress factor for fruit.

Find total nitrogen required for new growth of vegetative parts.

If the nitrogen required for growth is greater than the available nitrogen, then calculate the stress factors.

Calculate the nitrogen stress as ratio of available nitrogen to nitrogen needed for maximum growth.

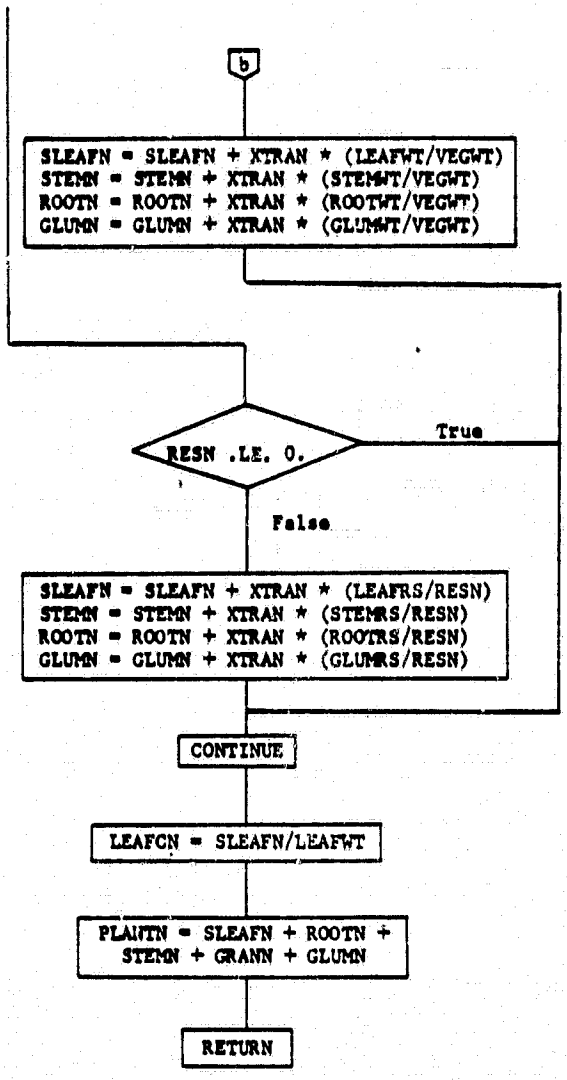
If the nitrogen requirement for maximum grain growth is less than or equal to the available nitrogen then calculate a reduction factor for vegetative growth.

If the nitrogen required for maximum grain growth is greater than the nitrogen available, then all the available nitrogen goes to grain growth, and vegetative growth is stopped (NV=0).

Calculate the total nitrogen to be added to each of the plant parts.

Calculate total nitrogen for the plant.

Nitrogen to be stored in vegetative tissues (this may be negative) is the difference between that taken up and that allocated for structural growth.

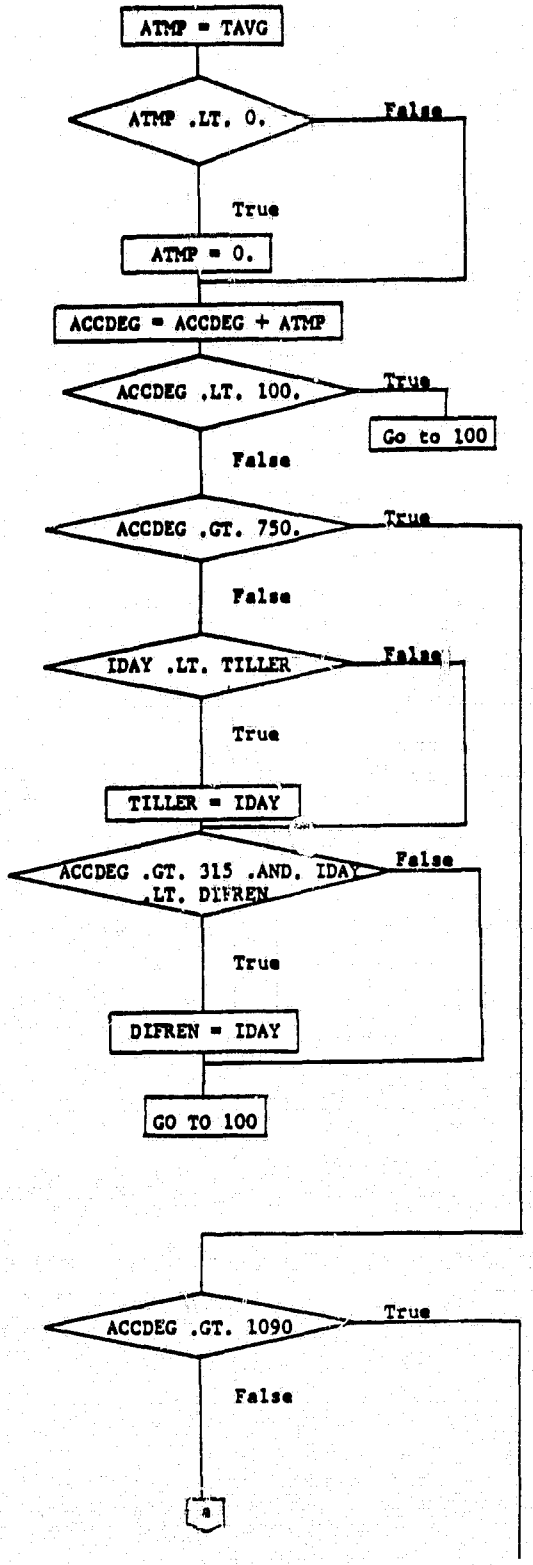


Allocate the excess to the various vegetative structures in proportion to their dry weights.

Withdraw deficit nitrogen which was used in growth from reserves in the various vegetative structures (XTRAN is negative).

Calculate the nitrogen concentration in leaves.

Calculate total nitrogen in plant.



Set up Dummy variable for average temperature.

If average temperature is less than 0°C, then set it to 0°C.

Add the average temperature into the temperature accumulator.

If less than 100 degrees has been accumulated, tillering has not begun. Go to routine to check for new secondary root, and/or leaves.

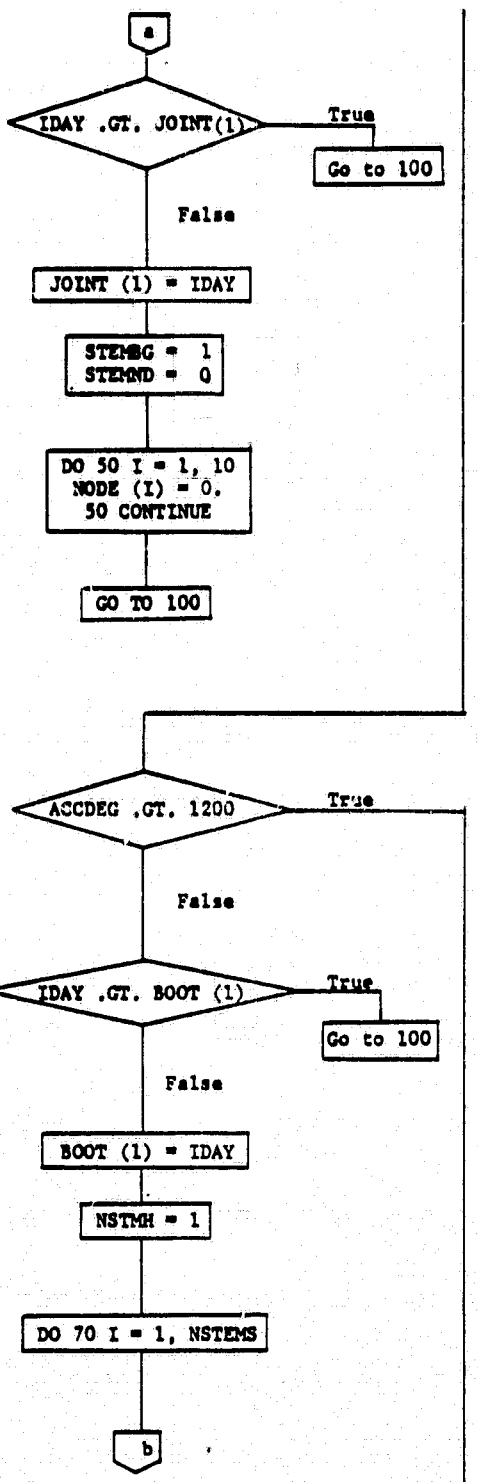
If the accumulated degrees are greater than 750, then beyond the tillering stage.

Plant is in the tillering stage and the variable TILLER is set to be equal to IDAY on the first day that the accumulated degrees goes beyond 100.

The first day that the accumulated degrees goes beyond 315 is defined to be the day of differentiation.

Go to routine to check for new secondary roots and/or leaves.

If the accumulated temperature is greater than 750 and less than or equal to 1090, then in jointing stage, otherwise beyond jointing.



On the first day that the accumulated temperature goes beyond 750 stem 1 (mainstem) is said to begin jointing.

On the day stem 1 begins jointing the variables STEMND + STEMBG (which mark the last stem to begin jointing and the next stem to joint) are initialized.

The array NODE is initialized on the day the jointing begins for stem 1.

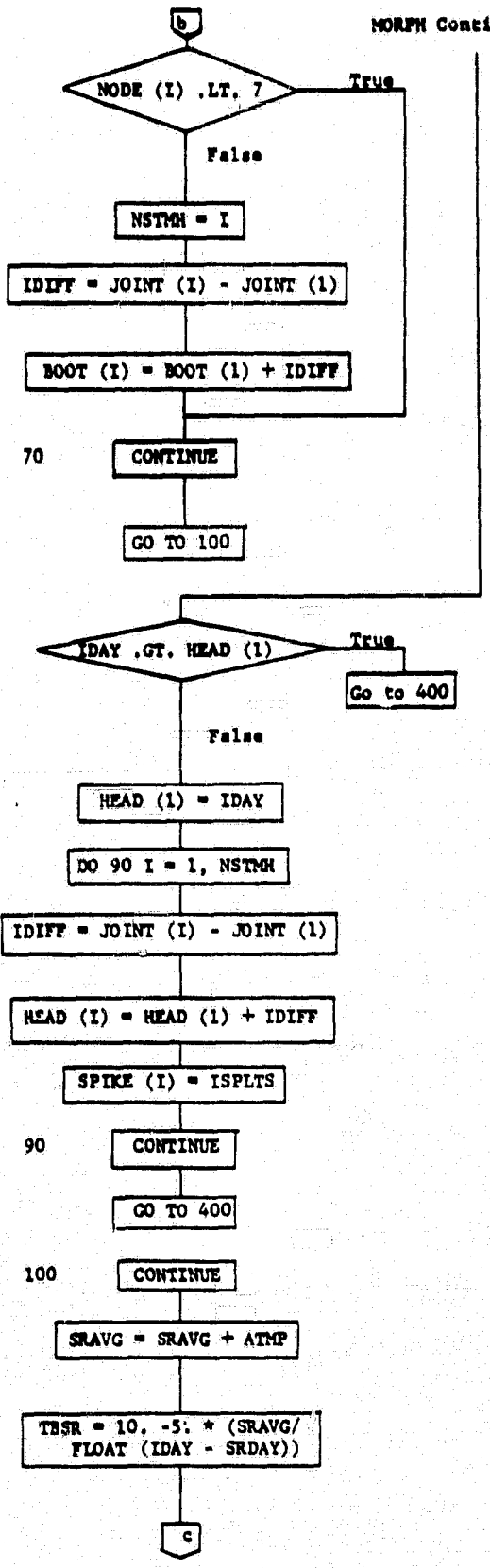
Go to the routine that checks for additional secondary roots and leaves.

If the accumulated number of degrees is greater than 1090 and less than or equal to 1200 then the plant is in the boot stage.

The array BOOT is used to indicate the day that a stem begins boot stage. This occurs for stem 1 on the first day the plant goes into the boot stage.

NSTMH which is the variable that keeps up with the number of stems heading is initialized.

Do for each stem on plant, on day 1 of Boot stage.



If the number of joints on a stem is less than seven, the stem will not head.

If there are seven joints then the stem is heading.

The difference in days between time stem 1 and stem I began jointing is calculated.

The delay for jointing and boot is assumed to be the same.

Go to the routine that checks for additional secondary roots and leaves.

Head (1) is set to IDAY on the first day the plant reaches the heading stage (accumulated degrees are greater than 1200).

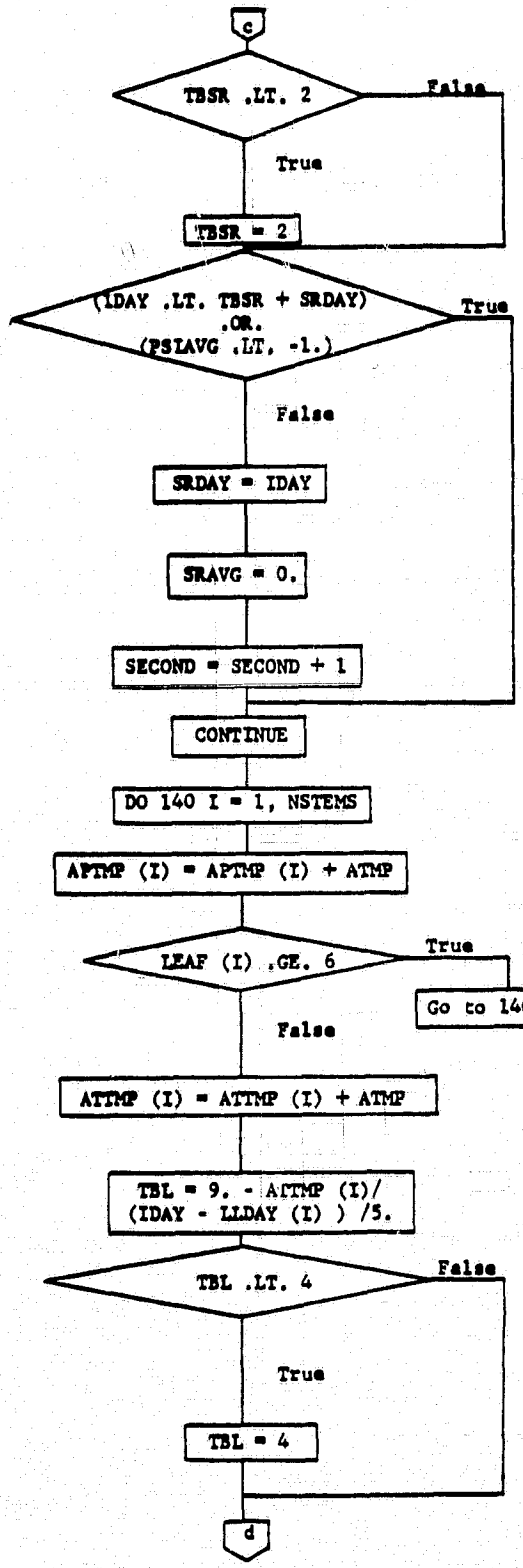
The difference between the heading of STEM 1 and STEM I is defined to be the same as that of JOINT 1 and JOINT I. This difference added to the Day Stem 1 began heading gives the Day heading begins for the other stems.

The number of spiklets for each stem is initialized on the first day of heading.

Go to the heading routine.

The temperature is added to an accumulator to be used to determine if secondary roots are to be added to the plant.

The time between secondary roots is a function of the average temperature since the initiation of the last secondary root.



The minimum time between the initiation of secondary roots is set to be 2 days.

If PSIAVG is greater than or equal to -1 bar and the time between secondary root initiation is sufficient, then we add a secondary root.

The variable SRDAY which denotes the the day the last secondary root was initiated is set to IDAY.

The variable that accumulates the temperature since intitiation of last secondary root is set to zero.

The variable that contains the number of secondary roots is incremented.

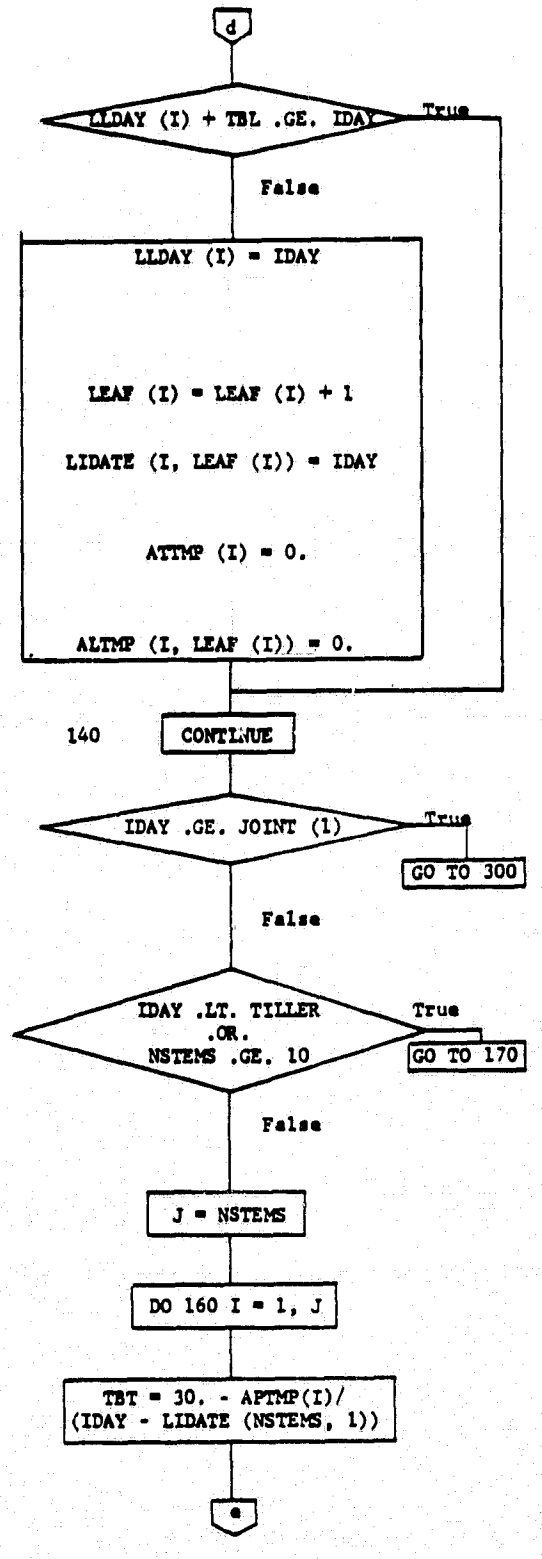
The variable APTMP contains the accumulated temperature for each stem since initiation of that stem.

No leaves will be added to a stem which already has 6 leaves.

ATTMP is the accumulated temperature for each stem since it initiated its last leaf.

The time between initiation of leaves is calculated for each stem independently and it is a function of ATTMP.

The time between initiation of leaves cannot be less than 4 days.



If insufficient time has passed for initiation of a new leaf on stem I then check the next stem.

When sufficient time has passed, and a new leaf on STEM I is initiated, then LLDAY (I) the variable which indicates the day STEM I initiated its last leaf, is set to IDAY.

The number of leaves of stem I is incremented.

The day of initiation for the new leaf is set.

The accumulated temperature since initiation of the last leaf is set to 0.

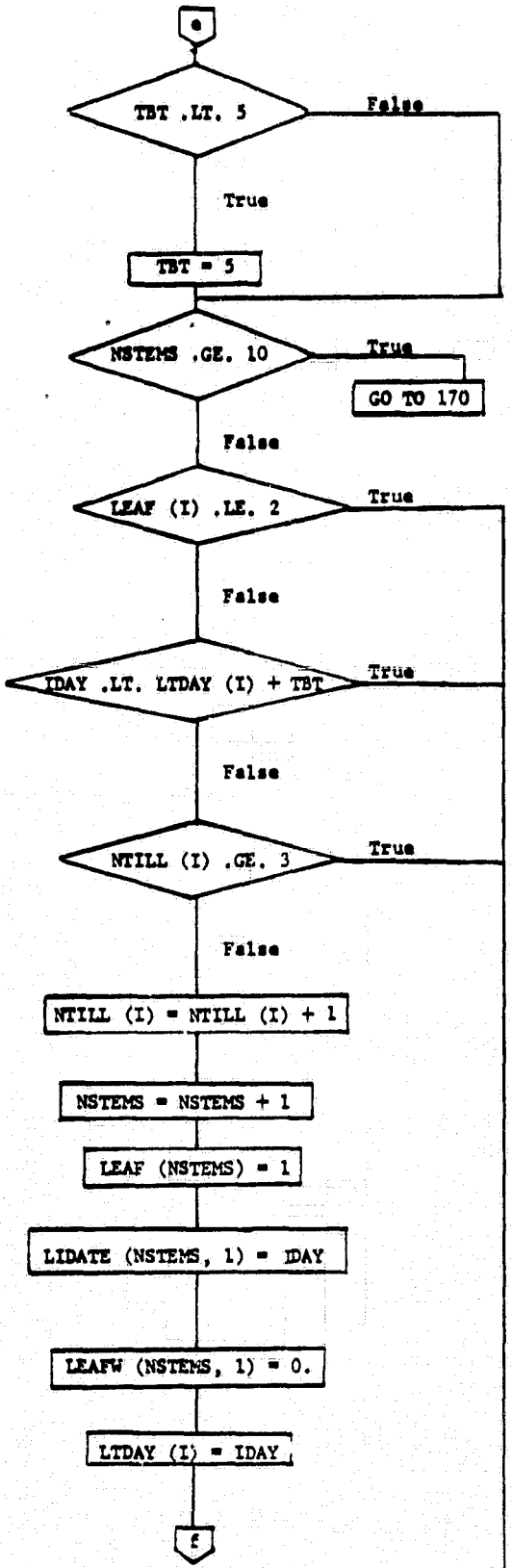
The accumulated temperature of the new leaf is initialized.

If jointing has begun, skip to jointing routine; there is no more tillering.

If tillering has not begun, or if there are ten stems, then no new tillers will be added.

Initialize the dummy J to be the current number of stems.

Each stem is capable of producing tillers, and TBT (time between tillers) is a function of the average temperature since initiation of the stem.



If the time between tillers is calculated to be less than 5 days, then it is set to be 5 days.

New stems added cannot make the total number of stems be greater than ten.

If a stem has less than three leaves, the next tiller will not be initiated.

If the number of days since stem initiated a tiller is less than the required number, then this stem does not initiate another tiller.

Each tiller (or stem) can produce a maximum of three tillers.

If all the requirements are satisfied, then a new tiller is initiated for Stem I.

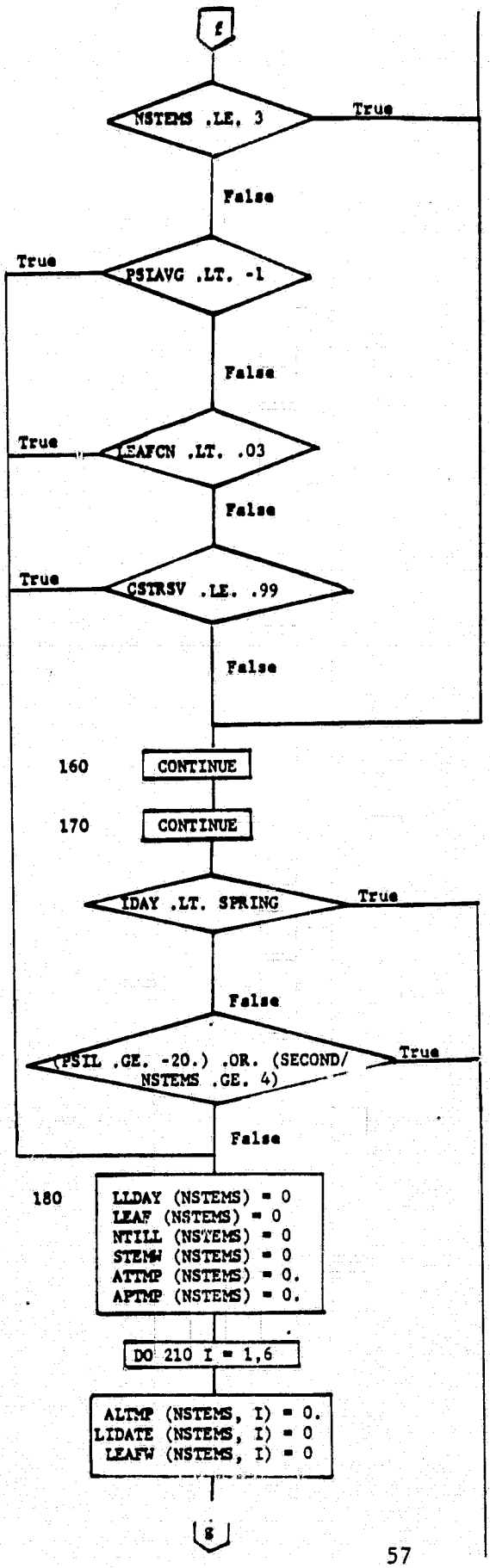
The total number of stems is incremented.

The number of leaves on the new stem is set to be 1.

The leaf initiation variable for leaf one of the new stem is set to be equal to IDAY.

The leaf weight of the leaf on the new stem is set to zero.

The day tiller I initiates a tiller is marked.



If there are less than four stems on the plant, then the new tiller will not be aborted immediately.

If the average soil water potential is less than -1 bars, then abort the new tiller.

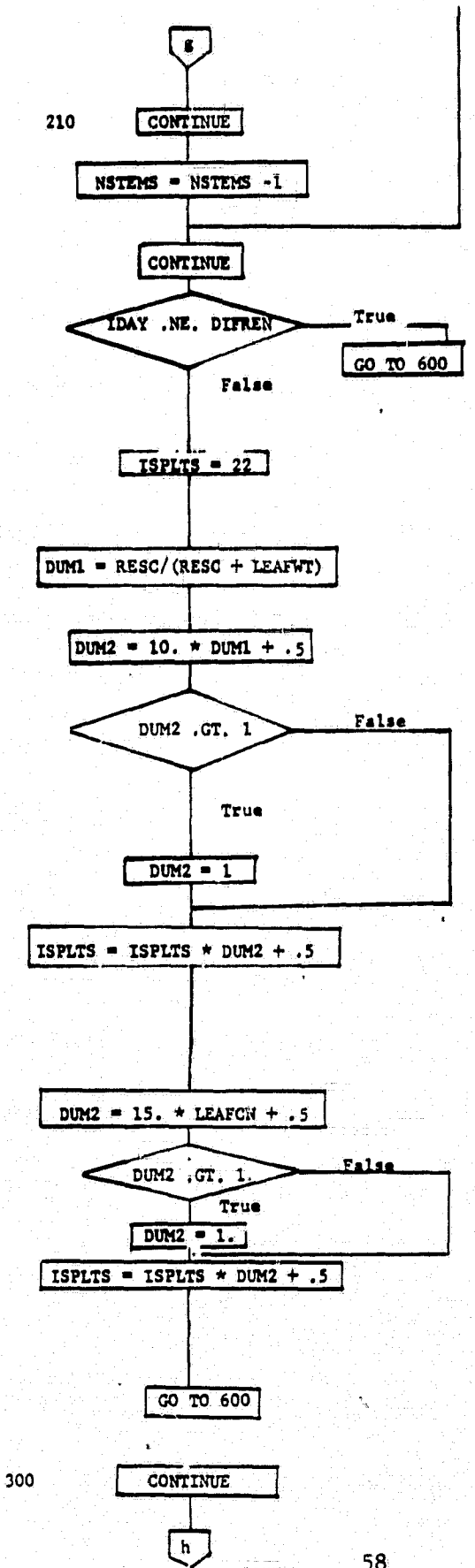
If the nitrogen concentration of the leaves is less than 3% then abort the new tiller.

If the plant has vegetative carbohydrate stress then abort the new tiller. Go to 180 to initialize the variables set up for this tiller. Do not check for initiation of more new tillers.

If past the first day of spring, then check for abortion of tillers.

If leaf water potential is less than -20 bars and the average number of secondary roots per stem is less than 4, then abort a tiller.

All the variables that pertain to the aborted tiller are set to zero.



The number of stems is decremented.

If it is not the day of differentiation, then return to MAIN.

On the day of differentiation, the number of spikelets per spike is set to 22.

A dummy variable is calculated to be a ratio of reserve carbohydrates to the sum of leaf weight and carbohydrate reserves.

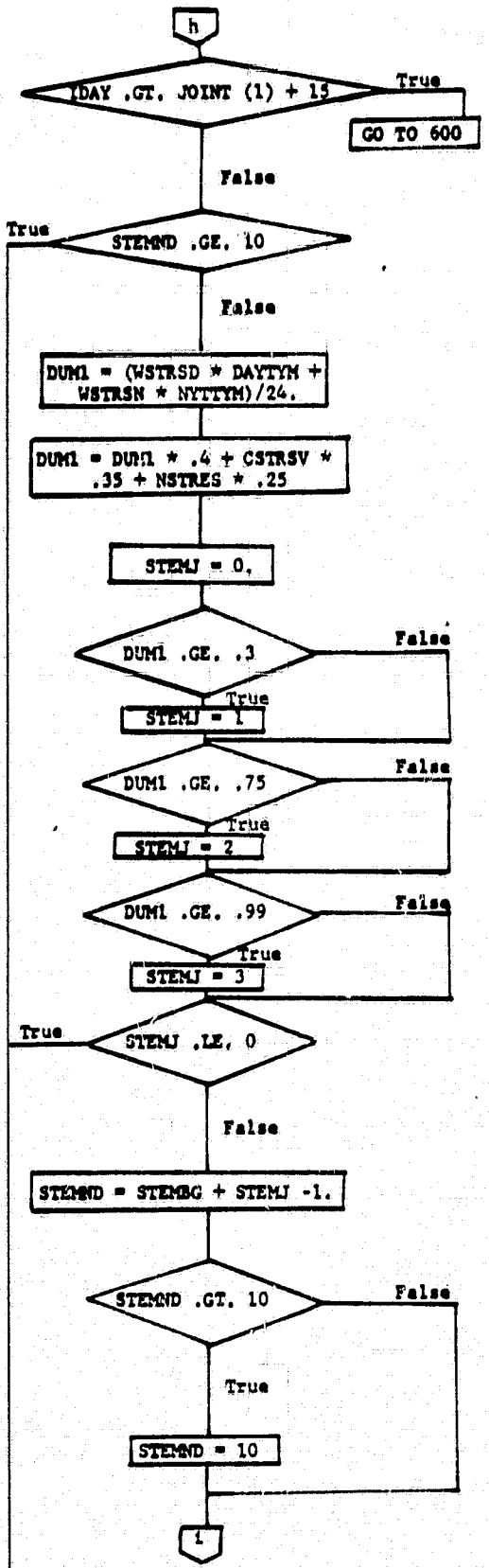
A second dummy variable is set equal to 10 times the first plus 0.5.

If the second variable is greater than 1 it is set equal to 1.

The number of spikelets per spike is multiplied by this dummy variable. If the ratio DUM1 is equal to or greater than .05, then there will be no reduction in spikelet number. If ratio is 0, then spikelets number is reduced by 50%.

The number of spikelets per spike is reduced if the leaf concentration of nitrogen is below .04. The maximum reduction is 50%.

Jointing routine.



If jointing began more than 15 days previous to IDAY, then return to MAIN.

If ten stems have begun jointing, then no more stems can begin jointing.

A dummy variable which is a function of water stress is calculated.

A dummy variable which is a function of water stress, vegetative carbohydrate stress, and nitrogen stress is calculated.

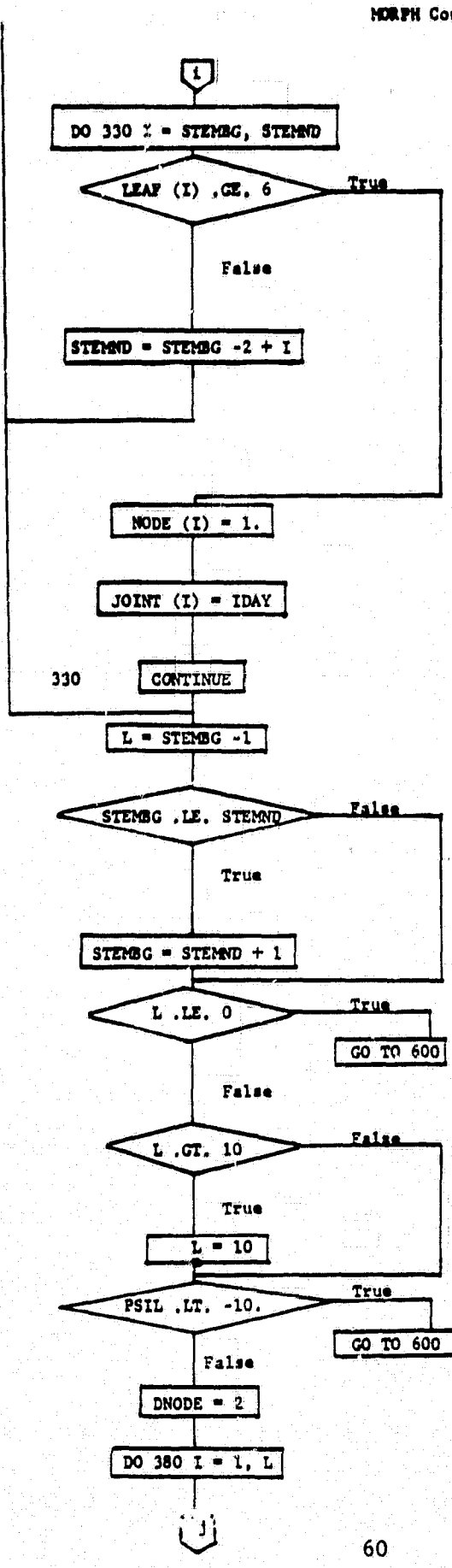
The number of stems to begin jointing on IDAY is set to zero initially.

The number of stems to begin jointing on IDAY is dependent upon the dummy variable DUM1.

If there is no nitrogen, carbohydrate or water stress, then three stems begin jointing.

The number of the last stem to begin jointing on IDAY is set.

The number of the last stem to begin jointing can be a maximum of 10.



Do for each stem beginning jointing today.

If stem has less than six leaves, it does not begin jointing.

The number of the last stem to begin jointing is reset to be one less than stem I since stem I has less than six leaves

Stem I has one joint to elongate on IDAY.

Stem I begins jointing on IDAY.

The variable L denotes the last stem to begin jointing previous to IDAY.

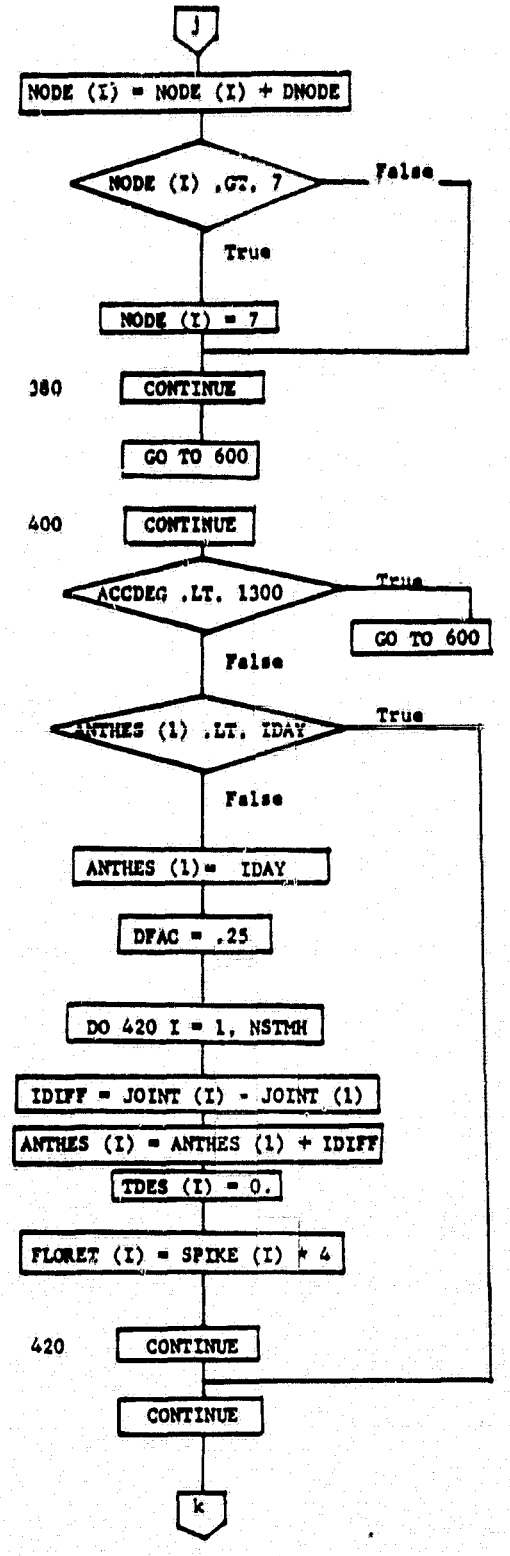
If stems begin jointing on IDAY, then the stem to begin jointing on IDAY plus one must be set.

If L is equal to zero then no stems began jointing previous to IDAY therefore return.

If L is greater than ten, then it is set to ten.

If leaf water potential is less than -10 bars, then return to MAIN.

The variable for the number of joints to elongate is set.



For the stem I, the number of joints elongated is incremented by DNODE.

There is a maximum of seven joints per stem.

Return to MAIN.

After heading routine.

If the accumulated temperature for the plant is less than 1300 degrees then return to the MAIN program.

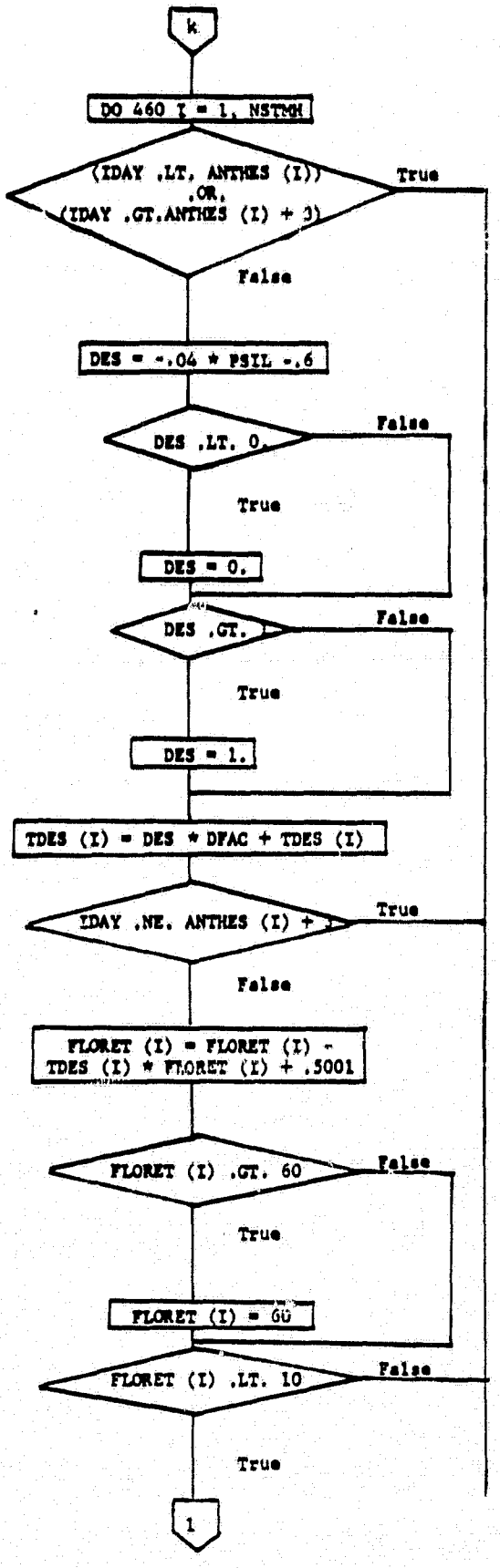
The first day the accumulated temperature becomes 1300 is set to be the beginning of Anthesis for stem 1.

A factor to be used for dessication of florets is initialized at .25.

The delay in jointing between stem 1 and the other stems, is assumed to apply for anthesis as well.

The array set up for dessication is initialized at zero.

The number of florets per plant is set to be the number of spiklets per spike times four.



If stem has not reached anthesis or if more than 3 days beyond, then go to end of loop.

Number of florets on stem I to be dessicated on IDAY is a function of leaf water potential.

If the dessication rate is less than zero, then set it to zero.

If the dessication rate is more than 1, then set it to one.

The florets dessicated on stem I are accumulated during anthesis. Only DFAC are eligible for dessication each day.

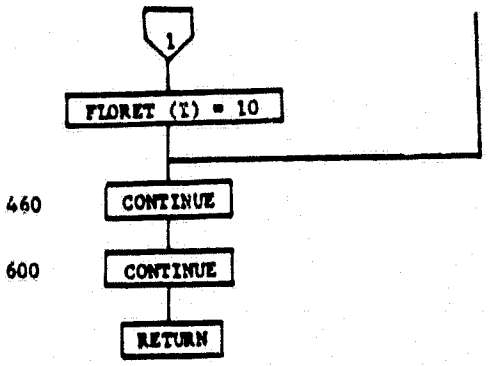
On the fourth day of anthesis, the florets are subtracted out.

The dessication factor is used to determine the total number of florets for Head I three days after anthesis began for Head I. (Florets become grain.)

If the total number of florets per spike is greater than sixty, then it is set to sixty.

If the total number of florets per spike is less than ten, then it is set to ten.

MORPH Continued



Return to MAIN program.

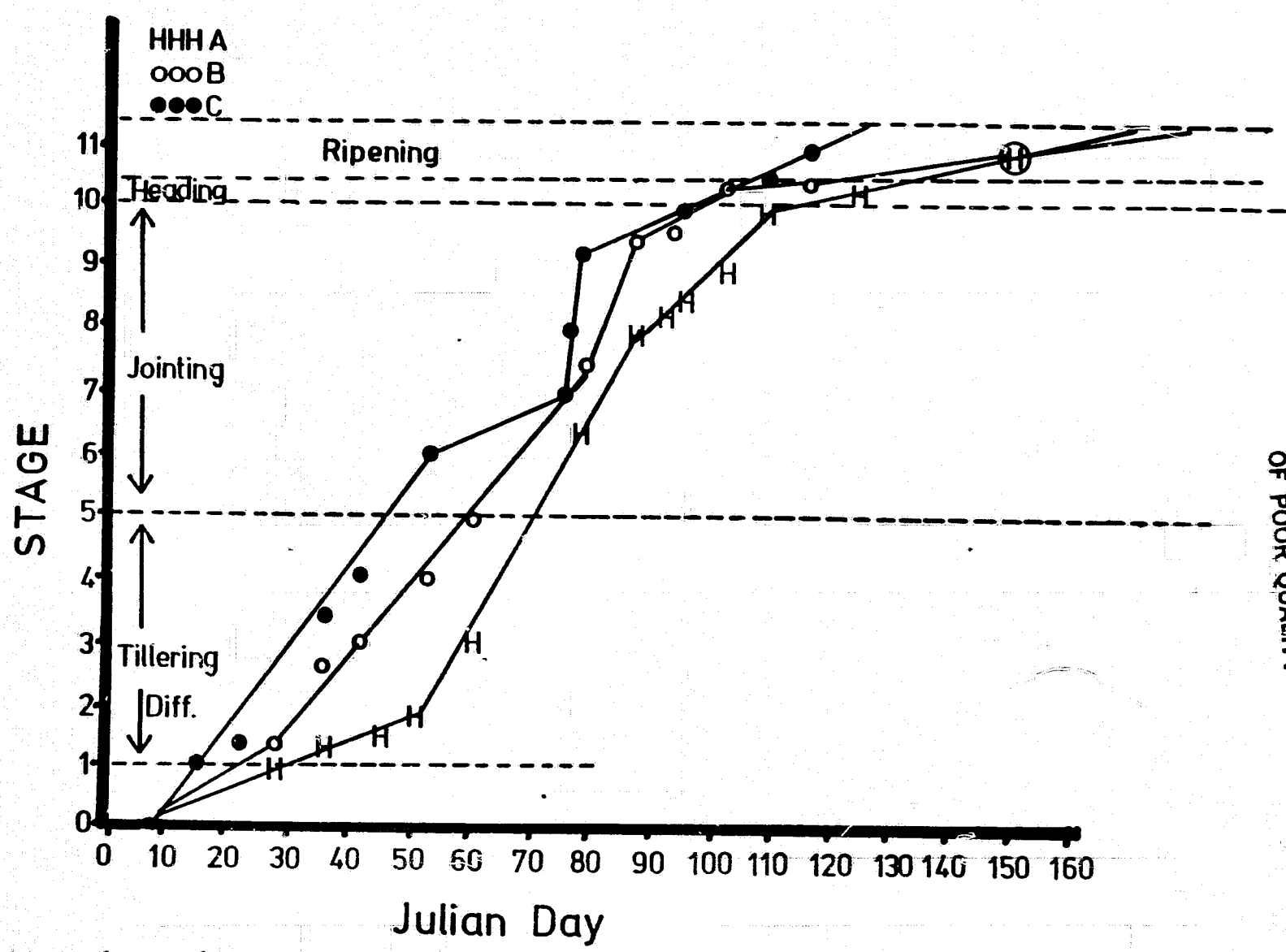


Figure 6. Developmental stage vs. Julian date for wheat crops maintained in three different temperature regimes.

in three temperature regimes. The temperature data for this experiment are presented in Table 1. Maturity (ITGF), and the termination of the simulation is determined as a linear function of running average temperature from anthesis. The data base for time of grain maturity is from Sofield et.al. (1977).

Referring to the flow charts beginning on page 53, if tillering has not yet begun, the computer is directed to statement 100 (page 54) where secondary roots and leaves are initiated. Heat units are accumulated from one secondary root initiation event to the next. The time between secondary root events is a function of the running avarage temperature. The function is arbitrarily chosen, and needs to be confirmed by further, controlled environment experiments. If sufficient time has elapsed, and, soil water potential is greater than -1 bar in the rooted portion of the soil, a secondary root is added.

Next, running average temperatures for each stem and for each leaf are updated. Time intervals between new leaf initiation events are a function of running average temperature, with a minimum time of 4 days. The data base for this temperature-time interval relationship is from Figures 1 and 2 of Friend et.al. (1962, p1299). After this leaf initiation, if tillering has not begun, the computer will default all further logic to the end of the subroutine.

Referring again to page 52, if 315 heat units (ACCDEG) have accumulated, differentiation begins. If 750 heat units have accumulated, tillering ends, and jointing begins, and the computer checks to see if time for jointing (1090 heat units) has passed. If so, it checks to see if the time for heading has arrived. The times of jointing, booting, heading, anthesis, and maturity of each of the stems are recorded separately. The time spread among the stems in booting, jointing and heading is maintained the same as that established in jointing.

Secondary root development occurs through the tillering, jointing and booting periods. Each primary tiller is capable of producing more tillers (up to three each), if the primary tiller has at least three leaves. The time required to produce these secondary tillers is a function of the running average temperature since the last (secondary tiller) was initiated. This function (bottom of page 56) has been chosen arbitrarily. We note that in view of the fact that a tiller may be aborted very quickly after it is initiated, it is very difficult to measure initiation rates except under conditions not favoring abortion. A great need exists here for further controlled environment research characterizing the rates of tillering and tiller abortion independently. When a new tiller is initiated, the leaf number associated with it is initialized to 1. Leaf number is limited to six per stem. If, the plant has less than four primary tillers (top of page 58), none will be aborted. However, if more exist, a newly initiated tiller will be aborted if either soil water potential in the root zone is less than -1.0 bar, leaf nitrogen concentration is less than three percent, or if any carbohydrate stress exists. The tiller will also be aborted if, after spring green up, leaf water potential is below -20.0 bar or there are less than four secondary roots per tiller.

Differentiation of all heads occurs at the same time (i.e. on the day of accumulation of 315 heat units), regardless of the age of the

tiller. The number of florets per spikelet is set at four. Variation in kernel number occurs only via variation in the number of spikelets per head, except that for the first three days after anthesis, florets may be lost from a particular head through dessication. Spikelet number may be reduced from a maximum of 22 per head either by carbohydrate or nitrogen shortage. Reductions up to 50 percent will occur in proportion to reserve carbohydrate levels below 6 percent of leaf dry weight. Additional reductions up to 50 percent will occur in proportion to leaf nitrogen concentrations below 4 percent. This approach to the calculation of kernel number may be criticized on several grounds. First, as Klepper (1980, pers. comm.) has noted, differentiation of all heads does not occur at the same time. Each head is differentiated when that tiller reaches the appropriate physiological age. Second, floret number is not constant among all spikelets. After the rachis is laid out, spikelet initiation begins about 35 percent of the way up the rachis and proceeds both up and down over a period of a month or so. During that time florets are initiated from the primary floret in each spikelet outward. During this time florets may be aborted due to physiological stresses, the younger being aborted first. Thus, the spikelets at the top and bottom of the head, typically, contain fewer florets. Finally, the data base for the abortion of florets in response to physiological stress is completely inadequate at present (although it can be developed via a routine and orderly experimental effort) indicating the need for a completely different differentiation model, and for a set of experiments in which heads are mapped, in time, over a range of temperatures, photosynthate and nitrogen supply levels.

At the top of page 61, all stems to be jointed must start jointing within 15 days of the first. An arbitrarily chosen composite variable which is a function of water stress, carbohydrate stress and nitrogen stress is used to determine whether one, two or three stems will begin jointing on the particular day. This logic is crude, but the model is not particularly sensitive to it, and it provides a means of spreading, in time, the jointing process in response to factors of known importance. There will be a maximum of seven joints in the elongated stem.

After 1300 heat units are accumulated, the first stem begins anthesis. The remaining heads begin anthesis the same number of days later as occurred in jointing. For three days after the beginning of anthesis in a head, florets may be dessicated if the average (over the day) leaf water potential falls below -15 bar. Dessication is limited to 25 percent of the florets per head per day. Finally, the number of florets per head reaching maturity is limited to 60, and it cannot fall below 10. Again, experimental verification of the water stress levels and other factors contributing to dessication at anthesis is needed.

Conclusions and Future Research Needs

The purpose of this paper is to document the basic ideas and constructs for a general physical/physiological process level winter wheat simulation model, and to assess the adequacy of the information

base (published literature, unpublished results, theses, etc.) for such a model. In constructing this model, we have found that while all of the data necessary may be obtained by certain well established experimental methods, by and large they do not now exist. Here, we outline the further research needed, process, by process, as we now see it.

Data needs, here, can generally be classified either as thresholds (e.g. minimum levels of tissue nitrogen which can be drawn on reserve basis to fulfill needs in other parts of the plant), or process rate coefficients. Nearly all of these data can be obtained in controlled environment experiments. The SPAR unit (Phene et.al., 1978, McKinion, 1980) has been designed expressly for this purpose. More SPAR units are needed at Mississippi State and at several other locations involved in the development of this model.

The model presented here does not contain a mechanism for the calculation of leaf water potential. Such a mechanism is being incorporated by Parton and others now at Fort Collins. Leaf water potential is used in estimating most of the plant process rates, including photosynthesis. The data base for the water stress reduction in photosynthesis must be confirmed in experiments at all stages of development in crops grown under natural light. A variety of patterns of development of water stress should be studied. The effect of leaf nitrogen and phosphorous levels on canopy photosynthetic efficiency must be measured. The effect of starch buildup on canopy photosynthesis must be measured. The effect of stand geometry on canopy light capture must be characterized. The latter can best be done in field plantings.

The relationships between temperature, and dry matter accretion rates in each class of organ must be worked out. The tissue water potential level below which growth ceases must be defined for each kind of organ. These experiments must include root observations. In addition to the root growth measurements at various temperatures, the effect of soil oxygen concentration and physical impedance must be characterized.

Three sets of parameters in regard to nitrogen and phosphorous are needed; the minimum concentration needed for new growth in each type of organ, the maximum concentration each class of organ can tolerate, and the minimum concentration to which the plant can reduce each class of organ for use as reserves.

Needed morphogenetic studies include the effect of temperature on the rates of secondary root and tiller formation. In the tillering study the effect of physiological stress on tiller abortion should be measured, and the processes of tiller abortion and tiller initiation should be characterized independently. This will require a considerable amount of destructive sampling in controlled environment experiments as well as a lot of microscope work.

The present model determines head differentiation at one time (the day of accumulation of 315 heat units). A head differentiation model has been written for use in future drafts which builds the rachis and then elaborates spikelets and florets at rates depending on environmental conditions, and, aborts florets in response to metabolic stresses. This model will have to be verified in SPAR experiments

where temperature and the rate of photosynthesis can be controlled independently.

The present model does not consider phosphorous nutrition. In the case of nitrogen uptake, only the passive movement of nitrate into the plant via the transpiration stream is simulated. Transpiration rates are too low in the seedling stage for this process to provide reasonable leaf nitrogen concentrations. Similar results have been reported (Baker, et.al., 1979) for the cotton model GOSSYM which incorporates the same RHIZOS model. Active uptake of ammonium, nitrate and phosphorous is now being incorporated in the UPTAKE subroutine of RHIZOS by Cole and Parton. A phosphorous balance model for the plant will be included in the next draft of WINTER WHEAT. These additions are required for the new head differentiation model.

In a winter winter wheat model fall conditions, hardiness levels, snow cover, root temperature, etc. all need to be considered in simulating winter tiller survival.

None of the experiments outlined here are particularly difficult, nor do they require the development of any new technology. They do however, require a considerable amount of time and equipment.

Output

Output from a typical "run" is included in Appendix d. It was run with soil physical parameters and weather data for the 1978-79 growing season at Akron, Colorado. Because the form of the model described here does not contain a mechanism for the "active" uptake of nitrogen, the nitrogen fertilizer input used in the simulation was double that of the field planting. Reference to the dictionary of terms makes the output self explanatory. The first block of output contains parameters entered by the operator from the terminal. The next block of output data lists the input soil parameters. The next two output block describe the simulated plant and soil system on a time interval selected by the operator and input from the terminal. The first of these blocks describes the plant on the output day. The second is a graphical depiction of the two dimension distributions of nitrate nitrogen, root dry matter, and soil water potential. Also available are maps of the ammonium nitrogen and soil water content. This output is included simply to suggest the kinds of information the model provides the user. It does not represent a validation effort, and the yield figure is not accurate.

Appendix a. Source Listing

```
C                    W H E A T  -  B L O C K   D A T A                          1
C
C    THIS PROGRAM FILE WAS CREATED BY MODIFYING THE CLEMSOM GOSSYM FILE         3
C                                                                      0000     4
C                                                                      0000     5
      BLOCK DATA                                                       0000     6
C     ***************************************************************  0000     7
C     *                                                             *  0000     8
C     *   BLOCK DATA SUBPROGRAM.   USED FOR INITIALIZATION OF       *  0000     9
C     *   VARIABLES FOUND IN COMMON STATEMENTS.                     *  0000    10
C     *                                                             *  0000    11
C     ***************************************************************  0000    12
C                                                                      0000    13
C                                                                             14
C                                                                             15
      REAL INT,LAI,LATUDE,NF,NV,NSTRES,NYTTYM,MH2O,LEAFWT,LEAFRS,             16
     . LEAFW,LEAFCN,JL,KL,JR,KR,JG,KG,JS,KS,JG1,LAMDAC,LAMDAS,               17
     . NPOOL,NEWES,NEWEP
      INTEGER DAYNUM,TILLER,DIFREN,BOOT,HEAD,ANTHES,SPIKE,FLORET,,           19
     . SPRING,SRDAY,SECOND,DACNT,DAZE,YR                                     20
C                                                                            21
C                                                                            22
      COMMON /CALEN / DACNT(12), DAZE, MO, YR                                23
      COMMON /CLIM  / CLIMAT(8),C1(9)                                        24
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN                     25
      COMMON /DIFFU / DIFF(20,6)                                             26
      COMMON /ETPARM/ ALPHA,GAMMA,LAMDAC,LAMDAS,U,WND                        27
      COMMON /EVTR  / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP             28
      COMMON /FERT  / FERN,FNH4,FNO3,OMA,RNNH4,RNNO3                         29
      COMMON /FIELD / FC(20)                                                 30
      COMMON /FRUIT / SPIKE(10),FLORET(10)                                   31
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W                32
      COMMON /GROW  / LEAFW(10,6),STEMW(10),GLUMW(10),GRANW(10)              33
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK                    34
      COMMON /H2ONO3/ VH2OC(20,6) , VNO3C(20,6)                              35
      COMMON /LASTAD/ LTDAY(10),LLDAY(10),ALTMP(10,6),ATTMP(10)
     .      ,APTMP(10)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT          37
      COMMON /LOCOUT/ KA(12),KHAR(20,6)                                      38
      COMMON /LOST  / WTSLFD                                                 39
      COMMON /MATR  / KRL(20), LR                                            40
      COMMON /NIT   / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRANN,GLUMN,PLANTN       41
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1                            42
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)                                    43
      COMMON /PARTS / LEAF(10),LIDATE(10,6),NTILL(10),NSTEMS
```

```
      COMMON /PHYTIM/ TILLER,JOINT(10),DIFREN,BOOT(10),HEAD(10),          45
     . ANTHES(10),SPRING,ACCDEG                                           46
      COMMON /PLOTS / NPN, NPP, NPR, NPW                                  47
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN         48
      COMMON /PS    / PSIS(20,6)                                          49
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC                   50
      COMMON /ROOTIM/ RTIMPD(20,6),SNAME(3),TSTBD(9,20),INRT,MRT          51
     .    ,TSTIMP(9,20),GH20C(9),FACR                                     52
      COMMON /RUTWT / RCH20, ROOTS, ROOTSV(20,6), RTWT(20,6,3)            54
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                        55
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),     56
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)          57
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN                   59
      COMMON /SROOT / SRAVG,SRDAY,SECOND                                  60
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,     61
     . STRSD,STRSN,FACL                                                   62
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT              63
      COMMON /TIMEBD/ THETAI                                         64
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3                     65
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)                   66
      COMMON /UPS   / SUPNO3,UPNO3                                        67
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT     68
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                        69
C                                                                  0000   70
C  VARIABLES OF 1 CHARACTER                                        0000   71
      DATA D/10./, G/1./, T/0./                                           72
C  VARIABLES OF 2 CHARACTERS                                       0000   73
      DATA EP/0./, ES/0./, FC/20*.267/, LR/3/, NK/6/, NL/20/,             74
     . C1/.3964,3.631,.03838,.07659,0.0,-22.97,-.3885,-.1587,-.01021/     75
      DATA KA/' ','0','1','2','3','4','5','6','7','8','9','+'/           76
      DATA KHAR/120*' '/                                                  77
C  VARIABLES OF 3 CHARACTERS                                       0000   78
      DATA KRL/2,1,1,17*0/,OMA/600./,SLF/.02/,SPN/0./,VNC/12*0./          79
C  VARIABLES OF 4 CHARACTERS                                       0000   80
      DATA DIFF/120*258.3/,DAMP/.002/,FNH4/0./,FNO3/1./,PSIS/120*-.175/   81
     .     ,RESC/0./, RTP1/.3/, RTP2/.1/, SESI/0./, RTWT/360*0./          82
C  VARIABLES OF 5 CHARACTERS                                       0001   83
      DATA CAPUP/0./, CUMEP/0./, CUMES/0./, SUMES/0./, SUMEP/0./,         84
     .     DACNT/31,28,31,30,31,30,31,31,30,31,30,31/, DTAVG/7*20./,     0001   85
     .     MH2O/0./, RNNH4/60./, RNNO3/40./, ROOTN/.0045/, ROOTS/0./,
     .     SESII/0./,THRLN/.3E-4/,VH2OC/120*.267/,VNH4C/12*0./,                87
     .     VNO3C/120*0./                                                       88
C  VARIABLES OF 6 CHARACTERS                                       0001   89
      DATA CUMRAN/0./, CUMSOK/0./, PSIAVG/-.175/, PSIMAX/-.175/,          90
```

```
     .     ROOTWT/.005/, SLEAFN/.0003/, ROOTCN/.037/, ROOTSV/120*0./           91
      DATA STEMWT/0./, SUPNO3/0./, TSOILD/20*0./, TSOILN/20*0./,          92
     .     TSOLAV/2*0./, WSTRSD/1./, WSTRSN/1./, WTSLFD/0./                 93
      DATA ALPHA/3.5/,GAMMA/.653/,LAMDAC/.23/,LAMDAS/.3/,                 94
     .     U/6./,WND/120./                                                  95
      END                                                          0001   96
```

```
      PROGRAM WHEAT                                                          97
C                                                                            98
C                                                                            99
      REAL INT,LAI,LATUDE,NF,NV,NSTRES,NYTTYM,MH2O,LEAFWT,LEAFRS,           100
     . LEAFW,LEAFCN,JL,KL,JR,KR,JG,KG,JS,KS,JG1,LAMDAC,LAMDAS,              101
     . NPOOL,NEWES,NEWEP
      INTEGER DAYNUM,TILLER,DIFREN,BOOT,HEAD,ANTHES,SPIKE,FLORET,           103
     . SPRING,SRDAY,SECOND,DACNT,DAZE,YR                                    104
C                                                                            105
      INTEGER TTL1(10),TTL3(10),TTL4(10),TTL5(10),                           106
     . UNITST(4),VNOUNI(6),VH2UNI(6),PSIUNI(6),NITUNT(4)                    107
      INTEGER TTL1R(10), TTL2R(10), UNITS(6), UNITSR(4)            0001 108
      DIMENSION CAPSCA(11),PSISCA(11),VNOSCA(11),ROOSCA(11)        0001 109
C                                                                            110
      COMMON /CALEN / DACNT(12), DAZE, MO, YR                                111
      COMMON /CLIM  / CLIMAT(8),C1(9)                                        112
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRAINCN                    113
      COMMON /DIFFU / DIFF(20,6)                                             114
      COMMON /ETPARM/ ALPHA,GAMMA,LAMDAC,LAMDAS,U,WND                        115
      COMMON /EVTR  / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP             116
      COMMON /FERT  / FERN,FNH4,FNO3,OMA,RNNH4,RNNO3                         117
      COMMON /FIELD / FC(20)                                                 118
      COMMON /FRUIT / SPIKE(10),FLORET(10)                                   119
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W                120
      COMMON /GROW  / LEAFW(10,6),STEMW(10),GLUMW(10),GRANW(10)              121
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK                    122
      COMMON /H2ONO3/ VH2OC(20,6) , VNO3C(20,6)                              123
      COMMON /LASTAD/ LTDAY(10),LLDAY(10),ALTMP(10,6),ATTMP(10)
     .      ,APTMP(10)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT          125
      COMMON /LOCOUT/ KA(12),KHAR(20,6)                                      126
      COMMON /LOST  / WTSLFD                                                 127
      COMMON /MATR  / KRL(20), LR                                            128
      COMMON /NIT   / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRAINN,GLUMN,PLANTN      129
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1                            130
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)                                    131
      COMMON /PARTS / LEAF(10),LIDATE(10,6),NTILL(10),NSTEMS
      COMMON /PHYTIM/ TILLER,JOINT(10),DIFREN,BOOT(10),HEAD(10),             133
     . ANTHES(10),SPRING,ACCDEG                                              134
      COMMON /PLOTS / NPN, NPP, NPR, NPW                                     135
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,PESP,SPN            136
      COMMON /PS    / PSIS(20,6)                                             137
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC                      138
      COMMON /ROOTIM/ RTIMPD(20,6),SNAME(3),YST90(9,20),INRT,MRT             139
     .    ,TSTIMP(9,20),GH2OC(9),FACR                                       140
```

```
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)                  142
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                              143
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),           144
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)                 145
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN                         147
      COMMON /SROOT / SRAVG,SRDAY,SECOND                                        148
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,           149
     . STRSD,STRSN,FACL                                                         150
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT                    151
      COMMON /TIMEBD/ THETAI                                                 152
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3                           153
      COMMON /TSOIL / TSOILD(20), TSOILN(20), TSOLAV(2)                         154
      COMMON /UPS   / SUPNO3,UPNO3                                              155
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT           156
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                              157
C                                                                               158
C                                                                          0001 159
      DATA ROOSCA/0.0,.0001,.0005,.005,.01,.015,.02,.025,.03,.035,.04/     0002 160
      DATA TTL1R/'ROOT','S IN',' EAC','H CE','LL, ','TOTA','L   ',         0002 161
     .  '   ','   ','   '/                                                  0002 162
      DATA TTL2R/'    ','AT T','HE E','ND O','F RU','TGRO','    ',         0002 163
     .  '   ','   ','   '/                                                  0002 164
      DATA UNITS/'G/CM','**3 ','SOIL','    ','    ','    '/               0002 165
      DATA UNITSR/' GM.',' DRY',' WEI','GHT '/                              0002 166
      DATA TTL1/'VOLU','METR','IC W','ATER',' CON','TENT',' OF ',           0002 167
     . 'SOIL','    ','    '/                                               0002 168
      DATA TTL3/'AT T','HE E','ND O','F MA','IN  ','    ','    ',          0002 169
     .  '   ','   ','   '/                                                  0002 170
      DATA TTL4/'PSIS',' FOR',' EAC','H LA','YER ','AND ','COLU',           0002 171
     . 'MN  ','    ','    '/                                               0002 172
      DATA TTL5/'VOLU','METR','IC N','ITRA','TE C','ONTE','NT O',           0002 173
     . 'F SO','IL  ','    '/                                               0002 174
      DATA PSISCA/-15.,-10.,-6.,-3.,-1.5,-1.,-.6,-.4,-.2,-.1,0./           0002 175
      DATA VNOSCA/0.0,.01,.02,.03,.04,.05,.06,.07,.08,.09,.1/               0002 176
      DATA PSIUNI/' BAR','S   ','    ','    ','    ','    '/               0002 177
      DATA VNOUNI/' MG/','N PE','R CM','**3 ','    ','    '/               0002 178
      DATA VH2UNI/'CM**','3/CM','**3 ','SOIL','    ','    '/               0002 179
      DATA UNITST/' MM ','WATE','R   ','    ','    '/                     0002 180
      DATA CAPSCA/0.0,.05,.1,.15,.2,.25,.3,.35,.4,.45,.5/                   0002 181
      DATA NITUNT/' MG ','N   ','    ','    ','    '/                     0002 182
      DIFREN=999                                                                183
      TILLER=999                                                                184
      DO 100 I=1,10                                                             185
      JOINT(I)=999                                                              186
```

```
      BOOT(I)=999                                                       187
      HEAD(I)=999                                                       188
      ANTHES(I)=999                                                     189
      STEMW(I)=0.                                                       190
      GLUMW(I)=0.                                                       191
      GRANW(I)=0.                                                       192
      SPIKE(I)=0                                                        193
      FLORET(I)=0                                                       194
      LEAF(I)=0                                                         195
      LTDAY(I)=0                                                        196
      LLDAY(I)=0                                                        197
      NTILL(I)=0
      ATTMP(I)=0.                                                       198
      APTMP(I)=0.
      DO 100 J=1,6                                                      199
      LEAFW(I,J)=0.                                                     200
      LIDATE(I,J)=0                                                     201
      ALTMP(I,J)=0.                                                     202
  100 CONTINUE                                                          203
      AHTMP=0.                                                          204
      SECOND=0                                                          205
      AREA=0.                                                           206
      WRITE(2,110)
  110 FORMAT(' INPUT LEAFW(1,1) RTWT(1,1,1) RTWT(1,2,1) RTWT(2,1,1)',
     . ' RTWT(3,1,1) PNFAC' )
      READ(1,*) LEAFW(1,1),RTWT(1,1,1),RTWT(1,2,1),RTWT(2,1,1),
     . RTWT(3,1,1),PNFAC
      WRITE(2,130)                                                      233
  130 FORMAT(' INPUT POPPLT F2 LATUDE LAI NOITR FACR')
      READ(1,*) POPPLT,F2,LATUDE,LAI,NOITR,FACR
      WRITE(2,140)                                                      236
  140 FORMAT(' INPUT KL KS KR KG')                                      237
      READ(1,*) KL,KS,KR,KG                                             238
      WRITE(2,150)                                                      239
  150 FORMAT(' INPUT JL JS JR JG JG1')                                  240
      READ(1,*) JL,JS,JR,JG,JG1                                         241
      WRITE(2,160)                                                      242
  160 FORMAT(' INPUT LEAFLGTH ROWSPACE PRINT G THRLN FACL')
      READ(1,*) XLEAFL,ROWSP,IPRNT,G,THRLN,FACL
      WRITE(2,170)                                                      245
  170 FORMAT(' TO SEE PLOT TYPE 1 UNDER FIRST LETTER OTHERWISE TYPE 0'/  246
     . '  ROOTS PSIS VH2OC VNO3C ')                                     247
      READ(1,*) NPR, NPP, NPW, NPN                                      248
      POPFAC=404685.6/POPPLT
      W=ROWSP/NK                                                        336
```

```
      LEAFWT=LEAFW(1,1)
      STEMWT=0.                                                          214
      GLUMWT=0.                                                          215
      GRANWT=0.                                                          216
      ROOTWT=(RTWT(1,1,1)+RTWT(1,2,1)+RTWT(2,1,1)+RTWT(3,1,1))*
     .       POPFAC*2./ROWSP*100.
      PLANTW=LEAFWT+ROOTWT
      VEGWT=LEAFWT+ROOTWT
      SLEAFN=.03*LEAFWT
      ROOTN=ROOTWT*.03
      STEMN=0.                                                           220
      GLUMN=0.                                                           221
      GRANN=0.                                                           222
      LEAFCN=.03                                                         223
      NSTEMS=1                                                           224
      SRAVG=0.                                                           225
      SRDAY=0                                                            226
      SPRING=70                                                         227
      LEAF(1)=1                                                          228
      ACCDEG=0.                                                          230
      PLANTN=SLEAFN+STEMN+ROOTN+GRANN+GLUMN                              231
C                                                                        232
      READ(5,*) LYRSOL                                                   249
C  LYRSOL = NUMBER OF SOIL LAYERS OF DIFFERENT CHARACTERISTICS           250
C  -- UP TO 5 ALLOWED                                                   251
C  LPT1 = PRINT SOILS INFORMATION IF = 0; OTHERWISE NOT.                 252
C  SOIL DIFFUSIVITY WATER CONTENT FUNCTIONS ARE IN :                     253
C   GARDNER,W.R. AND M.S.MAYHUGH. 1958. SSSAP 22:197-201.               254
C                                                                        255
C  SOIL WATER CONTENT PSI FUNCTION FROM:                                 256
C   BROOKS,R.H. AND A.T.COREY. 1964.HYD.PAPERS CSU 3:1-27. FOW.          257
C                                                                        258
      READ(5,*)(DIFFO(I),THETAO(I),BETA(I),SDEPTH(I),THETAS(I),          259
     . THETAR(I),AIRDR(I),ETA(I),BD(I),I=1,LYRSOL)                       260
      WRITE(6,180)LYRSOL                                                 261
  180 FORMAT(' NUMBER OF SOIL LAYERS',I2 //                              262
     .'  LAYER   MAX.DEPTH      DO      THETA 0      BETA'//              263
     .'    NO.',7X,'CM          CM       BAR/DAY     CC/CC')
      WRITE(6,185)(I,SDEPTH(I),DIFFO(I),THETAO(I),BETA(I),I=1,LYRSOL)    265
  185  FORMAT(' ',I4,5X,1P4E10.3)                                        266
C   SDEPTH = MAX. DEPTH OF LAYER                                         267
C   DIFFUSIVITY = DO EXP BETA*(VH2OC - THETAO) WHERE                     268
C   DO AND THETAO ARE INITIAL OR 15 BAR DIFF. AND WATER CONTENT ;        269
C   BETA = SLOPE OF LOG D - THETA CURVE.                                 270
C*****WARNING***** WATCH UNITS OF DIFF. CM BAR/DAY *******              271
```

```
C    PSIS = AIRDR*((VH2OC-THETAR)/(THETAS-THETAR))**(3/(2-ETA))                  272
C    WHERE AIRDR = THE AIR ENTRY PRESSURE: THETAR = RESIDUAL                     273
C    WATER CONTENT ; THETAS = SATURATED WATER CONTENT ;                          274
C    ETA = SLOPE OF SEMI-LOG PLOT. FOW.                                          275
C    BD  = BULK DENSITY OF LAYER                                                 276
C                                                                                277
       READ(5,*) DUMB,THETAI
C
C    MAKE BOTTOM LAYER TIME DEPENDENT BOUNDARY WHERE :                           279
C     VH2OC = THETAI FOR TIME LESS THEN TO                                       280
C     VH2OC = THETAI - 0.00385*(TIME - TO)                                       281
C OR VH2OC = 0.65*THETAI , WHICHEVER IS LEAST ;                                  282
C    SLOPES AND RESIDUAL WATER CONTENT ARE FROM :                                285
C     GERARD,C.D. AND L.N.NAMKEN. 1966. AGRON.J. 58:39-42. FOW.                  286
C                                                                                287
       WRITE(6,190) THETAI
 190   FORMAT(' INITIAL VH2O AT BOTTOM BOUNDARY =',1PE10.3)
C                                                                                291
       J = 1                                                                     292
       DELT = 1/NOITR                                                            293
C                                                                                294
       DO 210 LAYER =1,NL                                                        295
  200  CONTINUE                                                                  296
       IF(LAYER*D.LE.SDEPTH(J)) GO TO 205                                        297
       J = J+1                                                                   298
       IF(J.LT.5) GO TO 200                                                      299
  205  FLXMAX(J)=DIFFO(J)*((THETAS(J)-THETAR(J))/D)*(W*DELT*DAMP)*               300
      .EXP(BETA(J)*(THETAS(J)-THETAO(J)))                                        301
       FC(LAYER) = THETAS(J)                                                     302
       DO 210 KOLUMN = 1,NK                                                      303
       VH2OC(LAYER,KOLUMN) = THETAS(J)                                           304
       DIFF(LAYER,KOLUMN)=DIFFO(J)*EXP(BETA(J)*(VH2OC(LAYER,KOLUMN)-             305
      .THETAO(J)))                                                               306
       TEMP1 = (VH2OC(LAYER,KOLUMN)-THETAR(J))/(THETAS(J)-THETAR(J))             307
  210  PSIS(LAYER,KOLUMN) = 0.0009833*AIRDR(J)*TEMP1**(3./(2.-ETA(J)))          308
C    READ IN DATA TABLE OF H2O,BD, AND SOIL STRENGTH                      NASA 309
       READ(5,215)SNAME,MRT                                                      310
  215  FORMAT(3A4,2I2)                                                      NASA 311
C    PRINT DATA TABLE                                                     NASA 312
       WRITE(6, 220)SNAME,MRT                                                    313
  220  FORMAT(' SOIL ID.',3A4,'  NO.OF CURVES',I2)                               314
C                                                                          NASA 315
       DO 250 I=1,MRT                                                            316
       READ(5,*)INRT,GH2OC(I)                                                    317
       READ(5,*) (TSTBD(I,J),TSTIMP(I,J),J=1,INRT)                               318
```

```
C                                                                       NASA 319
      WRITE(6,230)INRT,GH2OC(I)                                             320
  230 FORMAT(' NO.OF DATA POINTS',I3,'  GRAVIMETRIC WATER CONTENT',F7.2)    321
      WRITE(6,240) (TSTBD(I,J),TSTIMP(I,J),J=1,INRT)                        322
  240 FORMAT(' BULK DENSITY  SOIL STRENGTH'/'     GM/CC      KG/CM2'/('    323
     .',2F12.2))                                                        NASA 324
  250 CONTINUE                                                          NASA 325
      IDAY=0                                                                337
      ITGF=60
      KTDAY=0
  260 CONTINUE                                                              338
      READ(5,*,END=640) (CLIMAT(I),I=1,8)
      IDAY=IDAY+1
      CALL CLYMAT                                                           342
      CALL SOIL                                                             343
      IF(TAVG.GE.4.) GO TO 265
      IDAY=IDAY-1
      GO TO 260
  265 CALL PNET
      CALL GROWTH                                                           345
      CALL MORPH                                                            346
      H2OBAL = TH2O - CUMRAN - CAPUP + CUMEP + CUMES + CUMSOK           0003 347
      IF(IDAY.LE.ANTHES(1)) GO TO 270                                     1977
      AHTMP=AHTMP+TAVG                                                    1978
      KTDAY=KTDAY+1
      TDUM=AHTMP/KTDAY
      ITGF=(-2.7)*TDUM+90.                                              1980
      IF(ITGF.GT.50) ITGF=50
  270 CONTINUE
      ITST=IDAY/IPRNT*IPRNT                                                 348
      IF(ITGF.LE.KTDAY) ITST=IDAY
      IF(IDAY.EQ.1) ITST=IDAY
      IF(ITST.NE.IDAY) GO TO 260
      WRITE(6,280) DAYNUM,IDAY
  280 FORMAT(//// 15X,' JULIAN DAY=',I3,10X,'IDAY=',I3,//)
      WRITE(6,300)                                                          353
  300 FORMAT('     PN          PSTAND      PTSN        PTSRED     ',
     . ' RESCF       PPLANT       RESP')
      WRITE(6,310)  PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP
  310 FORMAT(2x,9E11.3)
      WRITE(6,320)                                                          358
  320 FORMAT('     LEAFWT      STEMWT      GLUMWT      GRANWT      ROOTWT',
     .                '          SPN')
      WRITE(6,310) LEAFWT,STEMWT,GLUMWT,GRANWT,ROOTWT,SPN
      WRITE(6,340)                                                          361
```

```
340 FORMAT('     SPDWL       SPDSTM      SPDGLM      SPDGRN      ',
   . 'SPDWRT      CSTRSV      CSTRSF')
    WRITE(6,310) SPDWL,SPDSTM,SPDGLM,SPDGRN,SPDWRT,CSTRSV,CSTRSF          364
    WRITE(6,360)                                                          365
360 FORMAT('     RESC        RESN        REQN        NPOOL       ',
   . 'NSTRES        NV          NF')
    WRITE(6,310) RESC,RESN,REQN,NPOOL,NSTRES,NV,NF                        368
    WRITE(6,380)                                                          369
380 FORMAT('     SLEAFN      STEMN       GLUMN       GRANN       ',
   . 'LEAFCN      SUPNO3')
    WRITE(6,310) SLEAFN,STEMN,GLUMN,GRANN,LEAFCN,SUPNO3                   372
    WRITE(6,390)                                                          373
390 FORMAT('    SPIKE(I)    FLORET(I)    LEAF(I)    JOINT(I)    ',
   . 'BOOT(I)     HEAD(I)     ANTHES(I)')
    DO 400 I=1,NSTEMS                                                     376
    WRITE(6,410) SPIKE(I),FLORET(I),LEAF(I),JOINT(I),BOOT(I),             377
   . HEAD(I),ANTHES(I)                                                    378
400 CONTINUE                                                              379
410 FORMAT(10(I8,3X))
    WRITE(6,420)                                                          381
420 FORMAT('    SECOND       ACCDEG      PSIAVG       DIFREN     TILLER')  382
    WRITE(6,430) SECOND,ACCDEG,PSIAVG,DIFREN,TILLER                       383
430 FORMAT(I8,4X,F9.2,3X,E12.5,I8,4X,I8)                                  384
    WRITE(6,460)                                                          385
460 FORMAT('    DAYLNG         LAI         XLEAFL         INT',          386
   . '          TAVG')                                                    387
    WRITE(6,310) DAYLNG,LAI,XLEAFL,INT,TAVG                               388
    WRITE(6,480)                                                          389
480 FORMAT('    RCH2O         STRSD         STRSN         WSTRSD',       390
   . '       EP          ES')                                           391
    WRITE(6,310) RCH2O,STRSD,STRSN,WSTRSD,EP,ES                           392
    IF(NPN.EQ.1) CALL OUT(VNO3C,TTL5,TTL3,VNOSCA,                 0003    393
   .  VNOUNI,TNNO3,NITUNT)                                                394
    IF(NPW.EQ.1) CALL OUT(VH2OC,TTL1,TTL3,CAPSCA,                         395
   .  VH2UNI,TH2O,UNITST)                                                 396
    IF(NPR.EQ.1) CALL OUT(ROOTSV,TTL1R,TTL2R,                             397
   .  ROOSCA,UNITS,ROOTS,UNITSR)                                          398
    IF(NPP.EQ.1) CALL OUT(PSIS,TTL4,TTL3,PSISCA,                          399
   .  VH2UNI,TH2O,UNITST)                                                 400
    IF(ITGF.GT.KTDAY) GO TO 260
640 CONTINUE
    YIELD=GRANWT*14.8563/POPFAC                                          1982
    WRITE(6,660) YIELD,DAYNUM
660 FORMAT(///' *** FINAL YIELD (BU/ACRE) IS',F8.2,'   ON DAY',I4)
    STOP                                                                  405


    END                                                                   406
```

```
      SUBROUTINE CLYMAT                                                 0003 407
C  ***************************************************************      0003 408
C  *                                                             *      0003 409
C  *                    CLIMATE SUBROUTINE                       *      0003 410
C  *                                                             *      0003 411
C  ***************************************************************      0003 412
      REAL INT,LATUDE,LAI,NYTTYM                                             413
      INTEGER DAZE, YR, DACNT, DAYNUM                                        414
C                                                                     0003 415
C                                                                            416
      COMMON /CALEN / DACNT(12), DAZE, MO, YR                         0003 417
      COMMON /CLIM  / CLIMAT(8),C1(9)                                        418
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT          419
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                           420
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT                 422
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)                      423
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                           424
C                                                                            425
C                                                                            426
C                                                                     0003 427
      RI = CLIMAT(1)                                                         428
      TMAX =  CLIMAT(2)
      TMIN =  CLIMAT(3)
      MH2O=CLIMAT(4)                                                         431
      RAIN=CLIMAT(5)*25.4                                                    432
      DAYNUM = CLIMAT(7)                                                     433
      RN = RI * .8942 * .8 - 26.                                             434
C NET RADIATION IN WATTS/M**2                                         0003 435
      XLAT=LATUDE*.0174533                                                   436
      DEC=C1(1)                                                              437
      DO 100 I=2,5                                                           438
      J=I+4                                                                  439
      PHI=DAYNUM*.01721*(I-1)                                                440
      DEC=DEC+C1(I)*SIN(PHI)+C1(J)*COS(PHI)                                  441
  100 CONTINUE                                                               442
      DEC=DEC*.0174533                                                       443
      DAYLNG=ARCOS((-.014544-SIN(XLAT)*SIN(DEC))/(COS(XLAT)*COS(DEC)))       444
     . *7.6394                                                               445
      TDAY=(TMAX-TMIN)*.55+TMIN                                              446
      TNYT=(TMAX-TMIN)*.15+TMIN                                              447
C                                                                     0004 448
      CALL DATE                                                       0004 449
C                                                                     0004 450
      DAYTYM=DAYLNG                                                          451
      NYTTYM=24.-DAYLNG                                                      452
      TAVG=(TDAY*DAYTYM+TNYT*NYTTYM)/24.                                     453
C                                                                            454
C   PHOTOSYNTHESIS MUST BE CORRECTED TO REFLECT % SOLAR RADI-                455
C    ATION INTERCEPTED. TWO TERMS USED, THE FIRST CORRECTS FOR               456
C    AREA BETWEEN ROWS WITH NO COVER, THE SECOND IS TAKEN FROM               457
C    PAPER (LIGHT AND CROP PRODUCTION BY J L MONTEITH - FIELD                458
C   . CROP ABSTRACTS NOVEMBER 1965)                                          459
C                                                                            460
      TERM1=(2.*XLEAFL/ROWSP)                                                461
      IF(TERM1.GT.1.) TERM1=1.                                               462
      TERM2=1.-EXP(-.4*LAI)                                                  463
      INT=TERM1*TERM2                                                        464
C                                                                     0004 465
      CALL TMPSOL                                                            466
C                                                                     0004 467
      RETURN                                                          0004 468
      END                                                             0004 469
```

```
      SUBROUTINE DATE                                                    0004 470
C     ***************************************************************  0004 471
C     *                                                             *  0004 472
C     *   DATE SUBROUTINE.  CONVERTS JULIAN TO CALENDAR AND         *  0004 473
C     *    ALLOWS FOR LEAP YEARS.                                   *  0004 474
C     *                                                             *  0004 475
C     ***************************************************************  0004 476
      REAL LATUDE,NYTTYM                                                    477
      INTEGER DAZE,DACNT,YR,DAYNUM                                       0004 478
C                                                                        0004 479
      COMMON /CALEN / DACNT(12), DAZE, MO, YR                            0004 480
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT         481
C                                                                        0004 482
      DACNT(2) = 28                                                      0004 483
      IYR = YR/4                                                         0004 484
      IF(YR.EQ.IYR*4) DACNT(2) = 29                                      0004 485
      MO = 1                                                             0004 486
      DAZE = DAYNUM                                                      0004 487
      DO 1 I=1,12                                                        0004 488
      IF(DAZE.LE.DACNT(I)) GO TO 2                                       0004 489
      MO = MO + 1                                                        0004 490
      DAZE = DAZE - DACNT(I)                                             0004 491
    1 CONTINUE                                                           0004 492
    2 CONTINUE                                                           0004 493
      RETURN                                                             0004 494
      END                                                                0004 495
```

```
      SUBROUTINE TMPSOL                                                  496
C*****************************************************************     0004 497
C   THIS SUBROUTINE CALCULATES A TEMPERATURE PROFILE IN THE*            0004 498
C SOIL. ASSUMES HORIZONTAL HOMOGENEITY OF TEMPERATURE &    *            0004 499
C DISREGARDS MOISTURE CONTENT EFFECTS.                     *            0004 500
C FIRST, MAXIMUM (H) & MINIMUM (L) TEMPERATURES ARE        *            0004 501
C CALCULATED AT 2, 4, 8, & 16 INCH DEPTHS BY MULTIPLE      *            0004 502
C REGRESSION EQUATIONS OF                                  *            0005 503
C J. C. MCWHORTER & B. P. BROOKS, JR.  1965. CLIMATOLOGICAL*            0005 504
C AND SOLAR RADIATION RELATIONSHIPS. BULL. 715, MISS.      *            0005 505
C AGRI. EXP. STA., STARKVILLE.                             *            0005 506
C NOTE THAT THE GRID SIZE (D*W) IS NOT VARIABLE IN THIS    *            0005 507
C SUBROUTINE, BUT THE LAYER THICNESS IS FIXED AT 5 CM.     *            0005 508
C   MAX & MIN SOIL TEMPS FOR EACH OF THE LAYERS ARE THEN   *            0005 509
C OBTAINED BY INTERPOLATION & EXTRAPOLATION OF THE 2, 4,   *            0005 510
C 8, & 16 INCH TEMPS.                                      *            0005 511
C    FINALLY, DAYTIME AND NIGHTIME TEMPS(TSMX & TSMN)      *            0005 512
C ARE OBTAINED AS AVERAGE HOURLY VALUES FROM 7 A.M. THRU   *            0005 513
C SUNSET, & SUNSET THRU 7 A.M., RESPECTIVELY, USING AN     *            0005 514
C ALGORITHM FOR AIR TEMP PUBLISHED BY H. N. STAPLETON,     *            0005 515
C D. R. BUXTON, F. L. WATSON, D. J. NOLTING, AND D         *            0005 516
C D. N. BAKER.  UNDATED.  COTTON: A COMPUTER SIMULATION OF *            0005 517
C COTTON GROWTH.  TECH. BULL. 206, ARIZONA AGRI. EXP. STA. *            0005 518
C TUCSON.                                                  *            0005 519
C*****************************************************************     0005 520
      INTEGER DAYNUM                                                     521
      REAL LATUDE,NYTTYM                                                 522
      DIMENSION TSMX(20), TSMN(20), RECDAT(24)                          0005 523
C                                                                       0005 524
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT      525
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT            0005 526
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)                  527
C                                                                       0005 528
      J=8                                                                529
      DO 1 I = 1,6                                                      0005 530
      J=J-1                                                              531
    1 DTAVG(J) = DTAVG(J-1)                                              532
      DTAVG(1) = TAVG                                                   0005 533
      WTAVG = 0.                                                        0005 534
      J=7                                                                535
      IF(IDAY.LT.7) J=IDAY                                               536
      DO 2 I = 1,J                                                       537
    2 WTAVG = WTAVG +  DTAVG(I)                                          538
      WTAVG = WTAVG/J                                                    539
      WTAVGF = WTAVG*1.8 + 32.                                          0005 541
```

```
C THE NEXT EIGHT EQUATIONS ARE FROM MCWHORTER AND BROOKS.                0005 541
        T2H  = 1.1962*WTAVGF + 0.27389                                   0005 542
        T2L  = 0.960*WTAVGF + 1.4404                                     0005 543
        T4H  = 1.1493*WTAVGF + 1.1452                                    0005 544
        T4L  = 0.9126*WTAVGF + 2.9961                                    0005 545
        T8H  = 0.9655*WTAVGF + 8.3121                                    0005 546
        T8L  = 0.8700*WTAVGF + 7.9217                                    0005 547
        T16H = 0.8409*WTAVGF + 13.988                                    0005 548
        T16L = 0.8341*WTAVGF + 13.029                                    0005 549
C GET TEMP OF SOIL ( MAX ) BY INTERPOLATION OR EXTRAPOLATION.            0005 550
      T24 = T2H - T4H                                                    0005 551
      T48 = T4H - T8H                                                    0005 552
      TSMX(1)=(T2H+T4H+T24*1.031)/2.                                     NASA 553
      TSMX(2)=T8H+(T48*1.048)/2.                                         NASA 554
      T816 = .0492126 * (T8H - T16H)                                     NASA 555
      DO 6 I= 3,20                                                       NASA 556
      J=I-3                                                              NASA 557
        TSMX(I) = T8H - (2.18+(1+J*4)*5.) * T816/2.                      NASA 558
 6    CONTINUE                                                           NASA 559
C GET TEMP OF SOIL (MIN) BY INTERPOLATION OR EXTRAPOLATION.              NASA 560
      T24 = T2L - T4L                                                    NASA 561
      T48 = T4L - T8L                                                    NASA 562
      TSMN(1) = (T2L+T4L+T24*1.031)/2.                                   NASA 563
      TSMN(2) = T8L+(T48*1.048)/2.                                       NASA 564
      T816 = .0492126 * (T8L - T16L)                                     NASA 565
      DO 7 I=3,20                                                        NASA 566
      J=I-3                                                              NASA 567
      TSMN(I) = T8L - (2.18+(1+J*4)*5.) * T816 / 2.                      568
        IF(TSMN(I).LT.TSMX(I)) GO TO 7                                   0005 569
        TSMN(I) = (TSMN(I) + TSMX(I))/2.                                 0005 570
        TSMX(I) = TSMN(I)                                                0005 571
 7    CONTINUE                                                           0005 572
      DO 8 I=1,20                                                        573
C CONVERT TEMPS TO CENTIGRADE.                                           0005 574
        TSMX(I) = (TSMX(I)-32.)*.555556                                  0005 575
        TSMN(I) = (TSMN(I)-32.)*.555556                                  0005 576
 8    CONTINUE                                                           0005 577
      ISR = 12 - IFIX(DAYLNG*.5)                                         0005 578
      ISS = ISR + IFIX(DAYLNG+0.5)                                       0005 579
C HOUR OF SUNSET.                                                        0005 580
C SEE PP 57 OF STAPLETON, ET AL. FOR EQUATIONS DETERMINING RECDAT.       0005 581
      DO 9 LAYER = 1,20                                                  0005 582
      TMEAN = (TSMX(LAYER)+TSMN(LAYER)) * .5                             0005 583
      SWINGH = (TSMX(LAYER)-TSMN(LAYER)) * .5                            0005 584
      DO 11 IH=7,15                                                      0005 585
      RECDAT(IH) = TMEAN - SWINGH*COS(0.3927*(IH-7.))                    0005 586
      IH9 = IH + 9                                                       0005 587
      RECDAT(IH9) = TMEAN + SWINGH*COS(0.19635*(IH9-15.))                0005 588
 11   CONTINUE                                                           0005 589
      DO 12 IH=1,6                                                       0005 590
 12   RECDAT(IH) = TMEAN - SWINGH*COS(0.19635*(6-IH))                    0005 591
      SHRTD = 0.                                                         0005 592
      SHRTN = 0.                                                         0005 593
      DO 13 IH=7,ISS                                                     0005 594
      SHRTD = SHRTD + RECDAT(IH)                                         0005 595
C SUM OF HOURLY TEMPS IN DAYTIME.                                        0005 596
 13   CONTINUE                                                           0005 597
      TSOILD(LAYER) = SHRTD/(ISS-6)                                      0005 598
C AVERAGE TEMP OF SOIL DURING DAYTIME, DEG C.                            0005 599
      ISS1 = ISS + 1                                                     0005 600
      DO 14 IH=ISS1,24                                                   0006 601
      SHRTN = SHRTN + RECDAT(IH)                                         0006 602
C SUM OF HOURLY TEMPS IN NIGHTIME.                                       0006 603
 14   CONTINUE                                                           0006 604
      DO 15 IH=1,6                                                       0006 605
      SHRTN = SHRTN + RECDAT(IH)                                         0006 606
 15   CONTINUE                                                           0006 607
      TSOILN(LAYER) = SHRTN/(30-ISS)                                     0006 608
C AVERAGE TEMP OF SOIL DURING NIGHTIME.                                  0006 609
 9    CONTINUE                                                           0006 610
      DO 16 LAYER = 1, 2                                                 0006 611
      TSOLAV(LAYER)= (TSOILD(LAYER)*DAYLNG+TSOILN(LAYER)*(24.-DAYLNG))   0006 612
     . /24.                                                              0006 613
C AVERAGE SOIL TEMPERATURE, DEG C.                                       0006 614
 16   CONTINUE                                                           0006 615
      RETURN                                                             0006 616
      END                                                                0006 617
```

```
      SUBROUTINE SOIL                                                    0006 618
C  ***************************************************************     0006 619
C  *                                                             *     0006 620
C  *     SOIL SUBROUTINE.  CALLS FRTLIZ, GRAFLO, ET,             *     0006 621
C  *       UPTAKE, CAPFLO, AND NITRIF.                           *     0006 622
C  *                                                             *     0006 623
C  ***************************************************************     0006 624
      REAL LATUDE,LAI,MH2O,NEWES,NEWEP,NYTTYM,INT
      INTEGER DAYNUM                                                          626
C                                                                             627
      COMMON /CLIM  / CLIMAT(8),C1(9)                                         628
      COMMON /DIFFU / DIFF(20,6)                                              629
      COMMON /ETPARM/ ALPHA,GAMMA,LAMDAC,LAMDAS,U,WND                         630
      COMMON /EVTR  / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP              631
      COMMON /FERT  / FERN,FNH4,FNO3,OMA,RNNH4,RNNO3                          632
      COMMON /FIELD / FC(20)                                                  633
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W                 634
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK                     635
      COMMON /H2ONO3/ VH2OC(20,6) , VNO3C(20,6)                               636
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT           637
      COMMON /MATR  / KRL(20), LR                                             638
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)                                     639
      COMMON /PS    / PSIS(20,6)                                              640
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)                642
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                            643
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),         644
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)              645
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT                  647
      COMMON /TIMEBD/ THETAI                                                648
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3                         649
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)                       650
      COMMON /UPS   / SUPNO3,UPNO3                                            651
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                            652
C                                                                             653
      FERN=CLIMAT(8)                                                          654
      IF(IDAY.GT.1) GO TO 2                                                   655
      CALL FRTLIZ                                                             656
      WRITE(6,1000) VNO3C(1,1)                                                657
 1000 FORMAT(' VNO3C(1,1) = ',F10.4)                                          658
C  ALL FERTILIZER IS NO3.                                                     659
      OMA = 0.                                                                660
      RNNO3 = 0.                                                              661
      RNNH4 = 0.                                                              662
    2 CONTINUE                                                                663
      IF(FERN.GT.0.) CALL FRTLIZ
C                                                                             667
      IF(RAIN.GT.0.) CALL GRAFLO                                              668
C                                                                             669
      CALL ET                                                                 670
C                                                                             671
      SUPNO3 = 0.                                                             672
      SUMES=0.                                                                673
      SUMEP=0.                                                                674
C                                                                      0006 675
      DO 10 I=1,NOITR
      CALL UPTAKE                                                      0006 677
      IF(UPNO3.GT.0.) SUPNO3 = SUPNO3 +  UPNO3                         0006 678
      CALL CAPFLO                                                      0006 679
   10 CONTINUE                                                         0006 680
      CUMEP = CUMEP + NEWEP                                            0006 681
      CUMES = CUMES + NEWES                                            0006 682
C                                                                      0006 683
      SUPNO3 = SUPNO3*POPFAC*.1/ROWSP                                         684
C                                                                      0006 685
      DO 11 I=1,NOITR
      CALL CAPFLO                                                      0006 687
   11 CONTINUE                                                         0006 688
      CALL NITRIF                                                      0006 689
C                                                                      0006 690
      RETURN                                                           0006 691
      END                                                              0006 692
```

```
      SUBROUTINE FRTLIZ                                                  0006 693
C*****************************************************************     0006 694
C  ****  MODIFIED BY A. MARANI  MARCH 1980   ***************              695
C*****************************************************************        696
C SUBROUTINE ADDS FERTILIZER TO PROFILE. MUST BE CALLED AT      *     0006 697
C PLANTING DATE TO INITIALIZE NITROGEN & ORGANIC MATTER         *     0007 698
C PROFILE.  MAY BE CALLED FOR SIDE DRESSING.  INPUTS ARE:       *     0007 699
C FERN:  FERTILIZER INORGANIC NITROGEN, LBS N/ACRE.             *     0007 700
C FNH4:  FRACTION OF INORGANIC N  IN AMMONIA FORM. 0 TO 1       *     0007 701
C FNO3:  FRACTION OF INORGANIC N  IN NITRATE FORM. 0 TO 1       *     0007 702
C OMA:  ORGANIC MATTER PLOWED AT BEGINNING OF SEASON, LBS/ACRE, *     0007 703
C       MUST BE .GT. 0 TO INITIALIZE N & ORGANIC MATTER ARRAYS. *     0007 704
C RNNO3: RESIDUAL N  AS NITRATE IN UPPER 2 LAYERS, LBS/ACRE.      *      0007
C RNNH4: RESIDUAL N AS AMMONIUM IN UPPER 2 LAYERS, LBS/ACRE.      *      0007
C*****************************************************************     0007 707
C                                                                       0007 708
      COMMON /FERT  / FERN,FNH4,FNO3,OMA,RNNH4,RNNO3                       709
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W              710
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)                             711
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)                                  712
      WRITE(6,1000)                                                     0007 713
 1000 FORMAT('  FERTILIZER SUBROUTINE CALLED  ################## ')     0007 714
      IF(OMA.LE.0.) GO TO 2                                             0007 715
C OMA .GT. 0. IMPLIES INITIAL FERTILIZATION AT PLANTING DATE &          0007 716
C PLOWDOWN OF ORGANIC MATTER.                                           0007 717
      DO 3 L=1 , 2                                                         718
      DO 3 K=1 ,NK                                                         719
      VNC(L,K) = OMA * .01122/(D*2.) * .01
      VNO3C(L,K) = RNNO3 * .01122/(D*2.)
      VNH4C(L,K) = RNNH4 * .01122/(D*2.)
C                                                                          723
C   CHG LB/ACRE TO MG/CC IN TOP 2 LAYERS (.01122 LB/ACRE = 1 MG/CM**2)     724
C                                                                          725
  3   CONTINUE                                                             726
  2   CONTINUE                                                             727
C   FERTILIZER BROADCAST AND MIXED INTO UPPER 2 LAYERS OF SOIL.
      DUMY08 = FERN * FNO3 * .01122/(D*2.)
      DUMY09 = FERN * FNH4 * .01122/(D*2.)
      DO 5 LAYER  = 1, 2                                                   731
      DO 5 KOLUMN = 1,NK                                                   732
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + DUMY08                   733
C     ADDITION OF BROADCAST NITRATE FERTILIZER.                            734
      VNH4C(LAYER,KOLUMN) = VNH4C(LAYER,KOLUMN) + DUMY09                   735
C ADDITION OF BROADCAST AMMONIUM FERTILIZER.                            0007 736
  5   CONTINUE                                                          0007 737
      RETURN                                                            0007 738
      END                                                               0007 739
```

```
      SUBROUTINE GRAFLO                                                  0007 740
C  ***************************************************************     0007 741
C  *                                                             *     0007 742
C  *   GRAVITY FLOW OF NO3 AND H2O, AFTER RAIN OR IRRIGATION.    *     0007 743
C  *                                                             *     0007 744
C  ***************************************************************     0007 745
C RAIN OR IRRIGATION IS IN MM.                                           0007 746
      REAL MH2O                                                          747
      DIMENSION SOAKW(21), SOAKN(21)                                     0007 748
C WATER SOAKING INTO LAYER.                                              0007 749
C NITROGEN SOAKING INTO LAYER BY MASS FLOW OF H2O.                       0007 750
C                                                                        0007 751
      COMMON /FIELD / FC(20)                                             0007 752
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W                753
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK                0008 754
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)                           0801 755
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                           756
C                                                                        0008 757
C VH2OC: VOLUMETRIC WATER CONTENT, CM**3/CM**3.                          0008 758
C FC:  FIELD CAPACITY, BY LAYER, CM**3/CM**3.                            0008 759
C VNO3C: VOLUMETRIC NITROGEN CONTENT AS NITRATE, MG N/CC SOIL.           0008 760
C D:  DEPTH OF SOIL CELL, CM.                                            0008 761
C NL: NUMBER OF LAYERS IN PROFILE.                                       0008 762
C NK: NUMBER OF COLUMNS IN PROFILE.                                      0008 763
      CUMRAN = CUMRAN + RAIN                                             0008 764
      TSOAK = 0.                                                         0008 765
      DO 2 KOLUMN = 1, NK                                                0008 766
      SOAKW(NL+1) = 0.                                                   0008 767
      SOAKW(1) = RAIN*.10                                                0008 768
C H2O SOAKING INTO TOP LAYER, IN CM**3/CM**2.                            0008 769
      SOAKN(1) = 0.                                                      0008 770
C NITROGEN SOAKING INTO LAYER, IN MG/CM**2.                              0008 771
C IF NITROGEN IN RAINFALL IS TO BE ADDED, DO IT HERE.                    0008 772
      DO 3 LAYER = 1, NL                                                 0008 773
      H2O = SOAKW(LAYER) + VH2OC(LAYER,KOLUMN)*D                         0008 774
C TOTAL TEMPORARY AND RESIDUAL VOLUME OF H2O IN SOIL                     0008 775
C CELL, IN CM**3/CM**2.                                                  0008 776
      SOAKW(LAYER+1) = AMAX1(0., H2O-FC(LAYER)*D)                        0008 777
C H2O SOAKING INTO LAYER BENEATH, IN CM**3/CM**2.                        0008 778
      SOAKN(LAYER+1) = AMAX1(0.,SOAKW(LAYER+1)*(VNO3C(LAYER,KOLUMN) /    0008 779
     .(VH2OC(LAYER,KOLUMN)+SOAKW(LAYER)/D)))                             0008 780
C NITROGEN SOAKING INTO LAYER BENEATH, IN MG/CM**2.                      0008 781
 3    CONTINUE                                                           0008 782
      TSOAK = TSOAK + SOAKW(NL+1)                                        0008 783
      DO 4 LAYER = 1, NL                                                 0008 784

      IF(SOAKW(LAYER).LE.0.) GO TO 4                                     0008 785
C WHEN SOAKW .LT. 0, NO GRAVITY PERCOLATION OCCURS.                      0008 786
      VH2OC(LAYER,KOLUMN) = VH2OC(LAYER,KOLUMN) + (SOAKW(LAYER) -        0008 787
     . SOAKW(LAYER+1))/D                                                 0008 788
C VOLUMETRIC MOISTURE CONTENT OF SOIL CELL, IN CM**3/CM**3.              0008 789
      VNO3C(LAYER,KOLUMN) = AMAX1(0.,VNO3C(LAYER,KOLUMN)+(SOAKN(LAYER)   0008 790
     .-SOAKN(LAYER+1))/D)                                                0008 791
C VOLUMETRIC NITROGEN CONTENT OF SOIL CELL, IN MG/CM**3.                 0008 792
 4    CONTINUE                                                           0008 793
 2    CONTINUE                                                           0008 794
      CUMSOK = CUMSOK + 10.*TSOAK/FLOAT(NK)                              0008 795
      RETURN                                                             0008 796
      END                                                                0008 797
```

```
      SUBROUTINE ET                                                    0008 798
C  ***************************************************************    0008 799
C  *                                                             *    0008 800
C  *           EVAPOTRANSPIRATION SUBROUTINE                     *    0008 801
C  *                                                             *    0008 802
C  ***************************************************************    0008 803
C SUBROUTINE TAKEN ALMOST ENTIRELY FROM RITCHIE, A MODEL               0008 804
C  FOR PREDICTING EVAPORATION FROM A ROW CROP WITH INCOMPLETE COVER.    0008 805
C  WATER RESOURCES RESEARCH VOL. 8:1204.                               0008 806
C                                                                      0008 807
      REAL LAMDAC,LAMDAS,LAMDA,INT,MH2O,NEWES,NEWEP                         808
C                                                                      0008 809
      COMMON /ETPARM/ ALPHA,GAMMA,LAMDAC,LAMDAS,U,WND                       810
      COMMON /EVTR  / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP            811
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK              0008 812
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT           0008 814
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                          815
C                                                                      0008 816
      VP(TMP) = EXP(1.8282*TMP*(0.07046136-TMP*0.000215743))           0008 817
      P = RAIN                                                         0008 818
      RS = RI*.0169491525                                              0008 819
C RS = SOLAR RADIATION IN MM H2O/DAY.                                  0008 820
      TAVM1 = TAVG-1.                                                  0008 821
      DEL = VP(TAVG) - VP(TAVM1)                                       0008 822
C DEL=SLOPE OF SATURATION VAPOR PRESSURE CURVE AT MEAN AIR TEMP.       0008 823
      LAMDA = INT*LAMDAC + (1.-INT)*LAMDAS                             0008 824
C LAMDAC & LAMDAS = ALBEDOS OF CROP & SOIL.                            0008 825
C INT=INTERCEPTION (FRACTION OF INCIDENT RS)                           0008 826
C RNO=NET RADIATION ABOVE CANOPY (MM/DAY)                              0008 827
      RNO=(RS-LAMDA*RS)                                                0008 828
C TD & TW = DRY AND WET BULB TEMPERATURES.                             0008 829
      TD = TAVG                                                        0008 830
      VPO = VP(TD)                                                     0008 831
      TW = TMIN                                                        0008 832
C EO=POTENTIAL EVAPORATION RATE ABOVE CANOPY (MM/DAY)                  0008 833
C MODIFIED PENMAN EQ.                                                  0008 834
C W=WINDSPEED AT 2 METERS (MILES/DAY)                                  0008 835
C GAMMA=PSYCHROMETER CONSTANT                                          0008 836
      VPA = VP(TW)                                                     0008 837
      EO=(RNO*DEL/GAMMA+.262*(1.+0.0061*WND)*(VPO-VPA))/(DEL/GAMMA+1.)      838
C THE FOLLOWING CALCULATES ESO(POTENTIAL EVAP. RATE AT SOIL SURFACE)   0008 839
C RNS=NET RADIATION AT SOIL SURFACE BELOW CANOPY                       0008 840
      RNS=((1.-INT)-(1.-INT)*LAMDAS)*RS                                0008 841
      ESO=DEL*RNS/(DEL+GAMMA)                                          0008 842
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C STAGE I DRYING                                                        0008 843
C SESI=CUMULATIVE STAGE ONE EVAPORATION FROM SOIL SURFACE               0008 844
C U=UPPER LIMIT OF SESI                                                 0008 845
      IF(SESI.GT.U)GOTO 100                                             0008 846
C P=RAINFALL                                                            0008 847
      IF(P.GE.SESI)GOTO 101                                             0008 848
      SESI=SESI-P                                                       0008 849
99    SESI=SESI+ESO                                                     0009 850
      IF(SESI.GE.U)GOTO 102                                             0009 851
      ES=ESO                                                            0009 852
      GOTO 110                                                          0009 853
102   ES=ESO-.4*(SESI-U)                                                0009 854
      SESII=.6*(SESI-U)                                                 0009 855
      DUMY01 = SESII / ALPHA                                            0009 856
      T = DUMY01 * DUMY01                                               0009 857
      GO TO 110                                                         0009 858
101   SESI=0.                                                           0009 859
      GO TO 99                                                          0009 860
C STAGE II DRYING                                                       0009 861
100   IF(P.GE.SESII)GO TO 103                                           0009 862
      T=T+1.                                                            0009 863
      ES = ALPHA * (SQRT(T)-SQRT(T-1.))                                 0009 864
      IF(P.GT.0.)GO TO 104                                              0009 865
      IF(ES.GT.ESO)GO TO 105                                            0009 866
106   SESII=SESII+ES-P                                                  0009 867
      DUMY02 = SESII / ALPHA                                            0009 868
      T = DUMY02 * DUMY02                                               0009 869
      GO TO 110                                                         0009 870
105   ES=ESO                                                            0009 871
      GO TO 106                                                         0009 872
104   ESX=0.8*P                                                         0009 873
      IF(ESX.LT.ES)GO TO 107                                            0009 874
111   IF(ESX.GT.ESO)GO TO 108                                           0009 875
109   ES=ESX                                                            0009 876
      GO TO 106                                                         0009 877
108   ESX=ESO                                                           0009 878
      GO TO 109                                                         0009 879
107   ESX=ES+P                                                          0009 880
      GO TO 111                                                         0009 881
103   P=P-SESII                                                         0009 882
      SESI=U-P                                                          0009 883
      IF(P.GT.U)GO TO 101                                               0009 884
      GO TO 99                                                          0009 885
C TRANSPIRATION IS PROPORTIONAL TO LIGHT INTERCEPTION (INT).            0009 886
C  THIS REPRESENTS A MODIFICATION TO RITCHIE'S MODEL.                   0009 887
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110   EP=INT*EO                                                         0009 888
      IF(EO-ES.LT.0.) EO=ES+EP                                            889
      IF(EP.GT.(EO-ES))EP=EO-ES                                         0009 890
      AVGPSI = -1. * PSIAVG                                             0009 891
      IF(AVGPSI.GT.9.0) AVGPSI = 9.0                                      892
      RN = RI*.71536-26.                                                0009 893
C  RFEP = REDUCTION FACTOR FOR EVAPORATION FROM PLANT.  BASED ON        0009 894
C  UNPUBLISHED DATA OF BAKER & HESKETH. 1969.                           0009 895
      RFEPN = 749.5831405 + 0.9659065*RN - 54.6600986*TAVG              0009 896
     . - 194.6508431*AVGPSI - 0.0010226*RN*RN + 1.0153007*TAVG*TAVG +   0009 897
     . 29.775978*AVGPSI*AVGPSI + 0.0293687*RN*TAVG                      0009 898
     . - 4.206856*TAVG*AVGPSI                                           0009 899
      RFEPD = 749.5831405 + 0.9659065*RN                                0009 900
     . - 54.6600986*TAVG - 19.46508431 - 0.0010226*RN*RN +              0009 901
     . 1.0153007*TAVG*TAVG + .29775978 + 0.0293687*RN*TAVG              0009 902
     . - .4206856*TAVG                                                  0009 903
      RFEP = RFEPN/RFEPD                                                0009 904
      IF(RFEP.LE.0.0) RFEP = 0.01                                       0009 905
      EP = EP * RFEP                                                    0009 906
      RETURN                                                            0009 907
      END                                                               0009 908
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      SUBROUTINE UPTAKE                                                 0009 909
C*************************************************************        0009 910
C  *********  MODIFIED FEB 22 1980  ********************               0009 911
C   UPTAKE OF WATER FROM EACH SOIL CELL IS PROPORTIONAL TO *           0009 912
C THE PRODUCT OF ROOT WEIGHT CAPABLE OF UPTAKE AND THE     *           0009 913
C HYDRAULIC CONDUCTIVITY OF THE CELL.  THE SUM OF THE      *           0009 914
C UPTAKE FROM THE CELLS EQUALS TRANSPIRATION.  ALL NO3 IN  *           0009 915
C THE WATER TAKEN UP BY THE ROOTS IS ALSO TAKEN UP.        *           0009 916
C*************************************************************        0009 917
C EP - TRANSPIRATION BY PLANTS, MM/DAY.                                0009 918
C SUPNO3 - SUPPLY OF NITRATE FROM SOIL, MG.                            0009 919
      DIMENSION UPF(20,6)
      INTEGER DAYNUM
      REAL NEWES , NEWEP, NYTTYM, LATUDE, INT
C UPF - UPTAKE FACTOR, GM CM/DAY,                                      0009 922
C ROOT WEIGHT CAPABLE OF UPTAKE, GM/CELL.                                   923
C                                                                      0009 924
      COMMON /DIFFU / DIFF(20,6)                                            925
      COMMON /EVTR  / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP            926
      COMMON /FIELD / FC(20)                                           0009 927
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W               928
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)                              929
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT         930
      COMMON /MATR  / KRL(20), LR                                           931
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)              933
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),       934
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)              935
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3                  0009 937
      COMMON /UPS   / SUPNO3, UPNO3                                    0009 938
C                                                                      0009 939
C                                                                      0009 940
      DELT = 1. / NOITR                                                0009 942
      DUMY01 = (.10*NK*W*EP)*DELT                                      0009 943
      DUMY02 = D * W                                                   0009 944
      DES = ES * 0.1 *DELT / D                                              945
C MODIFIED FOR ES REMOVED FROM ALL KOLUMNS                                  946
      DO 8 I=1,20
      DO 8 J=1,6
      UPF(I,J)=0.
    8 CONTINUE
      DO 7 KOLUMN = 1,NK                                                    949
      DE = DES                                                              950
      IF(DE.GT.VH2OC(1,KOLUMN) - .25 * FC(1) )                              951
     .  DE =  VH2OC(1,KOLUMN) - .25 * FC(1)                                 952
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        IF(DE.LT.0.)  DE = 0.                                          953
       VH2OC(1,KOLUMN) = VH2OC(1,KOLUMN) - DE                          954
        SUMES = SUMES + DE * 10. *D                                    955
  7    CONTINUE                                                        956
        NEWES=SUMES/ NK                                                957
       DO 1 LAYER  =1, LR                                      0010    958
       KR = KRL(LAYER)                                         0010    959
       DO 1 KOLUMN =1, KR                                      0010    960
       UPF(LAYER,KOLUMN) = (RTWT(LAYER,KOLUMN,1) +
     . .20 * RTWT(LAYER,KOLUMN,2) + RTWT(LAYER,KOLUMN,3) )             962
C SUMS THE WEIGHT OF ROOTS 15 DAYS OLD OR LESS IN CELL.                0010    963
 1     CONTINUE                                                       0010    964
       DO 4 LAYER  = 1, LR                                     0010    965
       KR = KRL(LAYER)                                         0010    966
       DO 4 KOLUMN = 1, KR                                     0010    967
       UPF(LAYER,KOLUMN) = UPF(LAYER,KOLUMN) +
     .  UPF(LAYER,NK-KOLUMN+1)
C ADDS THE ROOTS GROWN BY THE PLANTS IN THE NEXT ROW TO GET             0010    970
C THE TOTAL WEIGHT OF ROOTS CAPABLE OF UPTAKE.                         0010    971
 4     CONTINUE                                                       0010    972
       NKH = NK/2                                              0010    973
       SUPF = 0.                                               0010    974
       DO 5 LAYER  = 1, LR                                     0010    975
       KR = KRL(LAYER)                                         0010    976
       IF (KR.GT.NKH) KR=NKH                                   0010    977
       DO 5 KOLUMN = 1, KR                                     0010    978
       UPF(LAYER,KOLUMN)=UPF(LAYER,KOLUMN)*DIFF(LAYER,KOLUMN)
C  **** NO DEPTH FACTOR FOR CALCULATING UPF ***** MODIFIED FEB 22              980
C UPTAKE FACTOR FOR EACH CELL, HAS UNITS OF GM CM/DAY.                 0010    981
C   MODIFIED BY DIVISION TO MEAN DEPTH OF LAYER                               982
       IF(UPF(LAYER,KOLUMN).LT.0.) UPF(LAYER,KOLUMN)=0.
       SUPF = SUPF + UPF(LAYER,KOLUMN)
C SUM OF UPTAKE FACTORS IN THE PROFILE.  USED FOR APPORTIONING         0010    984
C UPTAKE AMONG CELLS.                                                  0010    985
 5     CONTINUE                                                       0010    986
       UPNO3 = 0.                                              0010    987
       J = 1                                                           990
       DO 6 LAYER  = 1, LR                                     0010    991
  21   IF(LAYER*0.LE.SDEPTH(J)) GO TO 20                               992
       J = J + 1                                                       993
       IF(J.LT.5) GO TO 21                                             994
 20    KR = KRL(LAYER)                                                 995
       IF (KR.GT.NKH) KR=NKH                                   0010    996
       DO 6 KOLUMN = 1, KR                                     0010    997
       UPTH2O = (UPF(LAYER,KOLUMN)/SUPF) * DUMY01 / 2.         0010    998
```

```
      H2OUPT=UPTH2O/DUMY02                                              0010 999
C UPTAKE OF WATER FROM EACH CELL, CM**3/DAY.                            00101000
C EP HAS UNITS OF MM/DAY.                                               00101001
      IF(VH2OC(LAYER,KOLUMN).GT.THETAR(J) ) GO TO 23                        1002
      H2OUPT = 0.                                                           1003
      GO TO 24                                                              1004
   23 IF (H2OUPT.GT.VH2OC(LAYER,KOLUMN)-THETAR(J) ) H2OUPT=                 1005
     *           VH2OC(LAYER,KOLUMN)-THETAR(J)                              1006
   24  CONTINUE                                                             1007
      UPTH2O=H2OUPT*DUMY02                                              00101008
      VH2OC(LAYER,KOLUMN)=VH2OC(LAYER,KOLUMN)-H2OUPT                    00101009
      SUMEP=SUMEP+H2OUPT                                                00101010
C VOLUMETRIC WATER CONTENT OF CELL IS DECREASED BY AMOUNT               00101011
C OF UPTAKE FROM CELL.                                                  00101012
      IMGKOL = NK - KOLUMN + 1                                          00101013
C          IMAGE COLUMN, MIRRORED ABOUT CENTERLINE OF PLANE.            00101014
      VH2OC(LAYER,IMGKOL) = VH2OC(LAYER,IMGKOL) - H2OUPT                00101015
      SUMEP=SUMEP+H2OUPT                                                00101016
C          VOLUMETRIC WATER CONTENT OF IMAGE CELL IS ALSO REDUCED.      00101017
      UPNO3C=0.
      IF(VH2OC(LAYER,KOLUMN).LE.THETAR(J)) GO TO 31
      UPNO3C = UPTH2O*(VNO3C(LAYER,KOLUMN)/VH2OC(LAYER,KOLUMN))         00101018
C UPTAKE OF NO3 FROM CELL, MG N/DAY.                                    00101019
C ALL NO3 IN WATER UPTAKE STREAM IS TAKEN UP.                           00101020
   31 CONTINUE
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) - UPNO3C/DUMY02         00101021
C VOLUMETRIC NITRATE CONTENT OF CELL IS DECREASED BY AMOUNT OF          00101022
C UPTAKE FROM CELL, MG N/CC SOIL.                                       00101023
      UPNO3 = UPNO3 + UPNO3C                                            00101024
C SUM OF UPTAKE OF NITROGEN AS NITRATE FROM THE SOIL PROFILE,           00101025
C MG FOR THE DAY.                                                       00101026
      UPNO3I=0.
      IF(VH2OC(LAYER,IMGKOL).LE.THETAR(J)) GO TO 34
      UPNO3I = UPTH2O*(VNO3C(LAYER,IMGKOL)/VH2OC(LAYER,IMGKOL))         00101029
C          UPTAKE OF NO3 FROM IMAGE CELL, MG N/DAY.                     00101030
   34 CONTINUE
      VNO3C(LAYER,IMGKOL) = VNO3C(LAYER,IMGKOL) - UPNO3I/DUMY02         00101031
C          VOLUMETRIC NITRATE CONTENT OF IMAGE CELL IS ALSO DECREASED.  00101032
      UPNO3 = UPNO3 + UPNO3I                                            00101033
 6    CONTINUE                                                          00101034
      NEWEP=SUMEP*D/NK*10.                                              00101035
      RETURN                                                            00101036
      END                                                               00101037
```

```
      SUBROUTINE CAPFLO                                                    1038
C  ***************************************************************      00101039
C  *                                                             *      00101040
C  *  CAPILLARY FLOW OF NO3 AND H2O IN ALL DIRECTIONS.           *      00101041
C  *                                                             *      00101042
C  ***************************************************************      00101043
C                                                                         1044
C                                                                         1045
      REAL LAI                                                            1046
      DIMENSION FNL(20,6),FNU(20,6),FWL(20,6),FWU(20,6),COND(20,6)
C FLUX OF H2O TO THE LEFT OUT OF THE CELL, CM**3/CELL/DAY.              00101048
C FLUX OF H2O UPWARD OUT OF THE CELL, CM**3/CELL/DAY.                   00101049
C FLUX OF NITROGEN TO THE LEFT OUT OF THE CELL, MG N/CELL/DAY.          00101050
C FLUX OF NITROGEN UPWARD OUT OF THE CELL, MG N/CELL/DAY.               00101051
C                                                                       00101052
      COMMON /DIFFU / DIFF(20,6)                                          1053
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W             1054
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK              00111055
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)                            1056
      COMMON /PS    / PSIS(20,6)                                          1057
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                        1059
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),     1060
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)          1061
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3                  00111062
      COMMON /TIMEBD/ THETAI                                              1063
C                                                                      00111064
      DO 860 I=1,20
      DO 860 J=1,6
      FNL(I,J)=0.
      FNU(I,J)=0.
      FWU(I,J)=0.
      FWL(I,J)=0.
  860 CONTINUE
      NLM1 = NL-1                                                     NASA1069
      J = 1                                                               1070
      DELT = .5 / NOITR                                               NASA1071
      DO 4 LAYER  = 1, NL                                             00111072
  214 IF(LAYER*D.LE.SDEPTH(J))GO TO 15                                    1073
      J=J+1                                                               1074
      IF(J.LT.5) GO TO 214                                                1075
C  ***************************************************************************  1076
C       COND IS SOIL CONDUCTIVITY .                                       1077
   15    CONTINUE                                                         1078
      IF(LAYER.EQ.NL) THETAI=THETAS(J)
      DO 4 KOLUMN = 1, NK
```

C-2

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      DIFF(LAYER,KOLUMN)=0.
      IF(VH2OC(LAYER,KOLUMN).GT.THETAO(J)) DIFF(LAYER,KOLUMN) =
     . DIFFO(J)*EXP(BETA(J)*(VH2OC(LAYER,KOLUMN)-THETAO(J)))
C    DIFFUSIVITY FUNCTION FOUND IN :                                        1082
C     GARDNER AND MAYHUGH. 1966. SSSAP 22:197-201. FDW.                     1083
      COND(LAYER,KOLUMN)=0.
       IF(VH2OC(LAYER,KOLUMN).LE.THETAS(J) ) GO TO 4                        1084
       COND(LAYER,KOLUMN) = 0.12 * ((VH2OC(LAYER,KOLUMN)-THETAR(J) ) /      1085
     . (THETAS(J)-THETAR(J) ) )**(3.*ETA(J)/(ETA(J)-2.))                    1086
       IF(COND(LAYER,KOLUMN).GT.3.) COND(LAYER,KOLUMN) = 3.                 1087
C  ***************************************************************         1090
C                                                                           1091
 4     CONTINUE                                                    00111092
       DUMY01 = D * DAMP * DELT                                    00111093
       J = 1                                                               1094
       DO 5 LAYER  = 1, NL                                         00111095
 302   IF(LAYER*D.LE.SDEPTH(J)) GO TO 303                                  1096
       J = J + 1                                                           1097
       IF(J.LT.5) GO TO 302                                                1098
 303   DO 5 KOLUMN = 1, NK                                                 1099
       KM1 = KOLUMN - 1                                                    1100
       IF(KM1.EQ.0) KM1 = NK                                               1101
C  ***************************************************************         1102
C  DIFL IS THE ARITHMETIC MEAN OF DIFF OF THE TWO CELLS.                    1103
       DIFL = (DIFF(LAYER,KOLUMN)+DIFF(LAYER,KM1)) /2.                     1104
       FWL(LAYER,KOLUMN) = DIFL                                            1105
     .    *((VH2OC(LAYER,KOLUMN)-VH2OC(LAYER,KM1))/W) * DUMY01             1106
C FLOW OF WATER TO THE LEFT, OUT OF CELL, CM**3/CELL/DAY.          00111107
C SIMPLY DARCY'S LAW USING MEAN CONDUCTIVITY.                      00111108
       FWLMAX = (VH2OC(LAYER,KOLUMN)-VH2OC(LAYER,KM1))*W*D / 10.           1109
       IF(ABS(FWL(LAYER,KOLUMN)).GT.ABS(FWLMAX))FWL(LAYER,KOLUMN)=FWLMAX   1110
C  FWLMAX IS USED TO PREVENT EXCESSIVE WATER FLOW IN ONE ITERATION.         1111
C  ***************************************************************         1112
C  WHEN FLOW IS INTO THE CELL (NEGATIVE FWL) THE CORRECT CALCULATION        1113
C  OF FNL IS BY USING VNO3C AND VH2OC VALUES OF THE OTHER CELL.             1114
       IF(FWL(LAYER,KOLUMN).LT.0.) GO TO 304                               1115
       FNL(LAYER,KOLUMN) = FWL(LAYER,KOLUMN)*VNO3C(LAYER,KOLUMN)/          1116
     . VH2OC(LAYER,KOLUMN)                                                 1117
         GO TO 51                                                          1118
  304  FNL(LAYER,KOLUMN) = FWL(LAYER,KOLUMN)*VNO3C(LAYER,KM1) /            1119
     . VH2OC(LAYER,KM1)                                                    1120
C FLOW OF NO3 TO THE LEFT, OUT OF CELL, MG N/CELL/DAY.             00111121
C MASS FLOW OF NO3 IN H2O, GM/CELL.                                00111122
C  ***************************************************************1123
C  ***  REDISTRIBUTION OF NITRATES CAUSED BY DIFFERENCES IN THEIR           1124
```

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C       CONCENTRATIONS IN SOIL SOLUTION OF ADJACENT CELLS.  **********        1125
   51   FNL(LAYER,KOLUMN) = FNL(LAYER,KOLUMN) + (VNO3C(LAYER,KOLUMN) /        1126
     .VH2OC(LAYER,KOLUMN)-VNO3C(LAYER,KM1)/VH2OC(LAYER,KM1))*DELT*1.5         1127
 5     CONTINUE                                                            00111128
       J = 1                                                                 1129
       DO 6 LAYER  = 2, NL                                                 00111130
  2    IF(LAYER*D.LE.SDEPTH(J)) GO TO 203                                    1131
       J = J + 1                                                             1132
       IF(J.LT.5) GO TO 2                                                    1133
 203   DO 6 KOLUMN = 1,NK                                                    1134
C  ***************************************************************          1135
C  DIFU IS THE ARITHMETIC MEAN OF DIFF OF THE TWO CELLS                      1136
C  CONU IS THE CONDUCTIVITY OF THE UPPER CELL.                               1137
C  THE PROCEDURE ALLOWS FOR GRAVITY FLOW WHEN VH2OC OF UPPER CELL            1138
C  IS HIGHER THAN FIELD CAPACITY.                                            1139
       DIFU = (DIFF(LAYER,KOLUMN)+DIFF(LAYER-1,KOLUMN)) / 2.                 1140
       FWU(LAYER,KOLUMN)=(DIFU*(VH2OC(LAYER,KOLUMN)-VH2OC(LAYER-1,KOLUMN)    1141
     . ) / D - COND(LAYER-1,KOLUMN) ) * W * DAMP *DELT                       1142
C FLOW OF WATER UPWARD, OUT OF CELL, CM**3/CELL/DAY.                       00111143
       FWUMAX = (VH2OC(LAYER,KOLUMN)-VH2OC(LAYER-1,KOLUMN) ) *W*D / 10.      1144
       IF(ABS(FWU(LAYER,KOLUMN)).GT.ABS(FWUMAX))FWU(LAYER,KOLUMN)=FWUMAX     1145
C  FWUMAX IS USED TO PREVENT EXCESSIVE WATER FLOW IN ONE ITERATION.          1146
C  ***************************************************************          1147
C  WHEN FLOW IS DOWNWARD, VNO3C AND VH2OC OF UPPER CELL ARE USED.            1148
       IF(FWU(LAYER,KOLUMN).LT.0.) GO TO 300                                 1149
       FNU(LAYER,KOLUMN) = FWU(LAYER,KOLUMN)*VNO3C(LAYER,KOLUMN)/            1150
     . VH2OC(LAYER,KOLUMN)                                                   1151
         GO TO 61                                                            1152
 300   FNU(LAYER,KOLUMN) = FWU(LAYER,KOLUMN)*VNO3C(LAYER-1,KOLUMN)/          1153
     . VH2OC(LAYER-1,KOLUMN)                                                 1154
C FLOW OF NO3 UPWARD IN THE WATER, MG N/CELL/DAY.                          00111155
C  ***************************************************************          1156
C  *** REDISTRIBUTION OF NITRATES IN ADJACENT CELLS.  *************          1157
   61   FNU(LAYER,KOLUMN) = FNU(LAYER,KOLUMN) + (VNO3C(LAYER,KOLUMN) /       1158
     .VH2OC(LAYER,KOLUMN)-VNO3C(LAYER-1,KOLUMN)/VH2OC(LAYER-1,KOLUMN) )      1159
     . * DELT * 1.5                                                          1160
 6     CONTINUE                                                            00111161
       J=1                                                                   1162
       DO 16 LAYER = 1,NLM1                                                  1163
  40   IF(LAYER*D.LE.SDEPTH(J)) GO TO 41                                     1164
       J=J+1                                                                 1165
       IF(J.LT.5) GO TO 40                                                   1166
 41    DO 16 KOLUMN = 1,NK                                                   1167
       KP1 = KOLUMN + 1                                                      1168
       IF(KOLUMN.EQ.NK) KP1 = 1                                              1169
```

```
      FWICN = FWL(LAYER,KP1) - FWL(LAYER,KOLUMN) +                          1170
     . FWU(LAYER+1,KOLUMN) - FWU(LAYER,KOLUMN)                              1171
C FLUX OF H2O INTO THE CELL, NET, CM**3/CELL.                               1172
      VH2OC(LAYER,KOLUMN) = VH2OC(LAYER,KOLUMN) + FWICN/(D*W)               1173
C                                                                           1174
      IF(VH2OC(LAYER,KOLUMN).LE.AIRDR(J)) VH2OC(LAYER,KOLUMN)=AIRDR(J)      1175
  15  CONTINUE                                                              1176
      DO 30 KOLUMN = 1, NK                                                  1177
C  ***************************************************************          1178
C  THIS INSURES DRAINAGE AT THE BOTTOM LAYER.                               1179
      IF(VH2OC(NL,KOLUMN).LE.THETAI) GO TO 30                               1180
      CUMSOK = CUMSOK +(VH2OC(NL,KOLUMN)-THETAI)*D*W*10./ROWSP              1181
      VH2OC(NL,KOLUMN) = THETAI                                             1182
  30  CONTINUE                                                              1183
C   BOTTOM BOUNDARY FROM GERARD AND NAMKEN DATA                             1184
C                                                                           1185
      DO 7 LAYER  = 1, NL                                                   00111186
      DO 7 KOLUMN = 1,NK                                                    1187
       KP1 = KOLUMN + 1                                                     1188
       IF(KOLUMN.EQ.NK) KP1 = 1                                             1189
        IF(LAYER.EQ.NL) GO TO 71                                            1190
      FNICN = FNL(LAYER,KP1) - FNL(LAYER,KOLUMN) +                          1191
     . FNU(LAYER+1,KOLUMN) - FNU(LAYER,KOLUMN)                              00111192
        GO TO 72                                                            1193
  71  FNICN = FNL(LAYER,KP1) - FNL(LAYER,KOLUMN) - FNU(LAYER,KOLUMN)        1194
  72      CONTINUE                                                          1195
C FLUX OF NO3 INTO THE CELL, NET, MG N/CELL/DAY.                            00111196
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + FNICN/(D*W)               00111197
C VOLUMETRIC NITROGEN CONTENT OF SOIL CELL, MG N/CM**3.                     00111198
 7    CONTINUE                                                             00111199
      TH2O = 0.                                                             00111200
       TNNO3 = 0.                                                           1201
      J=1                                                                   1202
      DO 8 LAYER = 1,NL                                                     1203
C  ***************************************************************          1204
C  PSIS IS CALCULATED AFTER CAPFLO. PSIS IS -0.3 BAR FOR THETAS,            1205
C  -15.0 BAR FOR THETAR, AND ASYMPTOTIC FOR AIRDR.                          1206
  34  TEMP2= (THETAR(J)-AIRDR(J))/(THETAS(J)-AIRDR(J))                     1207
      TEMP3 = ALOG(50.) / ALOG(TEMP2)                                       1208
      IF(LAYER*D.LE.SDEPTH(J)) GO TO 35                                     1209
      J=J+1                                                                 1210
      IF (J.LT.5) GO TO 34                                                  1211
  35  DO 8 KOLUMN = 1, NK                                                   1212
      IF(VH2OC(LAYER,KOLUMN).GT.THETAR(J)) GO TO 45                         1213
      PSIS(LAYER,KOLUMN) = -15.                                             1214
      GO TO 50                                                              1215
  45   CONTINUE                                                             1216
      TEMP1 = (VH2OC(LAYER,KOLUMN)-AIRDR(J))/(THETAS(J)-AIRDR(J))           1217
      PSIS(LAYER,KOLUMN) = -0.3 * TEMP1**TEMP3                              1218
C H2O POTENTIAL OF SOIL CELL, IN BARS.                                      1219
C  ***************************************************************          1220
C                                                                           1221
 50   CONTINUE                                                             1222
      TH2O = TH2O + VH2OC(LAYER,KOLUMN)                                     00121223
      TNNO3 = TNNO3 + VNO3C(LAYER, KOLUMN)                                  1224
 8    CONTINUE                                                             00121225
      TH2O = TH2O * D * W *0.1                                              1226
C TOTAL WATER PROFILE                                                       00121227
      TNNO3 = TNNO3*D*W                                                     00121228
      RETURN                                                                00121229
      END                                                                   00121230
```

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      SUBROUTINE NITRIF                                                 1231
C  ****************************************************************   1232
C  *                                                              *   1233
C  *  S U B R O U T I N E   N I T R I F I C A T I O N             *   1234
C  *                                                              *   1235
C  ****************************************************************   1236
C                                                                       1237
C    SIMPLIED VERSION BASED ON KAFKAF1,HADAS,BAR-YOSEF MODEL            1238
      COMMON /FIELD / FC(20)                                            1239
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLS, THRLN, W           1240
      COMMON /H2ONO3/ VH2OC(20,6),VNO3C(20,6)                           1241
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)                               1242
      COMMON /TOTS  / DAMP,NOITR,TH2O,TNNH4,TNNO3                       1243
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)                 1244
      TNNH4 = 0.                                                        1245
      DO 5 L=1,2                                                        1246
      T = TSOLAV(L)                                                     1247
      FMIN = 7300000. * 10.**(-2758. /(T+273.))                         1248
      FNIT = .05 * 10.**( 12. - 3573.  /(T+273))                        1249
      DO 5 K=1,NK                                                       1250
      WFMIN = VH2OC(L,K)/FC(L)                                          1251
      DNMIN = VNC(L,K) * FMIN * WFMIN                                   1252
      VNC(L,K) = VNC(L,K) - DNMIN                                       1253
      VNH4C(L,K) = VNH4C(L,K) + DNMIN                                   1254
      WFNIT = 0.7 - 1.30 * (FC(L)- VH2OC(L,K))/FC(L)                    1255
      IF(WFNIT.LT.0.) WFNIT =0.                                         1256
      DNIT = VNH4C(L,K) * FNIT * WFNIT                                  1257
      VNH4C(L,K) = VNH4C(L,K) -DNIT                                     1258
      VNO3C(L,K) = VNO3C(L,K) + DNIT                                    1259
      TNNH4 = TNNH4 + VNH4C(L,K)                                        1260
    5 CONTINUE                                                          1261
      TNNH4 = TNNH4 * D * W                                             1262
      RETURN                                                            1263
      END                                                               1264
```

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      SUBROUTINE PNET                                                    1265
C  ************************************************************        1266
C  *                                                          *        1267
C  *                    PNET  SUBROUTINE                      *        1268
C  *                                                          *        1269
C  ************************************************************        1270
      REAL INT,LEAFWT,LEAFCN,LEAFRS,MH2O,LAI                             1271
C                                                                        1272
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN        1273
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT             1275
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                       1276
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN                 1277
      COMMON /RESV  / FZ,LEAFRS,ROOTRS,STEMRS,RESN,RESC                  1278
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                       1279
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT    1280
C                                                                        1281
C   LEAF WATER POTENTIAL IS FUNC OF SOLAR RADIATION, HUMIDITY            1282
C    AND SOIL WATER POTENTIAL                                            1283
C                                                                        1284
      PSIL=PSIAVG*5.                                                     1285
C                                                                        1286
C   CALCULATE PHOTOSYNTHESIS REDUCTION FACTOR FOR MOISTURE STRESS        1287
C    CURVE TAKEN FROM PAPER BY D W LAWLOR IN PHOTOSYNTHETICA 1976        1288
C    PAGES 378-387                                                       1289
C                                                                        1290
      PTSRED=0.                                                          1291
      IF(PSIL.LT.-18.) GO TO 10                                          1292
      PTSRED=(PSIL+18.)/13.                                              1293
      IF(PTSRED.GT.1.) PTSRED=1.                                         1294
   10 CONTINUE                                                           1295
C                                                                        1296
C   POTENTIAL CANOPY PHOTOSYNTHESIS IS A FUNCTION OF SOLAR               1297
C    RADIATION. CURVE FROM FLORENCE SPAR DATA 1979 UNPUBLISHED           129
C    (UNITS ARE GMS/M**2/DAY)                                            1299
C                                                                        1300
      PSTAND=8.218+RI*(.22138-.00012*RI)                                 1301
C                                                                        1302
C   IF LEAF NITROGEN CONC < 1% CALC PHOTOSYNTHESIS REDUCTION FACTOR      1303
C                                                                        1304
      PTSN=1.0                                                           1305
      IF(LEAFCN.LT..01) PTSN=100.*LEAFCN                                 1306
C                                                                        1307
C   CALC PHOTOSYNTHESIS REDUCTION FACTOR FOR LEAF LOADING FEEDBACK       1308
C    AS FUNCTION OF LEAF CARBOHYDRATE LEVEL. CURVE FROM RESEARCH         1309
C    BULLETIN 907 - SIMED                                                1310
C                                                                        1311
      STARCH=RESC/(RESC+LEAFWT+STEMWT)                                   1312
      RESCF=1.-.28*STARCH                                                1313
      IF(STARCH.GT..18.AND.STARCH.LE..23) RESCF=1.67-4.*STARCH           1314
      IF(STARCH.GT..23.AND.STARCH.LE..28) RESCF=3.74-13.*STARCH          1315
      IF(STARCH.GT..28) RESCF=.1                                         1316
C                                                                        1317
C   PHOTOSYNTHATE PRODUCED/PLANT = POTENTIAL CANOPY PHOTOSYNTHESIS       1318
C    ADJ FOR LIGHT INTERCEPTION, PLANT POPULATION & REDUCTION FACTORS.   1319
C    POPFAC/100 CONVERTS FROM G/M**2/DAY TO G/PLANT/DAY                  1320
C                                                                        1321
      PPLANT=PSTAND*INT*PTSN*PTSRED*RESCF*POPFAC/100.
C                                                                        1323
C   RESPIRATION LOSS IS A FUNCTION OF TEMPERATURE. THE CURVE IS          1324
C    FROM FLORENCE SPAR DATA 1979 UNPUBLISHED                            132
C                                                                        1326
      RESP=((TAVG-13.)/12500.*24.)*PLANTW                                1327
      IF(RESP.LT.0.) RESP=0.                                             1328
C                                                                        1329
C   REDUCE PHOTOSYNTHATE BY RESPIRATORY LOSS                             1330
C                                                                        1331
      PN=(PPLANT-RESP)*.68182
      IF(PN.LE.PNFAC) PN=PNFAC
      SPN=SPN+PN                                                         1334
      RETURN                                                             1335
      END                                                                1336
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      SUBROUTINE GROWTH                                                  1337
C                                                                        1338
C  ***************************************************************     1339
C  *                                                             *     1340
C  *                    GROWTH  SUBROUTINE                       *     1341
C  *                                                             *     1342
C  ***************************************************************     1343
C                                                                        1344
      REAL INT,LAI,LATUDE,NF,NV,NSTRES,NYTTYM,MH2O,LEAFWT,LEAFRS,        1345
     . LEAFW,LEAFCN,JL,KL,JR,KR,JG,KG,JS,KS,JG1,NPOOL
      INTEGER DAYNUM,TILLER,DIFREN,BOOT,HEAD,ANTHES,SPIKE,FLORET,        1347
     . SPRING,SRDAY,SECOND                                               1348
C                                                                        1349
      DIMENSION PDWL(10,6),PDSTEM(10),PDGLUM(10),PDGRAN(10)              1350
C                                                                        1351
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN                 1352
      COMMON /FRUIT / SPIKE(10),FLORET(10)                               1353
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W            1354
      COMMON /GROW  / LEAFW(10,6),STEMW(10),GLUMW(10),GRANW(10)          1355
      COMMON /LASTAD/ LTDAY(10),LLDAY(10),ALTMP(10,6),ATTMP(10)
     .     ,APTMP(10)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT      1357
      COMMON /LOST  / WTSLFD                                             1358
      COMMON /MATR  / KRL(20), LR                                        1359
      COMMON /NIT   / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRANN,GLUMN,PLANTN   1360
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1                        1361
      COMMON /PARTS / LEAF(10),LIDATE(10,6),NTILL(10),NSTEMS
      COMMON /PHYTIM/ TILLER,JOINT(10),DIFREN,BOOT(10),HEAD(10),         1363
     . ANTHES(10),SPRING,ACCDEG                                          1364
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN        1365
      COMMON /PS    / PSIS(20,6)                                         1366
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC                  1367
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)           1369
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                       1370
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDORT,SPDGLM,SPDGRN                  1372
      COMMON /SROOT / SRAVG,SRDAY,SECOND                                 1373
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,    1374
     . STRSD,STRSN,FACL                                                  1375
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT             1376
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)                  1377
      COMMON /UPS   / SUPNO3,UPNO3                                       1378
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT    1379
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                       1380
C                                                                        1381
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C    DETERMINE FACTOR TO CONVERT LEAF AREA TO WEIGHT. AREA IS IN CM**2      1382
C     & WEIGHT IS IN GRAMS. FROM UNPUBLISHED DATA FURNISHED BY SMIKA        1383
C                                                                           1384
       WTF=.0025                                                           1385
C                                                                          1386
C    DETERMINE FACTOR TO BE USED TO REDUCE POTENTIAL WEIGHT CHANGE         1387
C     DUE TO WATER STRESS.                                                 1388
C                                                                          1389
       RFWST=(WSTRSL*DAYTYM+WSTRSN*NYTTYM)/24.                             1390
C                                                                          1391
C    POTENTIAL STEM GROWTH IS FUNCTION OF TEMPERATURE & AGE                1392
C    POTENTIAL GLUME GROWTH IS FUNCTION OF TEMPERATURE & AGE               1393
C    POTENTIAL GRAIN DRY MATTER ACCUMULATION FUNCTION OF AGE & TEMP        1394
C                                                                          1395
       DO 100 I=1,NSTEMS                                                   1396
C                                                                          1397
C    POTENTIALS DURING HEADING                                             1398
C                                                                          1399
       POSTEM(I)=0.                                                        1400
       PDGLUM(I)=.000005                                                   1401
       PDGRAN(I)=.00008*TAVG-.0001                                         1402
       IF(PDGRAN(I).LT.0.) PDGRAN(I)=0.                                    1403
       IF(IDAY.GE.JOINT(I)) GO TO 40                                       1404
C                                                                          1405
C    POTENTIALS PRIOR TO JOINTING                                          1406
C                                                                          1407
       POSTEM(I)=.00005                                                    1408
       PDGLUM(I)=0.                                                        1409
       PDGRAN(I)=0.                                                        1410
       GO TO 100                                                           1411
   40  IF(IDAY.GE.BOOT(I)) GO TO 60                                        1412
C                                                                          1413
C    POTENTIALS DURING JOINTING                                            1414
C                                                                          1415
       POSTEM(I)=.0022                                                     1416
       PDGLUM(I)=0.                                                        1417
       PDGRAN(I)=0.                                                        1418
       GO TO 100                                                           1419
   60  IF(IDAY.GE.ANTHES(I)+4) GO TO 100                                   1421
C                                                                          1423
C    POTENTIALS DURING BOOT AND THRU ANTHESIS                              1424
C                                                                          1425
       POSTEM(I)=.0079
       PDGLUM(I)=.00002
       PDGRAN(I)=0.
```

```
C                                                                       1427
C    ZERO ACCUMULATORS FOR WEIGHT CHANGE POTENTIALS                     1428
C                                                                       1429
  100 CONTINUE                                                          1430
      SPDWL=0.                                                          1431
      SPDSTM=0.                                                         1432
      SPDGLM=0.                                                         1433
      SPDGRN=0.                                                         1434
C                                                                       1435
C    GO THRU LOOP FOR EACH STEM TO SUM POTENTIALS                       1436
C                                                                       1437
      IF(NSTEMS.LE.0) RETURN                                            1438
      DO 160 I=1,NSTEMS                                                 1439
      IF(LEAF(I).LE.0) GO TO 140                                        1440
      K=LEAF(I)                                                         1441
      DO 120 J=1,K                                                      1442
C                                                                       1443
C    CALCULATE POTENTIAL CHANGE IN LEAF AREA AS FUNCTION OF TIME        1444
C     FROM UNPUBLISHED DATA FURNISHED BY SMIKA                          1445
C                                                                       1446
C     ITIM=IDAY-LIDATE(I,J)                                             1447
C     IF(ITIM.LE.25) RADAY=.2                                           1448
C     IF((ITIM.GT.25).AND.(ITIM.LE.35)) RADAY=.6                        1449
C     IF((ITIM.GT.35).AND.(ITIM.LE.43)) RADAY=.8                        1450
C     IF((ITIM.GT.43).AND.(ITIM.LE.65)) RADAY=.07                       1451
C     IF(ITIM.GT.65) RADAY=0.                                           1452
      TDUM=TAVG                                                         1453
      IF(TDUM.GT.20.) TDUM=40.-TDUM                                     1454
      IF(TDUM.LT.0.) TDUM=0.                                            1455
      RADAY=TDUM/40.                                                    1456
      ALTMP(I,J)=ALTMP(I,J)+TAVG                                        1457
      ITIM=IDAY-LIDATE(I,J)                                             1458
      TDUM=ALTMP(I,J)/ITIM                                              1459
      ITDUM=-1.33*TDUM+51.83                                            1460
      IF(ITIM.GE.ITDUM) RADAY=0.                                        1461
C                                                                       1462
C    CONVERT POTENTIAL AREA GROWTH TO POTENTIAL WEIGHT INCREMENT        1463
C                                                                       1464
      PDWL(I,J)=RADAY*WTF*RFWST*FACL                                    1465
      SPDWL=SPDWL+PDWL(I,J)                                             1466
  120 CONTINUE                                                          1467
C                                                                       1468
C    IF PLANT IS HEADING STEM GROWTH = 0                                1469
C     SUM POTENTIAL DRY MATTER ACCUMULATION IN ALL STEMS                1470
C                                                                       1471
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```
  140 SPDSTM=SPDSTM+PDSTEM(I)*RFWST                                    1472
C                                                                      1473
C    SUM POTENTIAL DRY MATTER ACCUMULATION IN ALL GLUMES               1474
C                                                                      1475
      SPDGLM=SPDGLM+PDGLUM(I)*SPIKE(I)*RFWST                           1476
C                                                                      1477
C    SUM POTENTIAL DRY MATTER ACCUMULATION IN GRAIN                    1478
C                                                                      1479
      SPDGRN=SPDGRN+PDGRAN(I)*FLORET(I)*RFWST                          1480
  150 CONTINUE                                                         1481
C                                                                      1482
C    CALL ROOT GROWTH SUB TO GET TOTAL POTENTIAL DRY MATTER ACCUMULATION 1483
C     IN ROOT SYSTEM                                                   1484
C                                                                      1485
      KALL=0                                                           1486
      CALL RUTGRO(KALL)                                                1487
C                                                                      1488
C    PUT ON A PER PLANT BASIS                                          1489
C                                                                      1490
      SPDWRT=SPDWRT*2./ROWSP*POPFAC*100.                               1491
C                                                                      1492
C    CARBOHYDRATE DEMAND IS SUM OF DEMAND COMPONENTS FROM ALL PLANT PARTS 1493
C                                                                      1494
      CD=SPDWRT+SPDGLM+SPDSTM+SPDWL                                    1495
C                                                                      1496
C    CSTRES (SUPLY DEMAND RATIO) IS INDEX OF NUTRITIONAL STATUS OF PLANT 1497
C                                                                      1498
      CSTRSF=1.                                                        1499
      CSTRSV=1.                                                        1500
      CPOOL=RESC+PN
      RESC=CPOOL-SPDGRN
      IF(RESC.GT.0.) GO TO 200                                         1503
      CSTRSF=(RESC+SPDGRN)/SPDGRN                                      1504
      RESC=0.                                                          1505
      CSTRSV=0.                                                        1506
      GO TO 220                                                        1507
  200 RESC=RESC-CD                                                     1508
      IF(RESC.GE.0.) GO TO 220                                         1509
      CSTRSV=0.
      IF(CD.GT.0.) CSTRSV=(RESC+CD)/CD
      RESC=0.                                                          1511
C                                                                      1512
C                                                                      1513
  220 CONTINUE                                                         1514
C                                                                      1515
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C    CALL NITROGEN BUDGET SUB TO GET NSTRES, THE SUPPLY DEMAND RATIO FOR      1516
C     NITROGEN (ANALOGOUS TO CSTRES)                                          1517
C                                                                             1518
       CALL NITRO                                                             1519
       LEAFWT=0.                                                              1520
       STEMWT=0.                                                              1521
       GLUMWT=0.                                                              1522
       GRANWT=0.                                                              1523
       XTRAC=0.                                                               1524
C                                                                             1525
C    DISTRIBUTE DRY MATTER TO PLANT PARTS. CHANGE IN WEIGHT OF STEM =         1526
C     POTENTIAL CHANGE IN WEIGHT * SUPPLY DEMAND RATIOS FOR CARBOHYDRATE,     1527
C     AND NITROGEN                                                            1528
C                                                                             1529
       DO 400 I=1,NSTEMS                                                      1530
       IF(LEAF(I).LE.0) GO TO 340                                             1531
       K=LEAF(I)                                                              1532
       DO 320 J=1,K                                                           1533
       IF(PDWL(I,J).LE.0.) GO TO 300                                          1534
C                                                                             1535
C    ACCUMULATE LEAF AREA AND LEAF WT                                         1536
C                                                                             1537
       AREA=AREA+PDWL(I,J)/WTF*CSTRSV*NV                                      1538
       LEAFW(I,J)=LEAFW(I,J)+PDWL(I,J)*CSTRSV*NV                              1539
       XTRAC=XTRAC+PDWL(I,J)*CSTRSV*(1.-NV)                                   1540
  300  LEAFWT=LEAFWT+LEAFW(I,J)                                               1541
  320  CONTINUE                                                               1542
C                                                                             1543
C    ACCUMULATE STEM WT                                                       1544
C                                                                             1545
  340  STEMW(I)=STEMW(I)+PDSTEM(I)*RFWST*CSTRSV*NV
       XTRAC=XTRAC+PDSTEM(I)*RFWST*CSTRSV*(1.-NV)
       STEMWT=STEMWT+STEMW(I)                                                 1548
C                                                                             1549
C    ACCUMULATE WEIGHT IN THE GLUMES                                          1550
C                                                                             1551
       GLUMW(I)=GLUMW(I)+PDGLUM(I)*RFWST*CSTRSV*NV*SPIKE(I)
       XTRAC=XTRAC+PDGLUM(I)*SPIKE(I)*RFWST*CSTRSV*(1.-NV)
       GLUMWT=GLUMWT+GLUMW(I)                                                 1554
C                                                                             1555
C    ACCUMULATE WEIGHT IN THE GRAIN                                           1556
C                                                                             1557
       GRANW(I)=GRANW(I)+PDGRAN(I)*RFWST*CSTRSF*NF*FLORET(I)
       XTRAC=XTRAC+PDGRAN(I)*FLORET(I)*RFWST*CSTRSF*(1.-NF)
       GRANWT=GRANWT+GRANW(I)                                                 1560
```

```
  400 CONTINUE                                                          1561
C                                                                       1562
C   CALL ROOT GROWTH SUB & DISYRIBUTE DRY MATTER TO ROOTS.              1563
C                                                                       1564
      RCH2O=SPDWRT*CSTRSV*NV                                            1565
      XTRAC=XTRAC+SPDWRT*CSTRSV*(1.-NV)                                 1566
      KALL=1                                                            1567
      CALL RUTGRO(KALL)                                                 1568
C                                                                       1569
C   ADD CARBOHYDRATES TO RESC THAT WERE NEEDED BUT NOT USED             1570
C    BECAUSE OF NITROGEN STRESS                                         1571
C                                                                       1572
      RESC=RESC+XTRAC                                                   1573
C                                                                       1574
C   CALCULATE VEGWT & PLANTW                                            1575
C                                                                       1576
      PLANTW=LEAFWT+STEMWT+GLUMWT+GRANWT+ROOTWT+RESC                    1577
      VEGWT=PLANTW-GRANWT                                               1578
C                                                                       1579
C   DETERMINE MAX LEAF LENGTH BY USING LEAF WEIGHT. THIS VALUE IS       1580
C    USED TO DETERMINE % LIGHT INTERCEPTED                              1581
C                                                                       1582
      XMAXLW=0.                                                         1583
      DO 420 I=1,NSTEMS                                                 1584
      K=LEAF(I)                                                         1585
      IF(K.LE.0) GO TO 430
      DO 420 J=1,K                                                      1586
      IF(LEAFW(I,J).GT.XMAXLW) XMAXLW=LEAFW(I,J)                        1587
  420 CONTINUE                                                          1588
  430 CONTINUE
      XLEAFL=2.15*XMAXLW/WTF+1.                                         1589
      IF(XLEAFL.GT.13.9) XLEAFL=.74*XMAXLW/WTF+9.44                     1590
C                                                                       1591
C   COMPUTE NEW LEAF AREA INDEX                                         1592
C                                                                       1593
      LAI=AREA/POPFAC/100.                                              1594
C                                                                       1595
C                                                                       1596
      RETURN                                                            1597
      END                                                               1598
```

```
      SUBROUTINE NITRO                                                  1599
C  ***************************************************************    1600
C  *                                                             *    1601
C  *                    NITRO  SUBROUTINE                        *    1602
C  *                                                             *    1603
C  ***************************************************************    1604
C                                                                       1605
      REAL LEAFWT,LEAFCN,KL,KS,KR,KG,JL,JS,JR,JG,JG1,LEAFRS,            1606
     . NF,NSTRES,NV,NPOOL,LEAFR1                                        1607
C                                                                       1608
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN                1609
      COMMON /NIT   / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRANN,GLUMN,PLANTN  1610
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1                       1611
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC                 1612
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT   1613
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,   1614
     . STRSD,STRSN,FACL                                                 1615
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN                 1616
      COMMON /UPS   / SUPNO3,UPNO3                                      1617
C                                                                       1618
      NSTRES=1.                                                         1619
      NV=1.                                                             1620
      NF=1.                                                             1621
C                                                                       1622
C   CALCULATE NITROGEN RESERVES IN EACH TISSUE FROM TISSUE NITROGEN,    1623
C    MINIMUM POSSIBLE LEVELS & AN AVAILABILITY FACTOR (F2)              1624
C                                                                       1625
      LEAFRS=(SLEAFN-KL*LEAFWT)*F2                                      1626
      STEMRS=(STEMN-KS*STEMWT)*F2                                       1627
      ROOTRS=(ROOTN-KR*ROOTWT)*F2                                       1628
      GLUMRS=(GLUMN-KG*GLUMWT)*F2                                       1629
      IF(LEAFRS.LT.0.) LEAFRS=0.                                        1630
      IF(STEMRS.LT.0.) STEMRS=0.                                        1631
      IF(ROOTRS.LT.0.) ROOTRS=0.                                        1632
      IF(GLUMRS.LT.0.) GLUMRS=0.                                        1633
C                                                                       1634
C   CALCULATE TOTAL NITROGEN RESERVE                                    1635
C                                                                       1636
      RESN=LEAFRS+STEMRS+ROOTRS+GLUMRS                                  1637
C                                                                       1638
C   THE NITROGEN POOL AVAILABLE IS SUM OF NITROGEN TAKEN UP TODAY +     1639
C    RESERVES                                                           1640
C                                                                       1641
      NPOOL=SUPNO3+RESN                                                 1642
C                                                                       1643
```

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C    CALCULATE NITROGEN REQUIRED FOR NEW (PROPOSED) DRY WT GROWTH OF          1644
C     EACH ORGAN                                                              1645
C                                                                             1646
       LEAFR1=JL*SPDWL*CSTRSV                                                 1647
       STEMR1=JS*SPDSTM*CSTRSV                                                1648
       ROOTR1=JR*SPDWRT*CSTRSV                                                1649
       GLUMR1=JG*SPDGLM*CSTRSV                                                1650
       GRANR1=JG1*SPDGRN*CSTRSF                                               1651
C                                                                             1652
C    CALCULATE TOTAL REQUIREMENT OF NITROGEN FOR GROWTH                       1653
C                                                                             1654
       REQN=LEAFR1+STEMR1+ROOTR1+GLUMR1                                       1655
C                                                                             1656
C    IF NITROGEN REQUIREMENT FOR GROWTH OF GRAIN & VEGETATIVE PARTS >         1657
C     NITROGEN POOL, BUT < REQUIREMENT FOR GROWTH OF GRAIN ALONE THEN GET     1658
C     FULL GRAIN GROWTH & AMT LEFT GOES TO GROWTH OF VEGETATIVE PARTS         1659
C     (NF=1 & NV IS REDEFINED). IF REQUIREMENT > FOR GRAIN ALONE THEN         1660
C     NO VEGETATIVE GROWTH & GRAIN GROWTH REDUCED (NF IS REDEFINED, NV=0)     1661
C                                                                             1662
       IF((REQN+GRANR1).LE.NPOOL) GO TO 60                                    1663
       NSTRES=NPOOL/(REQN+GRANR1)                                             1664
       IF(GRANR1.GT.NPOOL) GO TO 40                                           1665
       NV=(NPOOL-GRANR1)/REQN                                                 1666
       GO TO 60                                                               1667
    40 NV=0.                                                                  1668
       NF=NPOOL/GRANR1                                                        1669
    60 CONTINUE                                                               1670
C                                                                             1671
C    IF NITROGEN REQUIREMENT IS = OR < NITROGEN POOL, THEN EACH ORGAN         1672
C     RESERVES WHATEVER IS REQUIRED FOR GROWTH                                1673
C                                                                             1674
       SLEAFN=SLEAFN+LEAFR1*NV                                                1675
       STEMN=STEMN+STEMR1*NV                                                  1676
       ROOTN=ROOTN+ROOTR1*NV                                                  1677
       GLUMN=GLUMN+GLUMR1*NV                                                  1678
       GRANN=GRANN+GRANR1*NF                                                  1679
C                                                                             1680
C    CALCULATE TOTAL PLANT NITROGEN CONTENT FOR CHECK ON THE BALANCE          1681
C                                                                             1682
       PLTN=SLEAFN+STEMN+ROOTN+GRANN+GLUMN                                    1683
C                                                                             1684
C    DIFFERENCE BETWEEN NEW & OLD NITROGEN IN SYSTEM ADDED TO THE DAYS        1685
C     UPTAKE REPRESENTS EITHER ADDITION OR WITHDRAWAL FROM RESERVE            1686
C                                                                             1687
       XTRAN=(SUPNO3+PLANTN)-PLTN                                             1688
C                                                                             1689
C    ADD TO OR SUBTRACT FROM RESERVES IN PROPORTION TO WT OF VARIOUS          1690
C     ORGANS                                                                  1691
C                                                                             1692
       IF(XTRAN.LT.0.) GO TO 80                                               1693
       SLEAFN=SLEAFN+XTRAN*(LEAFWT/VEGWT)                                     1694
       STEMN=STEMN+XTRAN*(STEMWT/VEGWT)                                       1695
       ROOTN=ROOTN+XTRAN*(ROOTWT/VEGWT)                                       1696
       GLUMN=GLUMN+XTRAN*(GLUMWT/VEGWT)                                       1697
       GO TO 90                                                               1698
    80 IF(RESN.LE.0.) GO TO 90                                                1699
       SLEAFN=SLEAFN+XTRAN*(LEAFRS/RESN)                                      1700
       STEMN=STEMN+XTRAN*(STEMRS/RESN)                                        1701
       ROOTN=ROOTN+XTRAN*(ROOTRS/RESN)                                        1702
       GLUMN=GLUMN+XTRAN*(GLUMRS/RESN)                                        1703
    90 CONTINUE                                                               1704
C                                                                             1705
C    CALCULATE LEAF NITROGEN CONCENTRATION AS % OF LEAF WEIGHT                1706
C                                                                             1707
       LEAFCN=SLEAFN/LEAFWT                                                   1708
C                                                                             1709
C    TOTAL THE PLANT NITROGEN                                                 1710
C                                                                             1711
       PLANTN=SLEAFN+ROOTN+STEMN+GRANN+GLUMN                                  1712
       RETURN                                                                 1713
       END                                                                    1714
```

```
      SUBROUTINE MORPH                                                  1715
C  ************************************************************       1716
C  *                                                          *       1717
C  *                    MORPH  SUBROUTINE                     *       1718
C  *                                                          *       1719
C  ************************************************************       1720
C                                                                       1721
      REAL INT,LAI,LATUDE,NF,NV,NSTRES,NYTTYM,MH2O,LEAFWT,LEAFRS,       1722
     . LEAFW,LEAFCN,JL,KL,JR,KR,JG,KG,JS,KS,JG1,NPOOL
      INTEGER DAYNUM,TILLER,DIFREN,BOOT,HEAD,ANTHES,SPIKE,FLORET,       1724
     . SPRING,STEMBG,STEMND,SRDAY,TBSR,SECOND,TBT,TBL,STEMJ,DNODE,ANTHND 1725
C                                                                       1726
      DIMENSION NODE(10),TDES(10)                                       1727
C                                                                       1728
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN                1729
      COMMON /FRUIT / SPIKE(10),FLORET(10)                              1730
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W           1731
      COMMON /GROW  / LEAFW(10,6),STEMW(10),GLUMW(10),GRANW(10)         1732
      COMMON /LASTAD/ LTDAY(10),LLDAY(10),ALTMP(10,6),ATTMP(10)
     .      ,APTMP(10)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT     1734
      COMMON /LOST  / WTSLFD                                            1735
      COMMON /MATR  / KRL(20), LR                                       1736
      COMMON /NIT   / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRANN,GLUMN,PLANTN  1737
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1                       1738
      COMMON /PARTS / LEAF(10),LIDATE(10,6),NTILL(10),NSTEMS
      COMMON /PHYTIM/ TILLER,JOINT(10),DIFREN,BOOT(10),HEAD(10),        1740
     . ANTHES(10),SPRING,ACCDEG                                         1741
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN       1742
      COMMON /PS    / PSIS(20,6)                                        1743
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC                 1744
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)          1746
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                      1747
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN                 1749
      COMMON /SROOT / SRAVG,SRDAY,SECOND                                1750
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,   1751
     . STRSD,STRSN,FACL                                                 1752
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT            1753
      COMMON /TSOIL / TSOILD(20), TSOILN(20), TSOLAV(2)                 1754
      COMMON /UPS   / SUPNO3,UPNO3                                      1755
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT   1756
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                      1757
C                                                                       1758
      ATMP=TAVG                                                         1759
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      IF(ATMP.LT.0.) ATMP=0.                                              1760
      ACCDEG=ACCDEG+ATMP                                                  1761
      IF(ACCDEG.LT.100.) GO TO 100                                        1762
      IF(ACCDEG.GT.750.) GO TO 40                                         1763
      IF(IDAY.LT.TILLER) TILLER=IDAY                                      1765
      IF(ACCDEG.GT.315..AND.IDAY.LT.DIFREN) DIFREN=IDAY                   1764
      GO TO 100                                                           1766
   40 IF(ACCDEG.GT.1090.) GO TO 60                                        1767
      IF(IDAY.GT.JOINT(1)) GO TO 100                                      1768
      JOINT(1)=IDAY                                                       1769
      STEMBG=1                                                            1770
      STEMND=0                                                            1771
      DO 50 I=1,10
      NODE(I)=0
   50 CONTINUE
      GO TO 100                                                           1772
   60 IF(ACCDEG.GT.1200.) GO TO 80                                        1773
      IF(IDAY.GT.BOOT(1)) GO TO 100                                       1774
      BOOT(1)=IDAY                                                        1775
      NSTMH=1                                                             1776
      DO 70 I=1,NSTEMS                                                    1777
      IF(NODE(I).LT.7) GO TO 70                                           1778
      NSTMH=I                                                             1779
      IDIFF=JOINT(I)-JOINT(1)                                             1780
      BOOT(I)=BOOT(1)+IDIFF                                               1781
   70 CONTINUE                                                            1782
      GO TO 100                                                           1783
   80 IF(IDAY.GT.HEAD(1)) GO TO 400                                       1784
      HEAD(1)=IDAY                                                        1785
      DO 90 I=1,NSTMH                                                     1786
      IDIFF=JOINT(I)-JOINT(1)                                             1787
      HEAD(I)=HEAD(1)+IDIFF                                               1788
      SPIKE(I)=ISPLTS                                                     1789
   90 CONTINUE                                                            1790
      GO TO 400                                                           1791
C                                                                         1792
C                                                                         1793
  100 CONTINUE                                                            1794
      SRAVG=SRAVG+ATMP                                                    1795
      TBSR=10.-.5*(SRAVG/FLOAT(IDAY-SRDAY))                               1796
      IF(TBSR.LT.2) TBSR=2                                                1797
C                                                                         1798
C    IF H2O IS OK AND ENOUGH TIME HAS PASSED SINCE LAST SECONDARY ROOT    1799
C     WAS FORMED, THEN WE GET A NEW ONE                                   1800
C                                                                         1801
```

```
      IF((IDAY.LT.TBSR+SRDAY).OR.(PSIAVG.LT.-1.)) GO TO 120                1802
      SRDAY=IDAY                                                           1803
      SRAVG=0.                                                             1804
      SECOND=SECOND+1                                                      1805
C                                                                          1806
C   CHECK ON NEW LEAVES                                                    1807
C                                                                          1808
  120 CONTINUE                                                             1809
      DO 140 I=1,NSTEMS                                                    1810
      APTMP(I)=APTMP(I)+ATMP
      IF(LEAF(I).GE.6) GO TO 140                                           1811
      ATTMP(I)=ATTMP(I)+ATMP                                               1812
      TBL=9.-ATTMP(I)/(IDAY-LLDAY(I))/5.                                   1813
      IF(TBL.LT.4) TBL=4                                                   1814
C                                                                          1815
C   IF SUFFICIENT TIME HAS PASSED SINCE LAST LEAF FORMED &                 1816
C    THERE ARE < 6 LEAVES ON THE STEM, THEN A NEW LEAF IS                  1817
C    FORMED                                                                1818
C                                                                          1819
      IF(LLDAY(I)+TBL.GE.IDAY) GO TO 140                                   1820
      LLDAY(I)=IDAY                                                        1821
      LEAF(I)=LEAF(I)+1                                                    1822
      LIDATE(I,LEAF(I))=IDAY                                               1823
      ATTMP(I)=0.                                                          1824
      ALTMP(I,LEAF(I))=0.                                                  1825
  140 CONTINUE                                                             1826
C                                                                          1827
C   IF THE PLANT IS JOINTING OR BEYOND THEN TILLERING IS COMPLETE          1828
C                                                                          1829
      IF(IDAY.GE.JOINT(1)) GO TO 300                                       1830
      IF((IDAY.LT.TILLER).OR.(NSTEMS.GE.10)) GO TO 170                     1831
C                                                                          1633
C   IF THERE ARE < 10 STEMS, ENOUGH CARBOHYDRATES ARE AVAILABLE            1834
C    & SUFFICIENT TIME HAS ELAPSED SINCE LAST TILLER WAS FORMED            1835
C    THEN ANOTHER TILLER IS FORMED                                         1836
C                                                                          1837
      J=NSTEMS                                                             1838
      DO 160 I=1,J                                                         1839
      TBT=30.-APTMP(I)/(IDAY-LIDATE(NSTEMS,1))
      IF(TBT.LT.5) TBT=5
      IF(NSTEMS.GE.10) GO TO 170                                           1840
      IF(LEAF(I).LE.2) GO TO 160                                           1841
      IF(IDAY.LT.LTDAY(I)+TBT) GO TO 160                                   1842
      IF(NTILL(I).GE.3) GO TO 160
      NTILL(I)=NTILL(I)+1
```

```
      NSTEMS=NSTEMS+1                                                    1843
      LEAF(NSTEMS)=1
      LIDATE(NSTEMS,1)=IDAY
      LEAFW(NSTEMS,1)=0.
      LTDAY(I)=IDAY                                                      1844
      IF(NSTEMS.LE.3) GO TO 160                                          1845
      IF(PSIAVG.LT.-1.) GO TO 180                                        1846
      IF(LEAFCN.LT..03) GO TO 180                                        1847
      IF(CSTRSV.LE..99) GO TO 180
  150 CONTINUE                                                           1851
  170 CONTINUE                                                           1852
C                                                                        1853
C   IF PAST FIRST DAY OF SPRING, LEAF OR SOIL H2O POTENTIAL             1854
C    IS < REQUIRED & A STEM HAS < 4 SECONDARY ROOTS, THEN               1855
C    ABORT THE LATEST TILLER                                            1856
C                                                                        1857
      IF(IDAY.LT.SPRING) GO TO 220                                       1858
      IF((PSIL.GE.-20.).OR.(SECOND/NSTEMS.GE.4)) GO TO 220               1859
  180 LLDAY(NSTEMS)=0
      LEAF(NSTEMS)=0                                                     1861
      NTILL(NSTEMS)=0
      STEMW(NSTEMS)=0                                                    1862
      ATTMP(NSTEMS)=0.
      APTMP(NSTEMS)=0.
C                                                                        1864
      DO 210 I=1,6                                                       1865
      ALTMP(NSTEMS,I)=0.
      LIDATE(NSTEMS,I)=0                                                 1866
      LEAFW(NSTEMS,I)=0                                                  1867
  210 CONTINUE                                                           1868
C                                                                        1869
C                                                                        1870
      NSTEMS=NSTEMS-1                                                    1871
C                                                                        1872
C                                                                        1873
  220 CONTINUE                                                           1874
C                                                                        1875
C   IF NOT DAY OF DIFFERENTIATION RETURN                                 1876
C                                                                        1877
      IF(IDAY.NE.DIFREN) GO TO 600                                       1878
C                                                                        1879
C   DETERMINE THE POTENTIAL NUMBER OF SPIKELETS PER SPIKE                1880
C                                                                        1881
      ISPLTS=22                                                          1882
      DUM1=RESC/(RESC+LEAFWT)                                            1883
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```
      DUM2=10.*DUM1+.5                                                  1884
      IF(DUM2.GT.1.) DUM2=1.                                            1885
      ISPLTS=ISPLTS*DUM2+.5                                             1886
      DUM2=15.*LEAFCN+.5                                                1887
      IF(DUM2.GT.1.) DUM2=1.                                            1888
      ISPLTS=ISPLTS*DUM2+.5                                             1889
      GO TO 600                                                         1890
C                                                                       1891
C   IF JOINTING IS COMPLETED THEN RETURN                                1892
C                                                                       1893
  300 CONTINUE                                                          1894
      IF(IDAY.GT.JOINT(1)+15) GO TO 600                                 1895
      IF(STEMND.GE.10) GO TO 340                                        1896
C                                                                       1897
C   DETERMINE THE NUMBER OF STEMS ALLOWED TO BEGIN JOINTING             1898
C    TODAY                                                              1899
C                                                                       1900
      DUM1=(WSTRSD*DAYTYM+WSTRSN*NYTTYM)/24.                            1901
      DUM1=DUM1*.4+CSTRSV*.35+NSTRES*.25                                1902
      STEMJ=0.                                                          1903
      IF(DUM1.GE..3) STEMJ=1                                            1904
      IF(DUM1.GE..75) STEMJ=2                                           1905
      IF(DUM1.GE..99) STEMJ=3                                           1906
C                                                                       1907
C   MARK THE FIRST & LAST STEMS TO BEGIN JOINTING TODAY                 1908
C                                                                       1909
      IF(STEMJ.LE.0) GO TO 340                                          1910
      STEMND=STEMBG+STEMJ-1                                             1911
      IF(STEMND.GT.10) STEMND=10                                        1912
C                                                                       1913
C   ELONGATE THE FIRST JOINT FOR EACH STEM BEGINNING JOINTING           1914
C                                                                       1915
      DO 330 I=STEMBG,STEMND                                            1916
      IF(LEAF(I).GE.6) GO TO 320                                        1917
      STEMND=STEMBG-2+I                                                 1918
      GO TO 340                                                         1919
  320 NODE(I)=1                                                         1920
      JOINT(I)=IDAY                                                     1921
  330 CONTINUE                                                          1922
C                                                                       1923
C   STEM DOES NOT JOINT BEFORE IT HAS SIX LEAVES                        1924
C                                                                       1925
  340 L=STEMBG-1                                                        1926
      IF(STEMBG.LE.STEMND) STEMBG=STEMND+1                              1927
      IF(L.LE.0) GO TO 600                                              1928
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```
      IF(L.GT.10) L=10                                                  1929
      IF(PSIL.LT.-10.) GO TO 600                                        1930
      DNODE=2                                                           1931
C                                                                       1932
C   FOR STEMS PREVIOUSLY BEGAN JOINTING THEN DETERMINE IF               1933
C    ADDITIONAL NODES ARE TO BE ADDED TODAY                             1934
C                                                                       1935
      DO 380 I=1,L                                                      1936
      NODE(I)=NODE(I)+DNODE                                             1937
      IF(NODE(I).GT.7) NODE(I)=7                                        1938
  380 CONTINUE                                                          1939
      GO TO 600                                                         1940
C                                                                       1941
C   DETERMINE DAY OF ANTHESIS & IF NOT WITHIN THE PERIOD                1942
C    THEN RETURN                                                        1943
C                                                                       1944
  400 CONTINUE                                                          1945
      IF(ACCDEG.LT.1300.) GO TO 600                                     1946
      IF(ANTHES(1).LT.IDAY) GO TO 440                                   1947
      ANTHES(1)=IDAY                                                    1948
      DFAC=.25                                                          1949
      DO 420 I=1,NSTMH                                                  1950
      IDIFF=JOINT(I)-JOINT(1)                                           1951
      ANTHES(I)=ANTHES(1)+IDIFF                                         1952
      TDES(I)=0.                                                        1953
      FLORET(I)=SPIKE(I)*4                                              1954
  420 CONTINUE                                                          1955
C                                                                       1956
C                                                                       1957
C                                                                       1958
  440 CONTINUE                                                          1959
      DO 460 I=1,NSTMH                                                  1960
      IF((IDAY.LT.ANTHES(I)).OR.(IDAY.GT.ANTHES(I)+3)) GO TO 460        1961
C                                                                       1962
C   DETERMINE FRACTION OF FLORETS DESSICATED DUE TO LOW LEAF WATER      1963
C    POTENTIAL & WIND                                                   1964
C                                                                       1965
      DES=(-.04)*PSIL-.6                                                1966
      IF(DES.LT.0.) DES=0.                                              1967
      IF(DES.GT.1.) DES=1.                                              1968
      TDES(I)=DES*DFAC+TDES(I)                                          1969
      IF(IDAY.NE.ANTHES(I)+3) GO TO 460                                 1970
C                                                                       1971
C   ELIMINATE THE DESSICATED FLORETS FROM THE ARRAY                     1972
C                                                                       1973
      FLORET(I)=FLORET(I)-TDES(I)*FLORET(I)+.5001                       1974
      IF(FLORET(I).GT.60) FLORET(I)=60
      IF(FLORET(I).LT.10) FLORET(I)=10
  460 CONTINUE                                                          1975
  600 CONTINUE                                                          1976
      RETURN                                                            1987
      END                                                               1988
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      SUBROUTINE RUTGRO(KALL)                                              1989
C*****************************************************************      00191990
C   THIS SUBROUTINE CALCULATES THE GROWTH (IN TERMS OF DRY          *     00191991
C MATTER) OF ROOTS IN EACH CELL FOR THE DAY.  FIRST, THE POTENTIAL  *     00191992
C GROWTH (PDWRT) FOR THE EXISTING SOIL WATER POTENTIAL (PSIS)       *     00191993
C AND TEMPERATURE (TSOILD & TSOILN) IS CALCULATED FOR EACH          *     00191994
C SOIL CELL, BASED ON THE WEIGHT OF ROOTS CAPABLE OF GROWTH         *     00191995
C IN EACH CELL (RTWTCG).  THEN THE ACTUAL GROWTH IS                 *     00191996
C DETERMINED, BASED ON THE CARBOHYDRATE SUPPLY FOR ROOT GROWTH      *     00191997
C AND THE POTENTIAL GROWTH FOR THE CELL.  THE ACTUAL GROWTH         *     00191998
C OCCURING FOR A GIVEN CELL MAY OCCUR WITHIN THE CELL OR IN         *     00191999
C THE CELLS TO THE RIGHT OR LEFT & BELOW.                           *     00192000
C   GROWTH IN THE 4 AVAILABLE CELLS IS BASED ON RELATIVE            *     00192001
C WATER POTENTIALS OF THE FOUR, WITH A HEAVIER WEIGHTING            *     00192002
C GIVEN TO DOWNWARD GROWTH.                                         *     00192003
C   THIS SUBROUTINE DRAWS HEAVILY ON THE IDEAS AND THEORIES OF      *     00192004
C  DR. M. G. HUCK, USDA-ARS, AUBURN, ALA.  THIS IS ESPECIALLY       *     00192005
C  AS REGARDS SLOUGHING.  C. F. 'A MODEL FOR SIMULATING ROOT        *     00192006
C  GROWTH AND WATER UPTAKE ', M. G. HUCK, F. W. T. PENNING DE       *     00192007
C  VRIES, AND M. G. KEIZER.  IN PRESS.                              *     00192008
C*****************************************************************      00192009
      REAL INT,LATUDE,LEAFWT,NF,NV,NYTTYM,LAI,NSTRES,MH2O
      DIMENSION DWRT(20,6)                                                 2011
      INTEGER DAYNUM                                                       2012
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W              2013
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT        2014
      COMMON /LOST  / WTSLFD                                               2015
      COMMON /MATR  / KRL(20), LR                                          2016
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESR,SPN          2017
      COMMON /PS    / PSIS(20,6)                                           2018
      COMMON /ROOTIM/ RTIMPD(20,6),SNAME(3),TSTBD(9,20),INRT,MRT           2019
     *   ,TSTIMP(9,20),GH2OC(9),FACR                                       2020
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)             2021
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA                         2022
      COMMON /SOILID/ DIFFD(5),THETAD(5),BETA(5),SDEPTH(5),THETAS(5),      2023
     *                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)            2024
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN                    2026
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,      2027
     * STRSD,STRSN,FACL                                                   2028
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT               2029
      COMMON /TSOIL / TSOILD(20), TSOILN(20), TSOLAV(2)                    2030
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT      2031
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL                         2032
C                                                                          2033
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      IF(KALL.EQ.1) GO TO 2                                              2034
      DO 40 I=1,20                                                       2035
      DO 40 J=1,6                                                        2036
      DWRT(I,J)=0.                                                       2037
      ROOTSV(I,J)=0.                                                     2038
   40 CONTINUE                                                           2039
      RUTWT = ROOTWT                                                  NASA2040
C G - WEIGHTING FACTOR FOR GEOTROPISM ( THE PREFERENCE OF ROOTS       NASA2041
C TO GROW DOWNWARD).                                                  NASA2042
C SLF - SLOUGHING FACTOR.                                             NASA2043
C THRLN - THRESHOLD WEIGHT TO GIVE LENGTH OF ROOTS REACHING           NASA2044
C OPPOSITE BOUNDARIES OF CELL FROM WHICH GROWTH ORIGINATED.           NASA2045
      SPDWRT = 0.                                                     NASA2046
      PSIMAX = -50.                                                   NASA2047
      DO 1 LAYER  = 1, LR                                             NASA2048
      KR = KRL(LAYER)                                                 NASA2049
      DO 1 KOLUMN = 1, KR                                             NASA2050
      DWRT(LAYER,KOLUMN)=RTWT(LAYER,KOLUMN,1)+RTWT(LAYER,KOLUMN,2)        2051
C ROOT WEIGHT CAPABLE OF GROWTH IN THE CELL, GM.                      NASA2052
C     THE 25 DAY LIMIT IS BASED ON ANALYSES FOR STEM GROWTH. C. F.    NASA2053
C  BAKER, D. N. ET. AL. (1973) 'AN ANALYSIS OF THE RELATION BETWEEN   NASA2054
C  PHOTOSYNTHETIC EFFICIENCY AND YIELD IN COTTON'.  1973 BELTWIDE     NASA2055
C  COTTON PRODUCTION RES. CONF. PROC.                                 NASA2056
      IF(PSIS(LAYER,KOLUMN).GT.PSIMAX) PSIMAX=PSIS(LAYER,KOLUMN)      NASA2057
 1    CONTINUE                                                        NASA2058
      CALMAX = 1980.7 + PSIMAX*(797.58+PSIMAX*(181.181+PSIMAX*10.9619)) NASA2059
       CALAVG = 1980.7 + PSIAVG*(797.58+PSIAVG*(181.181+PSIAVG*10.9619))NASA2060
       CALTSD = TDAY*(-71.3947+(TDAY*1.22793))                        NASA2061
       CALTSN = TNYT*(-71.3947+(TNYT*1.22793))                        NASA2062
       WSTRSD = (CALAVG+CALTSD+RN*(-0.512136-0.078977*PSIAVG) +       NASA2063
     .   (0.73493*PSIAVG*TDAY)) / 730.                                NASA2064
       WSTRSN = (CALAVG+CALTSN+17.92476+PSIAVG*(2.764195 +            NASA2065
     .   0.73493*TNYT)) / 730.                                        NASA2066
       IF(WSTRSD.LT.0.0001) WSTRSD = 0.0001                           NASA2067
       IF(WSTRSD.GT.1.0) WSTRSD = 1.0                                 NASA2068
       IF(WSTRSN.LT.0.0001) WSTRSN = 0.0001                           NASA2069
       IF(WSTRSN.GT.1.0) WSTRSN = 1.0                                 NASA2070
      DAYL1 = DAYLNG / 24.                                            NASA2071
      DAYL2 = (24.-DAYLNG) / 24.                                      NASA2072
      TSNL = TSOILN(4)                                                   2075
      TSDL = TSOILD(4)                                                   2076
       IF(TSDL.GT.30.)TSDL=30.                                        NASA2077
       IF(TSNL.GT.30.)TSNL=30.                                        NASA2078
      DO 24 LAYER = 1, LR                                             NASA2073
      LP1 = LAYER + 1-(LAYER/NL)                                      NASA2074
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      CALTSD = TSDL*(-71.3947+(TSDL*1.22793))                          NASA2079
      CALTSN = TSNL*(-71.3947+(TSNL*1.22793))                          NASA2080
      STRSD = (CALMAX + CALTSD + RN*(-0.512136-0.078977*PSIMAX) +          2081
     .  (0.73493*PSIMAX*TSDL)) / 730.                                  NASA2082
      STRSN = (CALMAX + CALTSN + 17.92476 + PSIMAX*(2.764195 +             2083
     .  0.73493*TSNL)) / 730.                                          NASA2084
      IF(STRSD.LT.0.0001) STRSD = 0.0001                                   2085
      IF(STRSD.GT.1.) STRSD = 1.                                           2086
      IF(STRSN.LT.0.0001) STRSN = 0.0001                                   2087
      IF(STRSN.GT.1.) STRSN = 1.                                           2088
C  ROOTXP PROVIDES ROOTS SAME EXPONENTIAL GROWTH POTENTIAL AS YOUNG      NASA2089
C  BOLLS.  DID NOT HAVE ROOT GROWTH DATA UNDER LUXURY CH2O SUPPLY.       NASA2090
      ROOTXP = ((-0.2120865+0.016079*TSDL)*DAYL1 +                      NASA2091
     .  (-0.2120865+0.016079*TSNL)*DAYL2)                               NASA2092
      IF(ROOTXP.LT.FACR) ROOTXP=FACR
      CALL RIMPED                                                       NASA2093
      KR = KRL(LAYER)                                                   NASA2094
      DO 37 KOLUMN = 1, KR                                              NASA2095
C POTENTIAL DELTA WEIGHT OF ROOTS FOR THE CELL, GM.                     NASA2097
      KP1 = KOLUMN+ 1- (KOLUMN/NK)                                      NASA2098
      KM1 = KOLUMN- 1+(1/KOLUMN)                                        NASA2099
      TEST = RTIMPD(LAYER,KOLUMN)                                       NASA2100
      IF(TEST.LT.RTIMPD(LAYER,KM1)) GO TO 41                            NASA2101
      TEST = RTIMPD(LAYER,KM1)                                          NASA2102
   41 IF(TEST.LT.RTIMPD(LAYER,KP1)) GO TO 42                            NASA2103
      TEST = RTIMPD(LAYER,KP1)                                          NASA2104
   42 IF(TEST.LT.RTIMPD(LP1,KOLUMN)) GO TO 43                           NASA2105
      TEST = RTIMPD(LP1,KOLUMN)                                         NASA2106
   43 RTPCT= (104.6 - 3.53*TEST/1.0216)*.01                             NASA2107
      IF(RTPCT.GT.1.) RTPCT=1.                                          NASA2108
      IF(RTPCT.LT..5) RTPCT=.5                                          NASA2109
C     PDWRT(LAYER,KOLUMN)= PDWRT(LAYER,KOLUMN)*RTPCT                    NASA2110
C  REDUCED POTENTIAL GROWTH BY WEAKEST SOIL STRENGTH CELL                NASA2111
      SPDWRT = SPDWRT + DWRT(LAYER,KOLUMN) *ROOTXP * RTPCT
C SUM OF POTENTIAL DELTA WEIGHT OF ROOTS FOR ALL CELLS, GM.             NASA2113
 37   CONTINUE                                                          NASA2114
 24   CONTINUE                                                          NASA2115
      WSTRSD = (STRSD + WSTRSD)/2                                          2116
      WSTRSN = (STRSN + WSTRSN)/2                                          2117
      RETURN                                                            NASA2118
  2   CONTINUE                                                          NASA2119
      RGCF = RCH2O / SPDWRT                                             NASA2120
C  RCH2O AND SPDWRT ARE IN GRAMS / PLANT AFTER RETURN FROM MAIN.        NASA2121
C ROOT GROWTH CORRECTION FACTOR.  RATIO OF AVAILABLE CARBOHYDRATE       NASA2122
C TO SINK STRENGTH.                                                     NASA2123
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      DO 5 LAYER  = 1, LR                                                NASA2124
      KR = KRL(LAYER)                                                    NASA2125
      DO 5 KOLUMN = 1, KR                                                NASA2126
      IF(IDAY.LE.3) GO TO 7                                              NASA2127
      IF(IDAY.LE.12) GO TO 6                                             NASA2128
      RTWT(LAYER,KOLUMN,3) = RTWT(LAYER,KOLUMN,3) + RTP2 *               NASA2129
     .  RTWT(LAYER,KOLUMN,2)                                             NASA2130
      RTWT(LAYER,KOLUMN,2) = RTWT(LAYER,KOLUMN,2) * (1.-RTP2)            NASA2131
 6    CONTINUE                                                           NASA2132
      RTWT(LAYER,KOLUMN,2) = RTWT(LAYER,KOLUMN,2) + RTP1 *               NASA2133
     .  RTWT(LAYER,KOLUMN,1)                                             NASA2134
      RTWT(LAYER,KOLUMN,1) = RTWT(LAYER,KOLUMN,1) * (1.-RTP1)            NASA2135
    7 DWRT(LAYER,KOLUMN) = RGCF * DWRT(LAYER,KOLUMN) *ROOTXP * RTPCT       2136
C     NOTE THAT RGCF CAN BE MODIFIED BEFORE USE ABOVE.                   NASA2137
C DELTA WEIGHT OF ROOTS, ACTUAL, FOR THE CELL, GM DM.                    NASA2138
C REDUCED FROM PDWRT DUE TO LACK OF CARBOHYDRATE.                        NASA2139
 5    CONTINUE                                                           NASA2140
      LRT = LR                                                           NASA2141
      NLR = LR                                                           NASA2142
      DO 8 L=1,NLR                                                       NASA2143
      LDC = G * (1-L/NL)                                                 NASA2144
      LD1 = L + 1 - (L/NL)                                               NASA2145
      KR = KRL(L)                                                        NASA2146
      DO 9 K=1,KR                                                        NASA2147
      KR1 = K + 1 -(K/NK)                                                NASA2148
       KL1 = K - 1 +(1/K)                                                NASA2149
      IRC = 1 - (K/NK)                                                   NASA2150
       LC = 1 - (1/K)                                                    NASA2151
C                                                                        NASA2152
      IF(RTWT(L,K,1)+RTWT(L,K,2).LT.THRLN) GO TO 10                          2153
      STR1 = (104.6 - 3.53*RTIMPD(L,K)/1.0216)*.01                       NASA2154
      IF(STR1.GT.1.)  STR1 = 1.                                          NASA2155
      IF(STR1.LT.0.)  STR1 = 0.                                          NASA2156
      STRL = (104.6 - 3.53*RTIMPD(L,KL1)/1.0216)*.01                     NASA2157
      IF(STRL.GT.1.)  STRL = 1.                                          NASA2158
      IF(STRL.LT.0.)  STRL = 0.                                          NASA2159
      STRR = (104.6 - 3.53*RTIMPD(L,KR1)/1.0216)*.01                     NASA2160
      IF(STRR.GT.1.)  STRR = 1.                                          NASA2161
      IF(STRR.LT.0.)  STRR = 0.                                          NASA2162
      STRD = (104.6 - 3.53*RTIMPD(LD1,K)/1.0216)*.01                     NASA2163
      IF(STRD.GT.1.)  STRD = 1.                                          NASA2164
      IF(STRD.LT.0.)  STRD = 0.                                          NASA2165
C                                                                        NASA2166
C                                                                        NASA2167
      SRWP = (1./PSIS(L,K)**3+IRC/PSIS(L,KR1)**3+LDC/PSIS(LD1,K)**3    + NASA2168
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     .  LC/PSIS(L,KL1)**3 )                                                    NASA2169
C  GROWTH INSIDE CELL                                                         NASA2170
      RTWT(L,K,1) = RTWT(L,K,1) + DWRT(L,K)*(1./PSIS(L,K)**3)/SRWP           NASA2171
C  GROWTH TO THE LEFT                                                         NASA2172
      RTWT(L,KL1,1)=RTWT(L,KL1,1)+DWRT(L,K)*(LC/PSIS(L,KL1)**3)/SRWP            2173
C  GROWTH TO THE RIGHT                                                        NASA2174
      RTWT(L,KR1,1)=RTWT(L,KR1,1)+DWRT(L,K)*(IRC/PSIS(L,KR1)**3)/SRWP           2175
C  GROWTH DOWNWARD                                                            NASA2176
      RTWT(LD1,K,1)=RTWT(LD1,K,1)+DWRT(L,K)*(LDC/PSIS(LD1,K)**3)/SRWP           2177
C                                                                            NASA2178
      IF(K.NE.KR.OR.KR.GE.6) GO TO 11                                            2179
C  INCREMENT KOLUMN COUNTER FOR THIS LAYER                                    NASA2180
      KRL(L) = KRL(L) + 1                                                    NASA2181
 11   CONTINUE                                                               NASA2182
      IF(L.NE.LR.OR.LR.GE.NL) GO TO 9                                        NASA2183
C  INCREMENT LAYER COUNTER                                                    NASA2184
      IF(K.EQ.1) LRT = LR + 1                                                NASA2185
      KRL(L+1) = KRL(L+1) + 1                                                NASA2186
      GO TO 9                                                                NASA2187
 10   CONTINUE                                                               NASA2188
C  GROWTH INSIDE CELL ONLY                                                    NASA2189
      RTWT(L,K,1) = RTWT(L,K,1) + DWRT(L,K)                                  NASA2190
C                                                                            NASA2191
 9    CONTINUE                                                               NASA2192
 8    CONTINUE                                                               NASA2193
      LR =LRT                                                                NASA2194
C                                                                            NASA2195
      ROOTS = 0.                                                             NASA2196
      PSITOT = 0.                                                            NASA2197
      PSINUM = 0.                                                            NASA2198
      DO 23 LAYER  = 1, LR                                                   NASA2199
      KR = KRL(LAYER)                                                        NASA2200
      DO 25 KOLUMN = 1, KR                                                   NASA2201
C SLOUGH ROOTS IN ALL BOX CARS IN ALL CELLS.                                 NASA2202
      WTBSLF = RTWT(LAYER,KOLUMN,2)                                          NASA2203
      RTWT(LAYER,KOLUMN,2) = WTBSLF*(1. - SLF)                               NASA2204
      WTSLFD = WTSLFD + (WTBSLF-RTWT(LAYER,KOLUMN,2))                        NASA2205
      ROOTSV(LAYER,KOLUMN) = RTWT(LAYER,KOLUMN,1) + RTWT(LAYER,KOLUMN,2)NASA2206
     .    + RTWT(LAYER,KOLUMN,3)                                             NASA2207
      ROOTS = ROOTS + ROOTSV(LAYER,KOLUMN)                                   NASA2208
 23   CONTINUE                                                               NASA2209
      ROOTWT = ROOTS * POPFAC * 2. / ROWSP * 100.                              2210
C  ROOTWT IS DOUBLED TO ACCOUNT FOR FULL PROFILE.                             NASA2211
      DO 25 LAYER = 2, LR                                                    NASA2212
      KR = KRL(LAYER)                                                        NASA2213
      DO 26 KOLUMN = 1, KR                                                   NASA2214
      IF(PSIS(LAYER,KOLUMN).LT.-15.) GO TO 26                                NASA2215
      PSITOT = PSITOT + PSIS(LAYER,KOLUMN)                                   NASA2216
      PSINUM = PSINUM + 1                                                    NASA2217
 26   CONTINUE                                                               NASA2218
 25   CONTINUE                                                               NASA2219
      IF(IFIX(PSINUM).LE.0) GO TO 27                                         NASA2220
      PSIAVG = PSITOT / PSINUM                                               NASA2221
      DROOT = ROOTWT - RUTWT                                                 NASA2222
      RETURN                                                                 NASA2223
   27 PSIAVG = -15.                                                          NASA2224
      WRITE(6,28)                                                            NASA2225
   28 FORMAT(/' ',42(1H*)/' *  PLANT IS DEAD DUE ',                         NASA2226
     .'TO MOISTURE STRESS  *'/' ',42(1H*))                                   NASA2227
      RETURN                                                                 NASA2228
      END                                                                    NASA2229
```

```
      SUBROUTINE RIMPED                                                 2230
C  ***************************************************************************NASA2231
C   THIS SUBROUTINE CALCULATES ROOT IMPEDENCE BASED UPON THE BULK       *NASA2232
C  DENSITY AND WATER CONTENT. THIS IS BASED UPON DATA FROM ARTICLES BY  *NASA2233
C  R.B.CAMPBELL,D.C.REICOSKY,AND C.W.DOTY J.OF SOIL AND WATER CONS.     *NASA2234
C  29:220-224,1974 AND                                                  *NASA2235
C  H.M.TAYLOR AND H.R.GARDNER. SOIL SCI.96:153-156,1963.                *NASA2236
C   A LINEAR TABLE LOOK-UP PROCEDURE IS USED. ASSUME ALL CURVES ARE     *NASA2237
C  READ AT THE SAME BD.                                                 *NASA2238
C                                                                       *NASA2239
C  ***************************************************************************NASA2240
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W             2241
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)                            2242
      COMMON /SOILID/ DIFFD(5),THETAD(5),BETA(5),SDEPTH(5),THETAS(5),   NASA2243
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)          2244
      COMMON /ROOTIM/ RTIMPD(20,6),SNAME(3),TSTBD(9,20),INRT,MRT          2245
     .    ,TSTIMP(9,20),GH2OC(9),FACR                                    2246
      J = 1                                                             NASA2247
C                                                                       NASA2248
      NKH = NK/2                                                        NASA2249
      DO 99 LAYER = 1,NL                                                NASA2250
   24 IF(LAYER*D.LE.SDEPTH(J))GO TO 25                                  NASA2251
      J=J+1                                                             NASA2252
      IF(J.LT.5)GO TO 24                                                NASA2253
C                                                                       NASA2254
   25 JJ = 1                                                            NASA2255
   26 IF(BD(J)-TSTBD(1,JJ))30,30,27                                     NASA2256
   27 JJ = JJ+1                                                         NASA2257
      IF(JJ.LE.INRT)GO TO 26                                            NASA2258
      JJ = JJ-1                                                         NASA2259
C                                                                       NASA2260
   30 DO 98 KOLUMN = 1,NKH                                              NASA2261
      TEST1=VH2OC(LAYER,KOLUMN)/BD(J)                                   NASA2262
      IK = 1                                                            NASA2263
   32 IF(TEST1-GH2OC(IK))35,40,33                                       NASA2264
   33 IK = IK+1                                                         NASA2265
      IF(IK.LE.MRT)GO TO 32                                             NASA2266
      IK = IK-1                                                         NASA2267
C  SOIL CELL H2O LESS THAN TEST H2O                                     NASA2268
   35 IF(IK.EQ.1)GO TO 40                                               NASA2269
C  CALCULATE SOIL STRENGTH                                              NASA2270
C   FOR VALUES OF BD LESS THAN TABLE VALUES                             NASA2271
      IF(JJ.GT.1)GO TO 39                                               NASA2272
      RTIMPD(LAYER,KOLUMN)=TSTIMP(IK-1,JJ)-(TSTIMP(IK-1,JJ)-TSTIMP(IK,JJNASA2273
     .))*((TEST1-GH2OC(IK-1))/(GH2OC(IK)-GH2OC(IK-1)))                  NASA2274
```

```
      GO TO 98                                                          NASA2275
C   FOR VALUES OF BD AND H2O BETWEEN TABLE VALUES                       NASA2276
   39 TEMP1=TSTIMP(IK,JJ-1)-(TSTIMP(IK,JJ-1)-TSTIMP(IK,JJ))*((TSTBD(IK, NASA2277
     .JJ-1)-BD(J))/(TSTBD(IK,JJ-1)-TSTBD(IK,JJ)))                       NASA2278
      TEMP2=TSTIMP(IK-1,JJ-1)-(TSTIMP(IK-1,JJ-1)-TSTIMP(IK-1,JJ))*((TSTBNASA2279
     .D(IK-1,JJ-1)-BD(J))/(TSTBD(IK-1,JJ-1)-TSTBD(IK-1,JJ)))            NASA2280
C                                                                       NASA2281
      RTIMPD(LAYER,KOLUMN)=TEMP2+(TEMP1-TEMP2)*((TEST1-GH2OC(IK-1))/(GH2NASA2282
     .OC(IK)-GH2OC(IK-1)))                                              NASA2283
      GO TO 98                                                          NASA2284
C   FOR VALUES OF H2O LESS THAN OR EQUAL TO TABLE H2O                   NASA2285
   40 RTIMPD(LAYER,KOLUMN)=TSTIMP(IK,JJ-1)-(TSTIMP(IK,JJ-1)-TSTIMP(IK,JJNASA2286
     .))*((TSTBD(IK,JJ-1)-BD(J))/(TSTBD(IK,JJ-1)-TSTBD(IK,JJ)))         NASA2287
C                                                                       NASA2288
   98 CONTINUE                                                          NASA2289
   99 CONTINUE                                                          NASA2290
C                                                                       NASA2291
      NKH = NKH+1                                                       NASA2292
      DO 109 KOLUMN=NKH,NK                                              NASA2293
      NKK=NK+1-KOLUMN                                                   NASA2294
      DO 108 LAYER = 1,NL                                               NASA2295
  108 RTIMPD(LAYER,KOLUMN)=RTIMPD(LAYER,NKK)                            NASA2296
  109 CONTINUE                                                          NASA2297
C                                                                       NASA2298
      RETURN                                                            NASA2299
      END                                                               NASA2300
```

```
      SUBROUTINE OUT(ARRAY,TTL1,TTL2,RANGE,UNITS,TOTAL,UNITST)          NASA2301
C  ***************************************************************    NASA2302
C  *                                                             *    NASA2303
C  *  THIS SUBROUTINE PLOTS THE SOIL SLAB AND THE DENSITIES      *    NASA2304
C  *  OF THE ARRAY ELEMENTS IN EACH CELL.                        *    NASA2305
C  *                                                             *    NASA2306
C  ***************************************************************    NASA2307
      INTEGER DAYNUM
      DIMENSION ARRAY(20,6), RANGE(11)                                    2308
      DIMENSION TTL1(10), TTL2(10), UNITS(6), UNITST(4)                NASA2309
C                                                                      NASA2310
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT       2311
      COMMON /PLOTS / NPN, NPP, NPR, NPW                                  2312
      COMMON /LOCOUT/ KA(12),KHAR(20,6)                                   2313
C                                                                      NASA2314
      DO 1 K=1, 6                                                      NASA2315
      DO 1 L=1, 20                                                     NASA2316
      ARAYLK = ARRAY(L,K)                                              NASA2317
      DO 2 I=1, 11                                                     NASA2318
      RANGE1 = RANGE(I)                                                NASA2319
      IF(ARAYLK.LE.RANGE1) GO TO 1                                     NASA2320
 2    CONTINUE                                                         NASA2321
      I = 12                                                           NASA2322
 1    KHAR(L,K) = KA(I)                                                NASA2323
      RANGE1 = RANGE(1)                                                NASA2324
      WRITE(6,100) TTL1,DAYNUM,TTL2,UNITS,KA(1),RANGE1,RANGE1,KA(2),     NASA23
     .  RANGE(2)                                                       NASA2326
 100  FORMAT(/6X,10A4,10X,'JULIAN DAY ',I3/6X,10A4//6X,'UNITS - ',6A4
     . ,5X,'LEGEND'/6X,'1 2 3 4 5 6 ',18X,A1,' <= ',F8.4/25X,
     . F8.4,' < ',A1,' <= ',F8.4)                                      NASA2329
      DO 14 L=1, 17, 2                                                    2330
      L1=L+1                                                              2331
14    WRITE(6,102)L,(KHAR(L,K),K=1,6),L1,(KHAR(L+1,K),K=1,6),             2332
     . RANGE((L+3)/2),KA((L+3)/2+1),RANGE((L+3)/2+1)                      2333
 102  FORMAT(1X,I2,3X,6A2 / 1X,I2,3X,6A2,7X,F8.4,' < ',                   2334
     .  A1,' <= ',F8.4)                                                   2335
      L19=19                                                              2336
      L20=20                                                              2337
      WRITE(6,104) L19,(KHAR(19,K),K=1,6),L20,(KHAR(20,K),K=1,6),         2338
     . RANGE(11),KA(12),TOTAL,UNITST                                      2339
 104  FORMAT(1X,I2,3X,6A2 / 1X,I2,3X,6A2,7X,F8.4,' < ', A1 //             2340
     . 6X,'TOTAL = ',F11.4,1X,4A4)                                        2341
      RETURN                                                           NASA2342
      END                                                              NASA2343
```

Appendix b. Typical Input Data Set

Terminal Input

LEAFW(1,1)	RTWT(1,1,1)	RTWT(1,2,1)	RTWT(2,1,1)	RTWT(3,1,1)
1	.020	.004	.007	.002

PNFAC	POPLT	FZ	LATITUDE	LAI	NOITR	FACR
.01	500000	.5	40	.0001	5	.09

KL	KS	KR	KG	JL	JS	JR	JG	JG1
.01	.01	.01	.01	.03	.03	.03	.03	.03

LEAFLENGTH	ROWSPACE	PRINT	G	THRLN	FACL
1.	30.	25	3	.2E-4	3

RNNH4=60 RNNO3=40.

```
5
0.051     0.168    40.12    22.50    0.420    0.160    -30.0    2.940    1.520
0.201     0.258    43.19    52.50    0.500    0.250    -15.0    2.770    1.320
0.175     0.162    32.83    90.10    0.480    0.160    -30.0    3.020    1.370
0.199     0.140    29.37   150.1     0.480    0.135    -5.00    2.370    1.370
0.183     0.104    27.93   200.1     0.480    0.100    -15.0    2.780    1.370
 0   41.
NO FOLK S L 7
 6    .05
0.9     .1
1.1    5.4
1.3   16.2
1.5   36.0
1.7   62.0
1.9   93.0
 6    .07
0.9     .1
1.1    2.5
1.3    7.8
1.5   22.6
1.7   44.5
1.9   71.3
 6    .09
0.9     .1
1.1    1.0
1.3    2.3
1.5   12.8
1.7   30.4
1.9   52.6
 6    .11
0.9     .1
1.1     .9
1.3    1.7
1.5    7.5
1.7   21.5
1.9   31.2
 6    .13
0.9     .1
1.1     .5
1.3    1.0
1.5    5.6
1.7   15.2
1.9   29.8
 6    .15
0.9     .1
```

```
 1.1    .2
 1.3    .5
 1.5   4.9
 1.7  13.9
 1.9  27.7
  6   .30
0.9    .1
 1.1    .2
 1.3    .5
 1.5    .9
 1.7   1.1
 1.9   1.3
340  12.2   1.7   0 0.00   0 263 120 155.0  5.00  9999  11.3 999.0 999.0
490  20.6   0.0   0 0.00   0 264   0  44.0  5.00  9999  13.1 999.0 999.0
509  25.6   6.1   0 0.00   0 265   0  86.0  5.00  9999  16.4 999.0 999.0
496  30.6   8.9   0 0.00   0 266   0 114.0  5.00  9999  19.0 999.0 999.0
256  25.6   8.3   0 0.00   0 267   0 114.0  5.00  9999  17.2 999.0 999.0
380  22.2  10.6   0 0.00   0 268   0 115.0  5.00  9999  16.9 999.0 999.0
484  27.8   7.8   0 0.00   0 269   0  97.0  5.00  9999  17.7 999.0 999.0
452  27.8   7.2   0 0.00   0 270   0  59.0  5.00  9999  17.6 999.0 999.0
364  30.0  13.9   0 0.00   0 271   0 137.0  5.00  9999  20.2 999.0 999.0
448  20.6   7.2   0 0.00   0 272   0 115.0  5.00  9999  15.4 999.0 999.0
475  25.6   3.9   0 0.00   0 273   0  96.0  5.00  9999  15.9 999.0 999.0
404  25.6   3.9   0 0.00   0 274   0  96.0  5.00  9999  15.9 999.0 999.0
366  25.6   3.9   0 0.00   0 275   0  96.0  5.00  9999  15.9 999.0 999.0
450  25.6   3.9   0 0.00   0 276   0  96.0  5.00  9999  15.9 999.0 999.0
437  18.1   1.1   0 0.00   0 277   0 242.3 13.60  12.8  13.3 999.0 999.0
440  15.8  -1.6   0 0.00   0 278   0 162.8 10.60  10.9  11.3 999.0 999.0
437  20.4  -4.1   0 0.00   0 279   0  90.7 12.60  12.3  12.7 999.0 999.0
432  24.6  -1.0   0 0.00   0 280   0  96.6 16.00  14.3  14.4 999.0 999.0
399  26.8   6.2   0 0.00   0 281   0  90.1 21.70  17.4  17.2 999.0 999.0
414  21.7   5.1   0 0.00   0 282   0  95.2 16.60  16.0  16.3 999.0 999.0
416  25.3   3.6   0 0.00   0 283   0 174.2 17.90  15.2  15.5 999.0 999.0
403  25.7   8.0   0 0.00   0 284   0 203.3 19.70  16.1  16.3 999.0 999.0
404  14.8   5.9   0 0.00   0 285   0 307.2 12.60  12.6  13.2 999.0 999.0
410  13.2  -1.5   0 0.00   0 286   0 138.7  9.90  10.9  11.6 999.0 999.0
401  18.7  -1.8   0 0.00   0 287   0 113.4 11.20  10.3  11.0 999.0 999.0
396  21.9   2.4   0 0.00   0 288   0 146.2 14.50  12.2  12.7 999.0 999.0
390  21.1  -1.4   0 0.00   0 289   0 221.7 13.90  11.7  12.3 999.0 999.0
310  20.2    .4   0 0.00   0 290   0 209.7 15.30  13.1  13.4 999.0 999.0
205  12.8    .5   0 0.00   0 291   0 115.1 10.10   9.7  10.6 999.0 999.0
308  24.5   2.8   0 0.00   0 292   0 190.7  7.40  12.3  12.5 999.0 999.0
289  25.5   2.1   0 0.00   0 293   0 123.2  4.90  14.1  13.8 999.0 999.0
202  19.6   8.4   0  .05   0 294   0 125.0  7.50  15.2  15.0 999.0 999.0
 62   7.9   -.4   0  .45   0 295   0 305.7  7.20   4.9   5.5 999.0 999.0
```

339	12.9	-2.0	0	0.00	0	296	0	161.2	7.10	6.3	6.4	999.0	999.0
334	20.5	.6	0	0.00	0	297	0	168.6	7.50	8.7	8.4	999.0	999.0
161	7.3	-2.4	0	0.00	0	298	0	269.4	6.50	5.1	5.3	999.0	999.0
332	17.5	-2.5	0	0.00	0	299	0	176.0	5.60	5.4	5.3	999.0	999.0
328	18.1	-.1	0	0.00	0	300	0	148.7	5.70	7.0	6.8	999.0	999.0
321	23.3	.3	0	0.00	0	301	0	178.7	5.20	8.1	7.8	999.0	999.0
327	24.6	-1.4	0	0.00	0	302	0	229.6	5.20	8.8	8.5	999.0	999.0
282	9.9	2.4	0	0.00	0	303	0	224.8	5.50	7.8	7.7	999.0	999.0
302	15.7	-3.9	0	0.00	0	304	0	109.4	5.60	7.3	7.3	999.0	999.0
234	19.1	-.3	0	0.00	0	305	0	86.0	7.30	8.8	8.5	999.0	999.0
298	22.1	.6	0	0.00	0	306	0	120.5	6.30	9.0	8.8	999.0	999.0
267	20.6	-.2	0	0.00	0	307	0	84.3	6.00	8.3	8.2	999.0	999.0
280	21.1	.3	0	0.00	0	308	0	209.0	8.70	9.7	9.5	999.0	999.0
155	9.2	0.0	0	0.00	0	309	0	172.2	3.50	6.9	7.1	999.0	999.0
278	12.9	-5.3	0	0.00	0	310	0	132.5	4.00	4.8	5.1	999.0	999.0
274	19.7	-3.1	0	0.00	0	311	0	195.8	4.20	7.0	6.9	999.0	999.0
254	23.8	1.2	0	0.00	0	312	0	176.8	4.80	9.1	8.9	999.0	999.0
280	16.5	1.3	0	0.00	0	313	0	154.1	5.10	8.4	8.3	999.0	999.0
57	1.3	-7.3	0	0.00	0	314	0	327.3	4.60	1.5	2.3	999.0	999.0
71	-4.7	-8.3	0	0.00	0	315	0	198.8	3.30	-1.5	-.8	999.0	999.0
68	3.9	-5.9	0	0.00	0	316	0	218.2	5.70	1.1	1.4	999.0	999.0
243	9.4	-7.1	0	0.00	0	317	0	172.0	4.10	1.0	1.2	999.0	999.0
135	-1.6	-8.4	0	0.00	0	318	0	95.7	3.20	.1	.6	999.0	999.0
125	1.2	-6.4	0	0.00	0	319	0	64.6	4.50	1.0	1.4	999.0	999.0
243	9.4	-7.5	0	0.00	0	320	0	100.7	4.10	.6	.7	999.0	999.0
253	9.6	-6.3	0	0.00	0	321	0	198.5	3.20	.5	.3	999.0	999.0
250	7.0	-8.1	0	0.00	0	322	0	167.3	3.20	0.0	0.0	999.0	999.0
47	-4.7	-11.7	0	0.00	0	323	0	267.3	2.90	-3.7	-3.0	999.0	999.0
50	-6.4	-11.7	0	0.00	0	324	0	168.3	2.40	-4.8	-4.1	999.0	999.0
77	-2.2	-10.5	0	0.00	0	325	0	126.8	3.60	-3.0	-2.5	999.0	999.0
190	7.9	-6.1	0	0.00	0	326	0	122.5	4.40	-.7	-.6	999.0	999.0
223	12.1	-7.3	0	0.00	0	327	0	251.4	3.10	-.3	-.4	999.0	999.0
138	6.9	-7.9	0	0.00	0	328	0	115.2	3.70	-.3	-.4	999.0	999.0
50	1.3	-3.2	0	.06	0	329	0	154.3	6.00	.3	.4	999.0	999.0
93	-.6	-4.0	0	0.00	0	330	0	205.3	4.70	.4	.4	999.0	999.0
227	.8	-9.0	0	0.00	0	331	0	192.6	3.60	-.5	-.5	999.0	999.0
107	5.2	-9.2	0	.03	0	332	0	144.1	4.70	-.7	-.6	999.0	999.0
213	6.7	-5.2	0	.02	0	333	0	125.5	4.20	-.3	-.4	999.0	999.0
194	11.3	-4.2	0	.02	0	334	0	122.5	4.60	.3	-.1	999.0	999.0
200	8.7	-9.6	0	.06	0	335	0	266.4	4.50	1.0	.9	999.0	999.0
153	-8.2	-16.1	0	.05	0	336	0	327.8	1.50	-1.1	-1.0	999.0	999.0
222	-5.2	-16.3	0	0.00	0	337	0	205.6	1.50	-2.0	-2.1	999.0	999.0
75	-4.9	-12.8	0	0.00	0	338	0	237.1	2.50	-1.6	-1.8	999.0	999.0
78	-4.9	-19.7	0	0.00	0	339	0	152.4	2.40	-1.0	-1.4	999.0	999.0
133	-7.8	-19.7	0	0.00	0	340	0	160.2	1.50	-1.8	-2.0	999.0	999.0

133	-13.4	-23.3	0	.11	0	341	0	160.2	1.50	-1.8	-2.0	999.0	999.0
133	-15.4	-28.0	0	0.00	0	342	0	160.2	1.50	-1.8	-2.0	999.0	999.0
133	-4.3	-25.5	0	0.00	0	343	0	160.2	1.50	-1.8	-2.0	999.0	999.0
141	.5	-14.9	0	0.00	0	344	0	191.4	2.70	-2.8	-2.8	999.0	999.0
218	3.3	-16.3	0	0.00	0	345	0	196.9	2.80	-2.6	-2.7	999.0	999.0
192	5.2	-11.2	0	0.00	0	346	0	178.2	3.60	-1.6	-1.7	999.0	999.0
214	1.6	-15.2	0	0.00	0	347	0	117.4	2.60	-3.0	-3.2	999.0	999.0
216	4.6	-8.9	0	0.00	0	348	0	192.0	3.10	-2.7	-2.8	999.0	999.0
199	4.4	-11.3	0	0.00	0	349	0	146.9	3.10	-2.7	-2.8	999.0	999.0
215	1.3	-12.0	0	0.00	0	350	0	194.4	2.10	-3.3	-3.5	999.0	999.0
215	.8	-12.5	0	0.00	0	351	0	194.4	2.10	-3.3	-3.5	999.0	999.0
215	.4	-7.0	0	0.00	0	352	0	194.4	2.10	-3.3	-3.5	999.0	999.0
193	7.5	-4.2	0	0.00	0	353	0	160.6	5.60	-.5	-.7	999.0	999.0
205	-1.5	-9.6	0	.02	0	354	0	313.2	2.90	-1.1	-1.5	999.0	999.0
200	4.7	-12.3	0	0.00	0	355	0	150.1	3.20	-2.7	-3.1	999.0	999.0
204	3.7	-12.0	0	0.00	0	356	0	205.0	3.60	-2.4	-2.7	999.0	999.0
123	1.3	-12.4	0	0.00	0	357	0	253.2	3.50	-2.5	-2.7	999.0	999.0
204	5.7	-9.9	0	0.00	0	358	0	207.4	3.80	-2.8	-2.8	999.0	999.0
170	-.1	-7.5	0	0.00	0	359	0	209.6	3.30	-2.7	-3.0	999.0	999.0
206	0.0	-14.5	0	0.00	0	360	0	120.7	2.60	-4.8	-5.1	999.0	999.0
190	5.9	-14.1	0	0.00	0	361	0	142.5	3.00	-4.7	-4.8	999.0	999.0
207	8.1	-13.2	0	0.00	0	362	0	171.1	3.20	-3.3	-3.6	999.0	999.0
127	-11.1	-19.2	0	0.00	0	363	0	205.7	1.10	-9.1	-9.3	999.0	999.0
145	-10.5	-21.1	0	0.00	0	364	0	104.2	1.00	-8.6	-8.6	999.0	999.0
185	-11.4	-20.9	0	0.00	0	365	0	114.3	1.10	-9.0	-9.2	999.0	999.0
189	-12.8	-24.8	0	0.00	0	1	0	319.5	.70	-12.8	-13.4	999.0	999.0
131	-4.1	-22.0	0	0.00	0	2	0	117.7	1.10	-11.7	-11.9	999.0	999.0
118	-1.8	-16.6	0	0.00	0	3	0	106.4	1.80	-7.8	-7.9	999.0	999.0
122	-8.7	-18.1	0	0.00	0	4	0	231.2	1.40	-9.7	-9.7	999.0	999.0
159	-9.3	-18.8	0	0.00	0	5	0	137.3	1.20	-9.6	-9.8	999.0	999.0
159	-5.4	-15.0	0	0.00	0	6	0	152.0	1.50	-8.4	-8.7	999.0	999.0
207	-5.8	-21.7	0	0.00	0	7	0	173.7	.90	-11.2	-11.7	999.0	999.0
211	.4	-20.7	0	0.00	0	8	0	141.3	1.30	-11.4	-11.7	999.0	999.0
202	.6	-18.3	0	0.00	0	9	0	133.8	1.70	-9.4	-9.7	999.0	999.0
192	-7.0	-15.2	0	0.00	0	10	0	240.7	1.60	-9.1	-9.2	999.0	999.0
126	5.4	-12.6	0	0.00	0	11	0	107.8	3.40	-5.7	-5.8	999.0	999.0
51	-2.3	-18.0	0	.04	0	12	0	261.2	2.40	-6.8	-6.7	999.0	999.0
250	-10.1	-23.3	0	0.00	0	13	0	163.1	.90	-9.4	-10.4	999.0	999.0
241	2.9	-27.0	0	0.00	0	14	0	126.6	1.10	-10.2	-11.8	999.0	999.0
208	7.6	-16.8	0	0.00	0	15	0	143.1	2.70	-6.4	-7.8	999.0	999.0
249	6.4	-17.4	0	0.00	0	16	0	123.9	3.20	-6.1	-7.0	999.0	999.0
246	3.3	-16.9	0	0.00	0	17	0	163.1	3.10	-5.8	-6.1	999.0	999.0
68	3.4	-7.2	0	.15	0	18	0	164.5	4.90	-3.1	-3.3	999.0	999.0
205	6.0	-13.4	0	0.00	0	19	0	175.0	3.40	-3.9	-4.2	999.0	999.0
268	.3	-6.8	0	0.00	0	20	0	476.5	3.50	-3.2	-3.4	999.0	999.0

261	5.7	-9.5	0	0.00	0	21	0	185.4	3.80	-3.4	-3.5	999.0	999.0
104	2.3	-15.9	0	0.00	0	22	0	352.1	3.00	-4.8	-5.1	999.0	999.0
277	-3.4	-20.3	0	0.00	0	23	0	276.5	1.40	-9.7	-9.9	999.0	999.0
261	4.8	-16.9	0	0.00	0	24	0	171.3	2.50	-7.4	-7.6	999.0	999.0
148	-2.9	-11.5	0	0.00	0	25	0	255.8	3.00	-5.9	-6.2	999.0	999.0
263	-7.7	-16.3	0	0.00	0	26	0	230.7	1.80	-8.0	-8.2	999.0	999.0
282	-6.3	-21.6	0	0.00	0	27	0	184.9	1.20	-10.2	-10.5	999.0	999.0
288	-4.8	-23.7	0	0.00	0	28	0	133.6	1.20	-10.7	-11.0	999.0	999.0
217	-10.8	-22.2	0	0.00	0	29	0	248.3	1.20	-9.8	-10.0	999.0	999.0
295	-12.7	-27.1	0	0.00	0	30	0	204.9	.80	-10.4	-10.4	999.0	999.0
311	-4.1	-27.4	0	0.00	0	31	0	118.3	.80	-11.3	-11.2	999.0	999.0
291	3.0	-22.2	0	0.00	0	32	0	131.1	1.50	-10.5	-10.4	999.0	999.0
296	-8.1	-25.6	0	0.00	0	33	0	107.0	1.00	-11.1	-10.9	999.0	999.0
317	-.2	-23.1	0	0.00	0	34	0	156.5	1.30	-10.6	-10.4	999.0	999.0
291	-2.4	-19.2	0	0.00	0	35	0	137.2	1.80	-10.0	-9.8	999.0	999.0
324	1.3	-19.9	0	0.00	0	36	0	145.7	1.80	-9.5	-9.4	999.0	999.0
271	.5	-12.0	0	0.00	0	37	0	168.9	2.90	-7.3	-7.2	999.0	999.0
197	4.2	-11.2	0	0.00	0	38	0	210.9	3.80	-5.8	-5.7	999.0	999.0
333	.8	-9.3	0	0.00	0	39	0	293.5	2.60	-4.4	-4.9	999.0	999.0
284	5.4	-11.8	0	0.00	0	40	0	170.0	3.80	-3.8	-4.1	999.0	999.0
314	9.7	-7.8	0	0.00	0	41	0	112.1	4.50	-2.2	-2.4	999.0	999.0
279	9.6	-4.6	0	0.00	0	42	0	126.0	4.90	-.5	-.6	999.0	999.0
216	11.4	-1.3	0	0.00	0	43	0	113.9	5.60	.1	-.1	999.0	999.0
276	17.8	-2.1	0	0.00	0	44	0	117.0	6.20	1.3	.8	999.0	999.0
345	17.7	-2.4	0	0.00	0	45	0	168.7	6.40	3.2	2.7	999.0	999.0
347	2.3	-16.4	0	0.00	0	46	0	287.5	2.10	-2.3	-2.8	999.0	999.0
196	-2.8	-18.6	0	0.00	0	47	0	254.4	1.30	-6.5	-6.6	999.0	999.0
336	6.4	-13.2	0	0.00	0	48	0	290.9	2.60	-4.0	-4.2	999.0	999.0
370	10.8	-10.9	0	0.00	0	49	0	155.6	3.10	-2.1	-2.4	999.0	999.0
348	13.1	-3.9	0	0.00	0	50	0	138.3	3.70	0.0	-.5	999.0	999.0
306	8.3	-5.8	0	0.00	0	51	0	270.4	3.30	.7	.5	999.0	999.0
283	6.5	-6.0	0	0.00	0	52	0	278.7	4.20	-.6	-1.0	999.0	999.0
360	7.7	-5.8	0	0.00	0	53	0	222.0	3.60	.3	0.0	999.0	999.0
320	2.1	-10.0	0	0.00	0	54	0	189.5	3.10	-1.0	-1.2	999.0	999.0
278	6.5	-7.4	0	0.00	0	55	0	203.8	3.20	-1.2	-1.3	999.0	999.0
299	9.6	-8.6	0	0.00	0	56	0	130.9	2.90	-.5	-.7	999.0	999.0
347	14.1	-4.6	0	0.00	0	57	0	109.9	3.80	2.0	1.4	999.0	999.0
84	2.3	-2.4	0	0.00	0	58	0	302.1	5.50	-.8	-.6	999.0	999.0
404	11.4	-3.0	0	0.00	0	59	0	146.6	5.10	2.9	2.5	999.0	999.0
369	12.9	-5.5	0	0.00	0	60	0	135.0	5.10	3.7	3.0	999.0	999.0
24	8.0	-7.4	0	0.00	0	61	0	278.2	4.80	1.5	1.5	999.0	999.0
40	.3	-11.0	0	0.00	0	62	0	358.8	2.60	-1.9	-1.9	999.0	999.0
42	7.5	-11.6	0	0.00	0	63	0	257.8	2.40	-1.0	-1.4	999.0	999.0
273	12.6	-7.2	0	0.00	0	64	0	239.9	3.60	2.5	1.7	999.0	999.0
243	12.9	-1.0	0	0.00	0	65	0	270.6	5.60	5.1	4.4	999.0	999.0

362	16.7	3.7	0	0.00	0	66	0	253.5	6.80	8.6	7.7	999.0	999.0
236	8.1	-1.6	0	.08	0	67	0	166.4	6.00	4.3	3.7	999.0	999.0
331	1.8	-9.1	0	.23	0	68	0	140.1	4.30	.4	.2	999.0	999.0
469	7.9	-11.3	0	0.00	0	69	0	194.0	3.70	-.1	-.2	999.0	999.0
473	17.2	-1.9	0	0.00	0	70	0	169.0	5.10	4.2	3.8	999.0	999.0
439	19.1	-2.7	0	0.00	0	71	0	146.5	5.30	5.9	5.4	999.0	999.0
338	7.5	-6.5	0	0.00	0	72	0	350.2	3.70	2.3	2.2	999.0	999.0
485	13.0	-8.7	0	0.00	0	73	0	129.6	3.50	3.5	2.8	999.0	999.0
414	12.9	-3.8	0	0.00	0	74	0	282.3	5.90	5.2	4.6	999.0	999.0
289	16.3	-2.3	0	0.00	0	75	0	272.9	6.70	5.8	5.1	999.0	999.0
330	16.1	-2.1	0	.03	0	76	0	140.1	5.60	7.6	6.9	999.0	999.0
114	4.9	-2.2	0	.35	0	77	0	273.6	6.40	1.7	2.0	999.0	999.0
486	3.9	-4.1	0	0.00	0	78	0	196.2	5.50	3.8	3.0	999.0	999.0
152	5.2	-4.0	0	0.00	0	79	0	179.0	5.80	1.8	1.5	999.0	999.0
65	7.0	-1.2	0	.02	0	80	0	239.2	7.20	2.6	2.1	999.0	999.0
227	3.7	-4.3	0	.26	0	81	0	42.7	5.50	.6	.7	999.0	999.0
525	3.2	-8.6	0	0.00	0	82	0	288.0	4.70	0.0	.4	999.0	999.0
533	8.0	-5.1	0	0.00	0	83	0	216.6	5.50	.4	.5	999.0	999.0
523	12.6	-3.0	0	0.00	0	84	0	281.0	6.10	3.7	3.4	999.0	999.0
214	1.0	-6.0	0	0.00	0	85	0	261.5	4.60	.9	1.0	999.0	999.0
520	17.2	-1.8	0	0.00	0	86	0	232.7	6.70	6.1	5.7	999.0	999.0
474	18.2	1.1	0	0.00	0	87	0	155.1	7.10	9.0	8.4	999.0	999.0
401	14.3	-.2	0	0.00	0	88	0	244.1	7.40	7.2	6.8	999.0	999.0
464	10.6	-1.1	0	.03	0	89	0	224.0	6.20	7.3	6.9	999.0	999.0
91	3.4	-1.9	0	.06	0	90	0	253.6	6.10	1.8	2.1	999.0	999.0
349	.3	-4.2	0	.05	0	91	0	231.3	4.60	.5	.8	999.0	999.0
513	4.9	-6.9	0	0.00	0	92	0	131.3	4.40	3.9	3.7	999.0	999.0
219	2.6	-4.8	0	0.00	0	93	0	165.3	4.90	1.6	1.7	999.0	999.0
476	9.7	-4.3	0	0.00	0	94	0	277.4	4.40	3.2	3.1	999.0	999.0
474	15.1	-2.8	0	0.00	0	95	0	218.0	5.60	5.9	5.5	999.0	999.0
503	17.0	-2.9	0	0.00	0	96	0	235.3	6.90	7.8	7.4	999.0	999.0
524	22.5	-.2	0	0.00	0	97	0	256.3	6.20	10.4	9.7	999.0	999.0
590	15.0	.9	0	0.00	0	98	0	217.0	5.30	10.0	9.5	999.0	999.0
520	21.9	-.9	0	0.00	0	99	0	307.0	6.30	11.0	10.6	999.0	999.0
50	6.4	2.5	0	.13	0	100	0	268.3	7.70	5.3	5.5	999.0	999.0
182	4.7	-3.1	0	.26	0	101	0	173.1	6.20	2.0	2.1	999.0	999.0
585	6.6	-3.9	0	0.00	0	102	0	393.1	5.00	3.9	3.4	999.0	999.0
471	15.5	-2.6	0	0.00	0	103	0	192.6	5.70	6.3	5.8	999.0	999.0
563	19.3	-1.0	0	0.00	0	104	0	124.9	6.90	9.9	9.4	999.0	999.0
593	24.9	-.4	0	.02	0	105	0	171.2	6.50	12.7	12.4	999.0	999.0
587	26.1	4.3	0	0.00	0	106	0	270.3	8.80	14.4	13.9	999.0	999.0
304	25.8	6.4	0	0.00	0	107	0	337.4	10.30	14.2	14.2	999.0	999.0
483	27.0	9.1	0	0.00	0	108	0	351.2	11.20	16.8	16.5	999.0	999.0
508	20.9	5.1	0	0.00	0	109	0	306.8	8.20	16.0	15.7	999.0	999.0
604	16.3	3.2	0	0.00	0	110	0	149.1	7.00	13.2	13.3	999.0	999.0

561	22.1	2.4	0	0.00	0	111	0	286.6	6.50	14.7	14.6	999.0	999.0
589	25.7	3.5	0	0.00	0	112	0	216.7	7.20	17.1	16.7	999.0	999.0
543	28.1	8.2	0	0.00	0	113	0	275.4	8.00	19.2	18.5	999.0	999.0
443	19.5	6.3	0	0.00	0	114	0	237.8	8.90	16.6	16.4	999.0	999.0
424	12.1	-.7	0	0.00	0	115	0	218.2	7.90	12.1	12.7	999.0	999.0
494	16.7	-.9	0	0.00	0	116	0	186.5	6.80	12.2	12.1	999.0	999.0
483	12.5	1.1	0	0.00	0	117	0	155.6	6.10	11.0	11.5	999.0	999.0
517	17.0	-1.8	0	0.00	0	118	0	243.5	5.70	11.3	11.4	999.0	999.0
626	19.2	-6.0	0	0.00	0	119	0	147.5	4.70	13.4	13.2	999.0	999.0
579	16.0	-2.2	0	0.00	0	120	0	263.7	6.50	13.8	13.9	999.0	999.0
449	20.7	7.0	0	.91	0	121	0	195.9	10.30	16.3	15.6	999.0	999.0
125	9.7	1.2	0	.63	0	122	0	305.5	8.10	7.2	7.4	999.0	999.0
407	8.7	-1.4	0	0.00	0	123	0	149.7	6.10	7.3	7.5	999.0	999.0
649	17.4	-1.8	0	0.00	0	124	0	177.3	7.50	10.8	10.8	999.0	999.0
574	26.1	6.1	0	0.00	0	125	0	212.4	9.10	13.9	13.6	999.0	999.0
646	28.3	7.2	0	0.00	0	126	0	235.4	7.80	14.8	14.9	999.0	999.0
495	17.9	3.1	0	.04	0	127	0	217.0	5.80	12.1	12.6	999.0	999.0
78	7.1	-.2	0	.70	0	128	0	279.2	8.00	6.2	6.5	999.0	999.0
147	3.7	-4.1	0	.29	0	129	0	174.1	5.60	2.1	2.5	999.0	999.0
544	4.2	-5.1	0	.29	0	130	0	209.0	5.30	2.6	2.7	999.0	999.0
635	16.2	-1.5	0	0.00	0	131	0	153.4	5.30	8.6	8.6	999.0	999.0
457	14.4	3.8	0	.11	0	132	0	139.5	8.50	10.1	10.3	999.0	999.0
596	20.6	1.0	0	0.00	0	133	0	133.7	8.80	12.3	12.4	999.0	999.0
605	22.5	6.6	0	.39	0	134	0	183.5	10.00	13.9	14.1	999.0	999.0
562	23.4	8.9	0	0.00	0	135	0	321.7	12.10	14.7	14.8	999.0	999.0
473	28.0	9.7	0	0.00	0	136	0	163.3	12.20	16.9	16.8	999.0	999.0
399	25.6	9.1	0	0.00	0	137	0	147.9	12.90	15.8	15.7	999.0	999.0
629	25.0	4.1	0	0.00	0	138	0	138.9	9.80	16.3	16.4	999.0	999.0
448	24.5	8.9	0	0.00	0	139	0	135.9	11.10	17.2	17.1	999.0	999.0
136	12.5	4.2	0	.24	0	140	0	176.0	7.30	11.2	11.2	999.0	999.0
409	17.6	3.7	0	0.00	0	141	0	258.4	8.70	12.5	12.5	999.0	999.0
530	20.8	4.1	0	0.00	0	142	0	145.6	9.10	14.6	14.3	999.0	999.0
445	14.7	4.5	0	0.00	0	143	0	112.3	8.00	13.7	13.6	999.0	999.0
414	19.4	-2.1	0	0.00	0	144	0	206.5	9.20	13.6	13.6	999.0	999.0
488	24.9	6.6	0	0.00	0	145	0	112.7	10.60	16.3	15.9	999.0	999.0
556	25.1	8.2	0	0.00	0	146	0	69.8	10.40	17.6	17.5	999.0	999.0
633	28.9	6.1	0	0.00	0	147	0	134.1	9.10	19.6	19.1	999.0	999.0
631	29.0	11.4	0	0.00	0	148	0	167.5	10.30	21.7	21.1	999.0	999.0
251	30.1	7.1	0	.16	0	149	0	156.7	11.50	16.3	16.4	999.0	999.0
328	10.6	2.7	0	.15	0	150	0	170.3	6.30	10.4	10.7	999.0	999.0
441	16.4	2.0	0	.03	0	151	0	90.7	6.80	12.2	12.1	999.0	999.0
586	22.1	1.6	0	0.00	0	152	0	79.2	7.80	14.2	13.9	999.0	999.0
659	23.6	4.2	0	0.00	0	153	0	126.7	7.20	16.9	16.5	999.0	999.0
637	29.8	6.0	0	0.00	0	154	0	107.6	7.90	19.4	18.9	999.0	999.0
645	29.8	10.3	0	0.00	0	155	0	122.4	9.20	21.4	20.6	999.0	999.0

699	32.4	10.2	0	0.00	0	156	0	205.7	10.00	23.7	22.6	999.0	999.0
748	26.9	11.8	0	.89	0	157	0	198.5	11.40	24.0	23.2	999.0	999.0
254	13.8	5.9	0	.25	0	158	0	161.3	9.20	15.4	15.7	999.0	999.0
98	9.0	4.1	0	.60	0	159	0	122.6	6.60	9.8	9.9	999.0	999.0
293	13.8	2.5	0	.60	0	160	0	73.3	6.60	9.4	9.5	999.0	999.0
722	23.2	2.1	0	0.00	0	161	0	92.5	7.90	14.7	14.4	999.0	999.0
715	28.6	6.8	0	0.00	0	162	0	99.4	10.20	18.1	17.8	999.0	999.0
710	30.5	10.6	0	0.00	0	163	0	104.9	11.40	19.8	19.6	999.0	999.0
727	34.9	11.2	0	0.00	0	164	0	106.5	11.40	21.0	20.7	999.0	999.0
622	35.5	11.7	0	0.00	0	165	0	140.4	13.40	21.8	21.5	999.0	999.0
504	27.9	13.7	0	0.00	0	166	0	116.8	14.40	21.0	20.9	999.0	999.0
613	26.5	13.1	0	0.00	0	167	0	181.8	13.90	21.9	21.4	999.0	999.0
328	21.3	9.9	0	0.00	0	168	0	180.9	11.50	17.8	17.9	999.0	999.0
425	29.2	10.0	0	0.00	0	169	0	189.4	11.40	19.1	18.8	999.0	999.0
544	21.1	6.1	0	0.00	0	170	0	256.2	7.00	17.1	17.1	999.0	999.0
724	28.3	6.9	0	0.00	0	171	0	112.1	8.00	20.7	20.2	999.0	999.0
720	32.8	7.5	0	0.00	0	172	0	54.7	9.20	23.2	22.6	999.0	999.0
687	29.0	9.0	0	0.00	0	173	0	142.2	13.60	24.3	23.6	999.0	999.0
299	22.6	13.4	0	.44	0	174	0	106.6	14.10	20.0	20.2	999.0	999.0
571	28.3	11.9	0	0.00	0	175	0	237.8	14.00	21.0	20.5	999.0	999.0
709	32.1	9.7	0	0.00	0	176	0	139.2	12.90	22.4	22.0	999.0	999.0
638	35.8	15.0	0	0.00	0	177	0	194.5	13.80	25.2	24.7	999.0	999.0
627	29.4	13.6	0	0.00	0	178	0	138.0	15.80	25.5	25.1	999.0	999.0
552	33.8	12.0	0	0.00	0	179	0	120.2	12.00	25.0	24.5	999.0	999.0
682	33.7	10.2	0	0.00	0	180	0	181.8	12.60	27.0	26.0	999.0	999.0
611	35.6	12.0	0	0.00	0	181	0	139.9	11.80	27.8	26.9	999.0	999.0
648	35.1	12.7	0	0.00	0	182	0	115.5	12.50	28.5	27.7	999.0	999.0
688	35.2	13.0	0	.14	0	183	0	136.8	13.70	29.3	28.4	999.0	999.0
394	33.2	14.7	0	.21	0	184	0	110.3	15.60	23.5	23.5	999.0	999.0
506	27.5	13.6	0	.83	0	185	0	79.9	15.40	22.6	22.6	999.0	999.0
475	27.2	13.3	0	0.00	0	186	0	121.0	15.80	21.8	21.8	999.0	999.0
484	27.4	12.4	0	0.00	0	187	0	184.1	15.70	22.6	22.2	999.0	999.0
714	33.5	10.9	0	0.00	0	188	0	68.7	11.00	22.6	22.3	999.0	999.0
612	35.7	12.0	0	0.00	0	189	0	118.4	12.50	23.5	23.1	999.0	999.0
622	35.5	11.7	0	0.00	0	190	0	140.4	13.40	21.8	21.5	999.0	999.0
504	27.9	13.7	0	0.00	0	191	0	116.8	14.40	21.0	20.9	999.0	999.0
613	26.5	13.1	0	0.00	0	192	0	181.8	13.90	21.9	21.4	999.0	999.0
328	21.3	9.9	0	0.00	0	193	0	180.9	11.50	17.8	17.9	999.0	999.0
425	29.2	10.0	0	0.00	0	194	0	189.4	11.40	19.1	18.8	999.0	999.0
544	21.1	6.1	0	0.00	0	195	0	256.2	7.00	17.1	17.1	999.0	999.0
724	28.3	6.9	0	0.00	0	196	0	112.1	8.00	20.7	20.2	999.0	999.0
720	32.8	7.5	0	0.00	0	197	0	54.7	9.20	23.2	22.6	999.0	999.0
687	29.0	9.0	0	0.00	0	198	0	142.2	13.60	24.3	23.6	999.0	999.0
299	22.6	13.4	0	.44	0	199	0	106.6	14.10	20.0	20.2	999.0	999.0
571	28.3	11.9	0	0.00	0	200	0	237.8	14.00	21.0	20.5	999.0	999.0

709	32.1	9.7	0	0.00	0	201	0	139.2	12.90	22.4	22.0	999.0	999.0
638	35.8	15.0	0	0.00	0	202	0	194.5	13.80	25.2	24.7	999.0	999.0
627	29.4	13.6	0	0.00	0	203	0	138.0	15.80	25.5	25.1	999.0	999.0
552	33.8	12.0	0	0.00	0	204	0	120.2	12.00	25.0	24.5	999.0	999.0
682	33.7	10.2	0	0.00	0	205	0	181.8	12.60	27.0	26.0	999.0	999.0
611	35.6	12.0	0	0.00	0	206	0	139.9	11.80	27.8	26.9	999.0	999.0
648	35.1	12.7	0	0.00	0	207	0	115.5	12.50	28.5	27.7	999.0	999.0
688	35.2	13.0	0	.14	0	208	0	136.8	13.70	29.3	28.4	999.0	999.0
394	33.2	14.7	0	.21	0	209	0	110.3	15.60	23.5	23.5	999.0	999.0
506	27.5	13.6	0	.83	0	210	0	79.9	15.40	22.6	22.6	999.0	999.0
475	27.2	13.3	0	0.00	0	211	0	121.0	15.80	21.8	21.8	999.0	999.0
484	27.4	12.4	0	0.00	0	212	0	184.1	15.70	22.6	22.2	999.0	999.0
714	33.5	10.9	0	0.00	0	213	0	68.7	11.00	22.6	22.3	999.0	999.0
612	35.7	12.0	0	0.00	0	214	0	118.4	12.50	23.5	23.1	999.0	999.0

Appendix c. Dictionary of Terms

DICTIONARY OF TERMS FOR WHEAT

ACCDEG - RUNNING TOTAL OF AVG TEMPERATURE (C)
ADJES - AN OPERATION ON SOIL EVAPORATION FOR CALCULATING FLOW
- OF WATER UP.
AHTMP - ACCUMULATION OF AVERAGE TEMPERATURE AFTER HEADING (C)
ALPHA - A CONSTANT, DEPENDENT ON HYDRAULIC PROPERTIES OF THE SOIL,
ALTMP - (I,J) ACCUMULATION OF AVERAGE TEMP SINCE LEAF J INITIATED ON STEM I (C)
AMAX1 - FORTRAN FUNCTION TO FIND MAXIMUM VALUE
AMIN1 - FORTRAN FUNCTION TO FIND MINIMUM VALUE.
ANTHES - (I) DAY ANTHESIS BEGAN FOR STEM I
APTMP - (I) ACCUMULATOR FOR AVERAGE TEMPERATURE SINCE INITIATION OF STEM I (C)
ARAYLK - NONSUBSCRIPTED ARRAY(L,K)
AREA - TOTAL LEAF AREA (CM**2)
ARRAY - NAME OF ARRAY FOR WHICH MAP IS DESIRED
ATMP - AVERAGE DAILY TEMPERATURE (DEG C)
ATTMP - (I) ACCUMULATION OF AVERAGE TEMP SINCE LAST TILLER INITIATED ON STEM I
AVGPSI - THE SOIL WATER POTENTIAL EFFECTING PHOTOSYNTHESIS
BOOT - (I) STEM I BEGAN BOOT STAGE ON THIS DAY
C1 - COEFFICIENTS FOR EQUATION USED TO CALCULATE DAY LENGTH
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 H2O ACROSS BOTTOM PROFILE (MM)
CD - CARBOHDRATE DEMAND (GRAMS)
CLIMAT - (I) DAILY INPUT (CLIMATE) VARIABLES
(1) SOLAR RADIATION. IN LY/DAY.
(2) MAX. AIR TEMP. IN DEG F.
(3) MIN. AIR TEMP. IN DEG.F.
(5) RAIN FALL.IN INCHES/DAY.
(6) PAN EVAPORATION
(7) JULIAN DAY NUMBER.
(8) AMOUNT OF FERTILIZER APPLICATION (LBS/ACRE)
COND - UNSATURATED HYDRAULIC CONDUCTIVITY, IN CM/DAY.
CONSCA - VECTOR OF BREAK POINTS FOR GRAPHICAL INTERPRETATION OF

VOLUMETRIC WATER CONTENT IN CC PER CC SOIL.
CSTRSF - FRUIT CARBOHYDRATE STRESS FACTOR
CSTRSV - RATIO OF CARBOHYDRATE SUPPLY TO DEMAND FOR VEG GROWTH
CUMEP - CUMULATIVE TRANSPIRATION, MM.
CUMES - CUMULATIVE SOIL EVAPORATION, MM.
CUMRAN - CUMULATIVE RAINFALL, MM.
CUMSOK - CUMULATIVE SOAK THROUGH, MM.
D - DEPTH (VERTICAL) OF EACH SOIL CELL, IN CM.
DACYT - NUMBER OF DAYS/MONTH
DAMP - DAMPING FACTOR TO APPROXIMATE LINEARIZATION OF EXPONENTIAL DECAY RESPONSE.
DAYL1 - FRACTION OF 24 HOUR PERIOD IN DAYLIGHT
DAYL2 - FRACTION OF 24 HOUR PERIOD IN NIGHT
DAYLNG - DAYLENGTH IN HOURS
DAYNUM - DAY NUMBER OF THE YEAR, IN JULIAN DAYS.
DAYTYM - TIME FROM SUNRISE TO SUNSET IN HOURS
DAZE - DAY OF MONTH
DEL - SLOPE OF SATURATION VAPOR PRESSURE CURVE AT MEAN AIR SOIL SURFACE, IN MM/DAY.
DELT - INCREMENT OF TIME OVER WHICH UPTAKE AND CAPILLARY FLOW IS SIMULATED, IN DAYS
DES - PERCENTAGE OF FLORETS TO BE DESSICATED
DFAC - DESSICATION FACTOR
DIFCN - DIFFERENTIAL CARBON NITROGEN QUOTIENT.
DIFF - DIFFUSIVITY OF SOIL, IN CM BAR/DAY.
DIFREN - DAY OF DIFFERENTIATION
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.
DNODE - NUMBER OF NODES ON EACH STEM JOINTING TO ELONGATE TODAY
DPSIDT - DERIVATIVE OF WATER POTENTIAL WITH RESPECT TO MOISTURE CONTENT, IN BARS/CC/CC.
DRAD - ARRAY OF DAILY RADIATION AMOUNTS NOT INTERCEPTED BY PLANTS, IN LANGLEYS.
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 DAYTIME TEMPERATURE FOR J DAYS AGO.
DUMAY - DUMMY ARRAY USED FOR LOCAL DIMENSIONED VARIABLES
DUMAY1 - DUMMY ARRAY USED FOR LOCAL DIMENSIONED VARIABLES.
DUMMY0 - DUMMY ARRAY TO SET ASIDE CORE
DUMY01 - DUMMY VARIABLE, USED TO REDUCE CPU TIME.
DUMY02 - DUMMY VARIABLE, USED TO REDUCE CPU TIME
DUMY03 - DUMMY VARIABLE, USED TO REDUCE CPU TIME
DUMY04 - DUMMY VARIABLE, USED TO REDUCE CPU TIME.
DWRT - ACTUAL INCREMENT OF ROOT WEIGHT FOR A GIVEN CELL, IN

GM/CELL/DAY.
E - TOTAL EVAPORATIVE LOSS FROM CROP.
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.
F2 - RESERVE NITROGEN AVAILABILITY COEFFICIENT
FACL - CALIBRATION FACTOR TO ADJUST POTENTIAL CHANGE IN LEAF AREA
FC - FIELD CAPACITY OF SOIL LAYER, IN CM**3/CM**3.
FERN - FERTILIZER NITROGEN APPLIED, IN LBS N/ACRE.
FLDCAP - FIELD CAPACITY OF BOTTOM SOIL LAYER, CM**3/CM**3.
FLORET - (I) NUMBER OF FLORETS (GRAIN) ON STEM I
FNH4 - FRACTION OF FERTILIZER NITROGEN WHICH IS AMMONIUM, DIMENSIONLESS.
FNICN - FLUX OF NITROGEN INTO THE CELL, NET, IN MG N/CELL.
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.
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.
GLUMCN - AVERAGE NITROGEN CONCENTRATION IN GLUMES
GLUMN - TOTAL GLUME NITROGEN (GRAMS)
GLUMR1 - GLUME NITROGEN REQUIREMENT FOR GROWTH (GRAMS)
GLUMRS - GLUME NITROGEN RESERVES (GRAMS)
GLUMW - (I) TOTAL WEIGHT OF ALL GLUMES ON STEM I (GRAMS)
GLUMWT - TOTAL WEIGHT OF ALL GLUMES ON PLANT (GRAMS)
GRAINCN - AVERAGE NITROGEN CONCENTRATION IN GRAIN
GRAIN - TOTAL GRAIN NITROGEN (GRAMS)
GRAIR1 - GRAIN NITROGEN REQUIREMENT FOR GROWTH (GRAMS)
GRAIW - (I) TOTAL WEIGHT OF ALL GRAIN ON STEM I (GRAMS)
GRAIWT - TOTAL WEIGHT OF ALL GRAIN ON PLANT (GRAMS)
H2O - TOTAL TEMPORARY AND RESIDUAL VOLUME OF H2O IN SOIL CELL, IN CM**3/CM**2
H2OBAL - WATER BALANCE
HEAD - (I) DAY STEM I REACHED HEADING STAGE
I - INDEX (DAILY) USED IN MANIPULATING DAILY WEATHER VARIABLES.
IDAY - DAY COUNTER WITH DAY 1 BEING DAY OF EMERGENCE. ONLY DAYS

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          WHEN AVERAGE TEMPERATURE AT OR ABOVE 4 DEG C ARE COUNTED
IDIFF   - DELAYS FOR BOOT JOINTING HEADING BETWEEN STEMS
IH      - HOUR OF THE DAY, FROM MIDNIGHT.
IH9     - NINE HOURS FROM THE CURRENT TIME.
IMGKOL  - IMAGE KOLUMN
INT     - FRACTION OF SOLAR RADIATION INTERCEPTED BY CROP, DIMENSIONLESS.
IPRNT   - INCREMENT OF DAYS BETWEEN PRINTOUT
IRC     - INDEX FOR WEIGHING ROOT GROWTH TO THE RIGHT IN RESPONSE
        - TO WATER POTENTIAL.
ISPLTS  - DUMMY FOR NUMBER OF SPIKELETS FOR STEM
ISR     - HOUR OF SUNRISE.  MIDNIGHT IS 0.
ISS     - HOUR OF SUNSET.  MIDNIGHT IS 0.
ISS1    - HOUR OF SUNSET PLUS ONE.
ITGF    - TIME FOR GRAIN FILL (DAYS)
IYR     - YEAR/4
J       - INDEX (DAILY) USED IN MANIPULATING DAILY WEATHER
          VARIABLES.
JG      - MIN PERCENTAGE OF NEW GLUME GROWTH REQUIRED TO BE NITROGEN
JG1     - MIN PERCENTAGE OF NEW GRAIN GROWTH REQUIRED TO BE NITROGEN
JL      - MIN PERCENTAGE OF NEW LEAF GROWTH REQUIRED TO BE NITROGEN
JM1     - AN INDEX FOR SOIL TEMPERATURE.
JOINT   - (I) IDAY STEM I BEGAN JOINTING STAGE
JR      - MIN PERCENTAGE OF NEW ROOT GROWTH REQUIRED TO BE NITROGEN
JS      - MIN PERCENTAGE OF NEW STEM GROWTH REQUIRED TO BE NITROGEN
K       - COLUMN NUMBER OF ARRAY.
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.
KG      - MIN LEVEL OF NITROGEN IN GLUME  ( % OF GLUME WEIGHT )
KHAR    - CHARACTERS PRINTED ON THE MAP.
KL      - MIN LEVEL OF NITROGEN IN LEAF   ( % OF LEAF WEIGHT )
KL1     - COLUMN TO LEFT  OF SOURCE OF ROOT GROWTH
KOLJMN  - COLUMN OF SOIL IN THE PROFILE, 1 TO NK.
KR      - MIN LEVEL OF NITROGEN IN ROOTS  ( % OF ROOT WEIGHT )
KRL     - COLUMN COUNTER FOR THE LAYER
KS      - MIN LEVEL OF NITROGEN IN STEM   ( % OF STEM WEIGHT )
L       - LAYER NUMBER OF ARRAY.
L1      - LAYER + 1.
L19     - LAYER 19.
L20     - LAYER 20.
LAI     - LEAF AREA INDEX
LAMDA   - TOTAL ALBEDO OF CROP AND SOIL, DIMENSIONLESS.
LAMDAC  - ALBEDO OF CROP, DIMENSIONLESS.
LAMDAS  - ALBEDO OF SOIL, DIMENSIONLESS.
LATUDE  - LATITUDE (DEG)
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LAYER - LAYER OF SOIL IN THE PROFILE.
LC - K - 1
LD1 - LAYER BELOW SOURCE CELL OF ROOT GROWTH
LDC - INDEX FOR WEIGHING ROOT GROWTH DOWNWARD IN RESPONSE TO
- WATER POTENTIAL
LEAF - (I) NUMBER OF LEAVES ON STEM I
LEAFCN - LEAF NITROGEN CONCENTRATION
LEAFR1 - LEAF NITROGEN REQUIREMENT FOR GROWTH (GRAMS)
LEAFRS - LEAF NITROGEN RESERVES (G)
LEAFW - (I,J) WEIGHT OF INDIVIDUAL LEAF
LEAFWT - TOTAL WEIGHT OF ALL LEAVES ON PLANT (GRAMS)
LIDATE - (I,J) IDAY WHEN LEAF J ON STEM I WAS INITIATED
LLDAY - (I) IDAY LAST LEAF INITIATED ON STEM I
LR - DEEPEST LAYER CONTAINING ROOTS
LTDAY - (I) IDAY LAST TILLER INITIATED ON STEM I
MAXMIN - TMAX MINUS TMIN
MH2O - METHOD OF WATER APPLICATION.
MO - MONTH
N - INDEX VARIABLE.
NBO - DUMMY VARIABLE FOR NUMBER OF BOX IN STORAGE TRAIN,
USED FOR ITERATION.
NBOX - 'BOXCAR' OF RTWT ARRAY CONTAINING ROOTS GROWN DURING A
PARTICULAR DAY, IN GMS/CELL.
NF - FACTOR FOR LIMITING FRUIT GROWTH IN RESPONSE TO N SHORTAGE.
NIT - AMOUNT OF INORGANIC NITROGEN PRESENT IN SOIL, IN MG N/CC SOIL.
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.
NKM - NUMBER OF COLUMNS MINUS 1.
NL - NUMBER OF LAYERS OF SOIL IN THE PROFILE.
NLL - NUMBER OF LAYERS MINUS 1.
NLR - NUMBER OF LAYERS CONTAINING ROOTS
NODE - (I) NUMBER OF NODES ON THE STEM
NOITR - DO NOITR ITERATIONS DURING DAY AND NOITR ITERATIONS DURING NITE
NPD - TRIGGER TO DETERMINE IF 'MAP' OF DIFFUSIVITY PRINTED DURING
EXECUTION.
NPN - TRIGGER TO DETERMINE IF 'MAP' OF NITRATE CONTENT PRINTED
DURING EXECUTION.
NPOOL - NITROGEN POOL (AVAILABLE), GRAMS
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.
NSTEMS - NUMBER OF STEMS ON THE PLANT
NSTMH - NUMBER OF STEMS HEADING
NSTRES - NITROGEN STRESS
NV - FACTOR FOR LIMITING VEGETATIVE GROWTH IN RESPONSE TO N SHORTAGE
NYTTYM - TIME FROM SUNSET TO SUNRISE, IN HOURS
OMA - ORGANIC MATTER ADDED TO THE PLOW ZONE AT BEGINNING OF SEASON, IN LBS/ACRE.
P - RAINFALL (LOCAL VARIABLE), IN MM/DAY.
PAH2O - PERCENT AVAILABLE WATER, OR VOLUMETRIC WATER CONTENT ABOVE WILTING POINT DIVIDED BY FIELD CAPACITY MINUS WILTING POINT, IN PERCENT.
PDGLUM - (I) POTENTIAL CHANGE IN WEIGHT OF GLUMES ON STEM I (GRAMS)
PDGRAN - (I) POTENTIAL CHANGE IN WEIGHT OF GRAIN ON STEM I (GRAMS)
PDSTEM - (I) POTENTIAL CHANGE IN WEIGHT OF STEM I (GRAMS)
PDWL - (I,J) POTENTIAL CHANGE IN WEIGHT OF LEAF J ON STEM I, GRAMS
PDWRT - POTENTIAL INCREMENT OF ROOT WEIGHT IN A GIVEN CELL, IN GM/DAY.
PLANTN - TOTAL NITROGEN CONTENT OF PLANT (GRAMS)
PLANTW - PLANT WEIGHT (GRAMS)
PLTN - TOTAL NITROGEN CONTENT OF PLANT
PN - NET PHOTOSYNTHATE AVAILABLE FOR GROWTH (GRAMS)
PNFAC - MIN VALUE FOR PN
POLINA - POLLINATION TRIGGER
POPFAC - POPULATION FACTOR (DM**2/PLANT)
POPPLT - PLANT POPULATION, IN PLANTS/ACRE.
PPLANT - GROSS PHOTOSYNTHATE PRODUCED PER PLANT TODAY (GRAMS)
PSIAVG - AVERAGE WATER POTENTIAL OF ROOT ZONE, IN BARS.
PSIL - AVERAGE LEAF WATER POTENTIAL, BARS
PSIMAX - MAXIMUM WATER POTENTIAL IN PROFILE OCCUPIED BY ROOTS IN BARS.
PSINUM - THE NUMBER OF CELLS OF WHICH PSIAVG IS CALCULATED
PSIS - SOIL WATER POTENTIAL, IN BARS.
PSISCA - VECTOR OF BREAK POINTS FOR GRAPHICAL INTERPRETATION OF SOIL WATER POTENTIAL IN BARS.
PSITOT - TOTAL OF PSI
PSIUNI - VECTOR USED TO WRITE UNITS OF SOIL WATER POTENTIAL.
PSTAND - GROSS DAILY PHOTOSYNTHATE PRODUCTION (GRAMS CO2/M**2/DAY)
PTSN - LOW NITROGEN CONCENTRATION PHOTOSYNTHESIS REDUCTION FACTOR
PTSRED - REDUCTION FOR PHOTOSYNTHESIS IN RESPONSE TO MOISTURE STRESS
RAD - AVERAGE DAILY SOLAR RADIATION FOR THE PREVIOUS WEEK, IN LANGLEYS/DAY.
RADAY - RATE OF AREA GROWTH

RADL1 - RAD LAGGED BY ONE WEEK.
RAIN - RAINFALL OR IRRIGATION, IN MM/DAY.
RANGE - ARRAY OF 11 NUMBERS TERMINATING THE RANGE OF EACH OF THE 10 CHARACTERS USED ON THE MAP.
RANGE1 - ARRAY OF 11 NUMBERS TERMINATING THE RANGE OF EACH OF THE 10 CHARACTERS USED ON THE MAP.
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.
REQN - TOTAL NITROGEN REQUIREMENT FOR GROWTH, GRAMS
RESC - TOTAL RESERVE CARBOHYDRATES FOR PLANT (GRAMS)
RESCF - LEAF LOADING FEEDBACK REDUCTION FACTOR FOR PHOTOSYNTHESIS
RESN - TOTAL RESERVE NITROGEN (GRAMS)
RESP - RESPIRATION LOSS (GRAMS)
RFEP - REDUCTION FACTOR FOR TRANSPIRATION DUE TO WATER STRESS ON CROP, DIMENSIONLESS.
RFEPD - REDUCTION FACTOR FOR TRANSPIRATION DUE TO MOISTURE STRESS,DAY
RFEPN - REDUCTION FACTOR FOR TRANSPIRATION DUE TO MOISTURE STRESS,NIGHT
RFWST - GROWTH REDUCTION FACTOR DUE TO WATER STRESS
RGCF - ROOT GROWTH CORRECTION FACTOR, DIMENSIONLESS.
RI - INCIDENT SOLAR RADIATION (LANGLEYS/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 (GRAMS)
ROOTR1 - ROOT NITROGEN REQUIREMENT FOR GROWTH
ROOTRS - ROOT NITROGEN RESERVES (GRAMS)
ROOTS - DRY WEIGHT OF ALL LIVING ROOTS IN PROFILE, IN GRAMS.
ROOTSV - ARRAY OF TOTAL DRY ROOT WEIGHT IN EACH SOIL CELL.
ROOTWT - TOTAL ROOT WEIGHT FOR PLANT (GRAMS)
ROOTXP - ROOT GROWTH EXPONENT
ROWSP - ROWS SPACING
RS - SOLAR RADIATION, IN MM/DAY.
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.

RTWTCG - WEIGHT OF ROOTS CAPABLE OF GROWTH, IN GMS/CELL.
RTWTCU - ROOT WEIGHT CAPABLE OF WATER UPTAKE, IN GM DM/CELL.
SECOND - NUMBER OF SECONDARY ROOTS ON PLANT
SESI - CUMULATIVE EVAPORATION FROM THE SOIL SURFACE DURING STAGE 1, IN MM.
SESII - CUMULATIVE EVAPORATION FROM THE SOIL SURFACE DURING STAGE 2, IN MM.
SH - ACCUMULATOR FOR UPTH2O WITHIN THE PROFILE.
SHRTD - SUM OF HOURLY TEMPERATURES DURING THE DAYTIME, IN DEG C.
SHRTN - SUM OF HOURLY TEMPERATURES DURING THE NIGHTTIME, IN DEG C.
SLEAFN - TOTAL LEAF NITROGEN (GRAMS)
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.
SOR - SUM OF OLD ROOTS IN A GIVEN CELL, IN GM/CELL.
SPDGLM - SUM OF TODAYS POTENTIAL CHANGE IN GLUME WT. (GRAMS)
SPDGRN - SUM OF TODAYS POTENTIAL CHANGE IN GRAIN WT. (GRAMS)
SPDSTM - SUM OF TODAYS POTENTIAL CHANGE IN STEM WT. (GRAMS)
SPDWL - SUM OF TODAYS POTENTIAL CHANGE IN LEAF WT. (GRAMS)
SPDWRT - SUM OF TODAYS POTENTIAL CHANGE IN ROOT WT. (GRAMS)
SPIKE - (I) NUMBER OF SPIKLETS ON STEM I
SPN - RUNNING TOTAL OF PN PRODUCED (GRAMS)
SPRING - NUMBER OF DAYS FROM EMERGENCE TO FIRST DAY OF SPRING
SQRT(T)- FORTRAN FUNCTION - SQUARE ROOT.
SRAD - WEEKLY SUM OF SOLAR RADIATION, IN LANGLEYS.
SRAVG - ACCUMULATED TEMP SINCE INTIATION OF LAST SECONDARY ROOT (C)
SRDAY - LAST SECONDARY ROOT INTIATED ON THIS DAY
SRPSIS - SUM OF RECIPROCAL SOIL WATER POTENTIALS, IN 1/BARS.
SRWP - SUM OF RECIPROCAL WATER POTENTIALS, IN 1/BARS.
STAH - WEEKLY SUM OF DAILY MAXIMUM AIR TEMPERATURE, IN DEG F.
STAL - WEEKLY SUM OF DAILY MINIMUM AIR TEMPERATURE, IN DEG F.
STARCH - RATIO OF STARCH TO TOTAL LEAF WEIGHT
STEMBG - NEXT STEM TO BEGIN JOINTING
STEMCN - AVERAGE NITROGEN CONCENTRATION IN STEMS
STEMJ - NUMBER OF STEMS TO BEGIN JOINTING TODAY
STEMN - TOTAL STEM NITROGEN (GRAMS)
STEMND - LAST STEM THAT HAS BEGUN JOINTING
STEMR1 - STEM REQUIREMENT FOR VEGETATIVE GROWTH
STEMRS - STEM RESERVES OF NITROGEN (GRAMS)
STEMW - (I) WEIGHT OF STEM I (GRAMS)
STEMWT - TOTAL WEIGHT OF ALL STEMS ON PLANT (GRAMS)
STRESD - FRACTION OF DAY LENGTH DURING WHICH PLANT IS NOT UNDER MOISTURE STRESS.

STRESN - FRACTION OF NIGHT TIME DURING WHICH PLANT IS NOT UNDER MOISTURE STRESS.
SUPF - SUM OF UPTAKE FACTORS OF THE CELLS, IN GM CM/DAY.
SUPNO3 - SUPPLY OF NITRATE TO PLANTS FROM SOIL, IN MG/DAY.
SWING - DIFFERENTIAL TEMPERATURE OF THE SOIL LAYER FOR THE DAY, I
SWINGH - HALF THE DIFFERENCE BETWEEN THE MAXIMUM AND MINIMUM TEMPERATURES.
SWINGT - DIFFERENTIAL TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
SWINGY - DIFFERENTIAL TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
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 = ARTIFICIAL 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.
TAH - AVERAGE DAILY MAXIMUM AIR TEMPERATURE FOR THE PREVIOUS WEEK, IN DEG F.
TAHL1 - TAH LAGGED BY ONE WEEK.
TAHL2 - TAH LAGGED BY TWO WEEKS.
TAL - AVERAGE DAILY MINIMUM AIR TEMPERATURE FOR THE PREVIOUS WEEK, IN DEG F.
TALL1 - TAL LAGGED BY ONE WEEK.
TALL2 - TAL LAGGED BY TWO WEEKS.
TAVG - DAILY AVERAGE TEMPERATURE, IN DEG C.
TAVM1 - AVERAGE TEMPERATURE MINUS 1 DEG, IN DEG C.
TBL - TIME BETWEEN LEAVES (DAYS)
TBSR - TIME BETWEEN SECONDARY ROOTS (DAYS)
TBT - TIME BETWEEN TILLERS (DAYS)
TD - DRY BULB TEMPERATURE, IN DEG C.
TDAY - AVERAGE DAYTIME TEMPERATURE.
TDES - (I) % OF FLORETS DESSICATED ON STEM I DURING ANTHESIS
TH2O - TOTAL WATER IN THE PROFILE, MM.
TH2OC - TOTAL TEMPORARY AND RESIDUAL VOLUME OF H2O IN SOIL CELL, IN CM**3/CM**2.
THRLN - THRESHOLD WEIGHT TO GIVE LENGTH OF ROOTS REACHING OPPOSITE BOUNDARIES OF CELL FROM WHICH GROWTH ORIGINATED, IN GMS.
TILLER - FIRST TILLER INITIATED ON THIS DAY
TMAX - MAXIMUM TEMPERATURE DURING THE DAY, IN DEG C.

TMEAN - MEAN TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
TMEANT - MEAN TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
TMEANY - MEAN TEMPERATURE OF THE SOIL LAYER FOR THE DAY, IN DEG C.
TMIN - MINIMUM TEMPERATURE DURING THE DAY, IN DEG C.
TMP - AIR TEMPERATURE
TNNH4 - TOTAL NITROGEN AS AMMONIUM IN THE PROFILE, IN MG N/SOIL SLAB.
TNNO3 - TOTAL NITRATE IN THE PROFILE, MG N.
TNYT - AVERAGE NIGHTIME TEMPERATURE.
TOTAL - TOTAL OF CONTENTS OF THE CELLS IN THE PROFILE.
TRANSP - TRANSPIRATION RATE, IN MM/DAY.
TSAL - AVERAGE SOIL TEMPERATURE IN THE LAYER.
TSDL - TEMPERATURE OF SOIL LAYER DURING DAYTIME
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.
TSOAK - TOTAL WATER SOAKING THROUGH BOTTOM OF PROFILE, MM.
TSOILD - AVERAGE TEMPERATURE OF THE LAYER DURING DAYTIME, IN DEG C.
TSOILN - AVERAGE TEMPERATURE OF THE LAYER DURING NIGHTTIME, IN DEG C.
TSOLAV - AVERAGE TEMPERATURE OF THE LAYER OVER 24 HOURS, IN DEG C.
TTL0 - TITLE USED FOR GRAPHICAL OUTPUT.
TTL1 - LINE 1 OF TITLE OF MAP.
TTL1R - LINE 1 OF TITLE OF MAP
TTL2 - LINE 2 OF TITLE OF MAP.
TTL2R - LINE 2 OF TITLE OF MAP
TTL6 - TITLE USED FOR GRAPHICAL OUTPUT.
TW - WET BULB TEMPERATURE, IN DEG C.
U - UPPER LIMIT OF CUMULATIVE EVAPORATION FROM SOIL DURING STAGE 1 DRYING, IN MM.
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.
VEGWT - TOTAL PLANT WEIGHT LESS GRAIN WEIGHT (GRAMS)
VH2OC - VOLUMETRIC WATER CONTENT OF A CELL, IN CM**3/CM**3.
VH2UNI - VECTOR USED TO WRITE UNITS OF VOLUMETRIC WATER CONTENT.
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.
VPD - SATURATION VAPOR PRESSURE AT DRY BULB TEMPERATURE, IN MB.
W - WIDTH OF EACH SOIL CELL, IN CM.
WATTSM - INCIDENT RADIATION IN WATTS/SQ M.
WND - WINDRUN IN MILES PER DAY
WSTRSD - REDUCTION FACTOR FOR WATER STRESS DURING DAY. RATIO OF TIME LEAF IS TURGID ENOUGH (ABOVE -7 BARS) FOR GROWTH TO DAYLENGTH
WSTRSN - REDUCTION FACTOR FOR H2O STRESS DURING THE NIGHT
WTAVG - AVERAGE TEMPERATURE FOR THE LAST 7 DAYS.
WTAVGF - AVERAGE TEMPERATURE FOR THE LAST 7 DAYS IN FARENHEIT.
WTBSLF - WEIGHT TO BE SLOUGHED
WTF - FACTOR FOR CONVERTING LEAF WEIGHT TO AREA
WTSLFD - TOTAL ROOT WEIGHT SLOUGHED
XLEAFL - LENGTH OF LARGEST LEAF ON PLANT (CM)
XMAXLW - WEIGHT OF LARGEST LEAF ON PLANT (GRAMS)
XTRAC - EXTRA CARBOHYDRATE (GRAMS)
XTRAN - EXTRA NITROGEN (GRAMS)
YIELD - YIELD IN BUSHELS/ACRE
YR - YEAR

Appendix d. Typical Output

```
NUMBER OF SOIL LAYERS 5

 LAYER    MAX.DEPTH      DO       THETA O      BETA

   NO.        CM          CM        BAR/DAY     CC/CC
   1       2.250E+01 5.100E-02 1.680E-01 4.012E+01
   2       5.250E+01 2.010E-01 2.580E-01 4.319E+01
   3       9.010E+01 1.750E-01 1.620E-01 3.283E+01
   4       1.501E+02 1.990E-01 1.400E-01 2.937E+01
   5       2.001E+02 1.830E-01 1.040E-01 2.793E+01
INITIAL VH20 AT BOTTOM BOUNDARY = 4.100E+01
SOIL ID. NORFOLK S L  NO.OF CURVES 7
NO.OF DATA POINTS  6  GRAVIMETRIC WATER CONTENT   0.05
BULK DENSITY  SOIL STRENGTH
    GM/CC       KG/CM2
         0.90        0.10
         1.10        5.40
         1.30       16.20
         1.50       36.00
         1.70       62.00
         1.90       93.00
NO.OF DATA POINTS  6  GRAVIMETRIC WATER CONTENT   0.07
BULK DENSITY  SOIL STRENGTH
    GM/CC       KG/CM2
         0.90        0.10
         1.10        2.50
         1.30        7.80
         1.50       22.60
         1.70       44.50
         1.90       71.30
NO.OF DATA POINTS  6  GRAVIMETRIC WATER CONTENT   0.09
BULK DENSITY  SOIL STRENGTH
    GM/CC       KG/CM2
         0.90        0.10
         1.10        1.00
         1.30        2.30
         1.50       12.80
         1.70       30.40
         1.90       52.60
NO.OF DATA POINTS  6  GRAVIMETRIC WATER CONTENT   0.11
BULK DENSITY  SOIL STRENGTH
    GM/CC       KG/CM2
         0.90        0.10
         1.10        0.90
         1.30        1.70
         1.50        7.50
         1.70       21.50
         1.90       31.20
NO.OF DATA POINTS  6  GRAVIMETRIC WATER CONTENT   0.13
BULK DENSITY  SOIL STRENGTH
    GM/CC       KG/CM2
         0.90        0.10
         1.10        0.50
         1.30        1.00
         1.50        5.60
         1.70       15.20
         1.90       29.80
NO.OF DATA POINTS  6  GRAVIMETRIC WATER CONTENT   0.15
BULK DENSITY  SOIL STRENGTH
    GM/CC       KG/CM2
         0.90        0.10
         1.10        0.20
         1.30        0.50
         1.50        4.90
         1.70       13.90
         1.90       27.70
NO.OF DATA POINTS  6  GRAVIMETRIC WATER CONTENT   0.30
BULK DENSITY  SOIL STRENGTH
    GM/CC       KG/CM2
         0.90        0.10
         1.10        0.20
         1.30        0.50
         1.50        0.90
         1.70        1.10
         1.90        1.30
 FERTILIZER SUBROUTINE CALLED  ####################
VNO3C(1,1) =      0.0898
 FERTILIZER SUBROUTINE CALLED  ####################
```

JULIAN DAY=263 IDAY= 1

PN	PSTAND	PTSN	PTSRED	RESCF	PPLANT	RESP
0.100E-01	0.696E+02	0.100E+01	0.100E+01	0.100E+01	0.147E-05	0.000E+00
LEAFWT	STEMWT	GLUMWT	GRANWT	ROOTWT	SPN	
0.100E+01	0.294E-04	0.000E+00	0.000E+00	0.187E+00	0.100E-01	
SPOOL	SPDSTM	SPDGLM	SPDGRN	SPDWRT	CSTRSV	CSTRSF
0.102E-02	0.500E-04	0.000E+00	0.000E+00	0.159E-01	0.588E+00	0.100E+01
RESC	RESN	REQN	NPOOL	NSTRES	NV	NF
0.000E+00	0.118E-01	0.300E-03	0.118E-01	0.100E+01	0.100E+01	0.100E+01
SLEAFN	STEMN	GLUMN	GRANN	LEAFCN	SUPNO3	
0.298E-01	0.883E-06	0.000E+00	0.000E+00	0.298E-01	0.133E-07	
SPIKE(I)	FLORET(I)	LEAF(I)	JOINT(I)	BOOT(I)	HEAD(I)	ANTHES(I)
0	0	1	999	999	999	999
SECOND	ACCDEG	PSIAVG	DIFREN	TILLER		
0	5.43	-0.30166E+00	999	999		
DAYLNG	LAI	XLEAFL	INT	TAVG		
0.123E+02	0.296E-02	0.306E+03	0.261E-05	0.543E+01		
RCH2O	STRSD	STRSN	WSTRSD	EP	ES	
0.937E-02	0.100E+01	0.100E+01	0.100E+01	0.615E-05	0.193E+01	

VOLUMETRIC NITRATE CONTENT OF SOIL JULIAN DAY 263
AT THE END OF MAIN

UNITS - MG/N PER CM**3

	1 2 3 4 5 6		LEGEND
		<=	0.0000
		0.0000 < 0 <=	0.0100
1	* * * * * *		
2	* * * * * *	0.0100 < 1 <=	0.0200
3	1 1 1 1 1 1		
4	0 0 0 0 0 0	0.0200 < 2 <=	0.0300
5	0 0 0 0 0 0		
6	0 0 0 0 0 0	0.0300 < 3 <=	0.0400
7	0 0 0 0 0 0		
8	0 0 0 0 0 0	0.0400 < 4 <=	0.0500
9	0 0 0 0 0 0		
10	0 0 0 0 0 0	0.0500 < 5 <=	0.0600
11	0 0 0 0 0 0		
12	0 0 0 0 0 0	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 = 94.2476 MG N

VOLUMETRIC WATER CONTENT OF SOIL AT THE END OF MAIN — JULIAN DAY 263

UNITS = CM**3/CM**3 SOIL

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

TOTAL = 285.6189 MM WATER

ROOTS IN EACH CELL, TOTAL AT THE END OF RUTGRO — JULIAN DAY 263

UNITS = G/CM**3 SOIL

	1 2 3 4 5 6		LEGEND
		<= 0	0.0000
		0.0000 < 0 <=	0.0001
1	6 2 0		
2	3 1	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 = 0.0347 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN AT THE END OF MAIN — JULIAN DAY 263

UNITS = CM**3/CM**3 SOIL

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

TOTAL = 285.6189 MM WATER

ROOTS IN EACH CELL, TOTAL — JULIAN DAY 288
AT THE END OF RUTGRO

UNITS = G/CM**3 SOIL

	1 2 3 4 5 6		LEGEND
		<=	0.0000
1	5 2 0 0	0.0000 < 0 <=	0.0001
2	3 4 2 1 0 0	0.0001 < 1 <=	0.0005
3	3 2 1 0 0		
4	2 2 1 0	0.0005 < 2 <=	0.0050
5	2 1 0 0		
6	1 0 0	0.0050 < 3 <=	0.0100
7	0 0		
8	0	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 = 0.0860 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN — JULIAN DAY 288
AT THE END OF MAIN

UNITS = CM**3/CM**3 SOIL

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

TOTAL = 277.9714 MM WATER

JULIAN DAY= 75 IDAY= 50

PN	PSTAND	PTSN	PTSRED	RESCF	PPLANT	RESP
0.298E-01	0.622E+02	0.100E+01	0.716E+00	0.208E+00	0.438E-01	0.000E+00
LEAFWT	STEMWT	GLUMWT	GRANWT	ROOTWT	SPN	
0.145E+01	0.503E-02	0.000E+00	0.000E+00	0.935E+00	0.192E+01	
SPDWL	SPDSTM	SPDGLM	SPDGRN	SPDWRT	CSTRSV	CSTRSF
0.980E-02	0.134E-03	0.000E+00	0.000E+00	0.238E-01	0.100E+01	0.100E+01
RESC	RESN	REQN	NPOOL	NSTRES	NV	NF
0.537E+00	0.176E-01	0.101E-02	0.130E-01	0.100E+01	0.100E+01	0.100E+01
SLEAFN	STEMN	GLUMN	GRANN	LEAFCN	SUPNO3	
0.324E-01	0.131E-03	0.000E+00	0.000E+00	0.225E-01	0.461E-03	

SPIKE(I)	FLORET(I)	LEAF(I)	JOINT(I)	BOOT(I)	HEAD(I)	ANTHES(I)
0	0	6	999	999	999	999
0	0	5	999	999	999	999
0	0	5	999	999	999	999

SECOND	ACCDEG	PSIAVG	DIFREN	TILLER		
10	436.46	-0.17863E+01	31	8		
DAYLNG	LAI	XLEAFL	INT	TAVG		
0.119E+02	0.224E+01	0.320E+03	0.584E+00	0.418E+01		
RCH2O	STRSO	STRSN	WSTRSO	EP	ES	
0.238E-01	0.100E+01	0.100E+01	0.854E+00	0.875E+00	0.251E+00	

JULIAN DAY=288 IDAY= 25

PN	PSTAND	PTSN	PTSRED	RESCF	PPLANT	RESP
0.716E-01	0.771E+02	0.100E+01	0.100E+01	0.974E+00	0.105E+00	0.000E+00
LEAFWT	STEMWT	GLUMWT	GRANWT	ROOTWT	SPN	
0.111E+01	0.133E-02	0.000E+00	0.000E+00	0.464E+00	0.622E+00	
SPDWL	SPDSTM	SPDGLM	SPDGRN	SPDWRT	CSTRSV	CSTRSF
0.135E-01	0.150E-03	0.000E+00	0.000E+00	0.209E-01	0.100E+01	0.100E+01
RESC	RESN	REQN	NPOOL	NSTRES	NV	NF
0.151E+00	0.129E-01	0.104E-02	0.136E-01	0.100E+01	0.100E+01	0.100E+01
SLEAFN	STEMN	GLUMN	GRANN	LEAFCN	SUPNO3	
0.276E-01	0.374E-04	0.000E+00	0.000E+00	0.252E-01	0.708E-03	

SPIKE(I)	FLORET(I)	LEAF(I)	JOINT(I)	BOOT(I)	HEAD(I)	ANTHES(I)
0	0	4	999	999	999	999
0	0	2	999	999	999	999
0	0	2	999	999	999	999

SECOND	ACCDEG	PSIAVG	DIFREN	TILLER
7	273.14	-0.41528E+00	999	8

DAYLNG	LAI	XLEAFL	INT	TAVG		
0.112E+02	0.541E+00	0.315E+03	0.173E+00	0.897E+01		
RCH2O	STRSD	STRSN	WSTRSD	EP	ES	
0.209E-01	0.100E+01	0.100E+01	0.100E+01	0.523E+00	0.368E+00	

VOLUMETRIC NITRATE CONTENT OF SOIL JULIAN DAY 288
AT THE END OF MAIN

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

TOTAL = 95.2948 MG N

VOLUMETRIC WATER CONTENT OF SOIL JULIAN DAY 288
AT THE END OF MAIN

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

TOTAL = 277.9714 MM WATER

VOLUMETRIC NITRATE CONTENT OF SOIL JULIAN DAY 75
AT THE END OF MAIN

UNITS - MG/N PER CM**3

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

TOTAL = 75.4926 MG N

VOLUMETRIC WATER CONTENT OF SOIL JULIAN DAY 75
AT THE END OF MAIN

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

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

TOTAL = 248.6794 MM WATER

ROOTS IN EACH CELL, TOTAL JULIAN DAY 75
AT THE END OF RUTGRO

UNITS - G/CM**3 SOIL

	1 2 3 4 5 6		LEGEND
		<=	0.0000
		0.0000 < 0 <=	0.0001
1	4 2 0 0		
2	9 7 4 2 1 0	0.0001 < 1 <=	0.0005
3	4 3 2 2 1 0		
4	4 3 2 2 0 0	0.0005 < 2 <=	0.0050
5	3 2 2 1 0 0		
6	2 2 2 1 0	0.0050 < 3 <=	0.0100
7	2 2 1 0 0		
8	2 1 1 0	0.0100 < 4 <=	0.0150
9	1 1 0 0		
10	1 0 0	0.0150 < 5 <=	0.0200
11	0 0		
12	0	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 = 0.1732 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN AT THE END OF MAIN — JULIAN DAY 75

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

TOTAL = 248.6794 MM WATER

JULIAN DAY=120 IDAY= 75

PN	PSTAND	PTSN	PTSRED	RESCF	RPLANT	RESP
0.378E-01	0.962E+02	0.100E+01	0.507E+00	0.178E+00	0.554E-01	0.000E+00
LEAFWT	STEMWT	GLUNWT	GRANWT	ROOTWT	SPN	
0.179E+01	0.798E-02	0.000E+00	0.000E+00	0.147E+01	0.303E+01	
SPDWL	SPDSTM	SPDGLM	SPDGRN	SPDWRT	CSTRSV	CSTRSF
0.522E-02	0.126E-03	0.000E+00	0.000E+00	0.270E-01	0.100E+01	0.100E+01
RESC	RESN	REQN	NPOOL	NSTRES	NV	NF
0.681E+00	0.194E-01	0.970E-03	0.200E-01	0.100E+01	0.100E+01	0.100E+01
SLEAFN	STEMN	GLUMN	GRANN	LEAFCN	SUPNO3	
0.347E-01	0.179E-03	0.000E+00	0.000E+00	0.194E-01	0.594E-03	

SPIKE(I)	FLORET(I)	LEAF(I)	JOINT(I)	BOOT(I)	HEAD(I)	ANTHES(I)
0	0	6	999	999	999	999
0	0	6	999	999	999	999
0	0	6	999	999	999	999

SECOND	ACCDEG	PSIAVG	DIFREN	TILLER
10	638.13	-0.23342E+01	31	8
DAYLNG	LAI	XLEAFL	INT	TAVG
0.138E+02	0.390E+01	0.320E+03	0.788E+00	0.472E+01
RCH2O	STRSD	STRSN	WSTRSD	EP	ES
0.270E-01	0.100E+01	0.100E+01	0.739E+00	0.199E+01	0.390E+00

VOLUMETRIC NITRATE CONTENT OF SOIL AT THE END OF MAIN — JULIAN DAY 120

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

TOTAL = 68.8718 MG N

VOLUMETRIC WATER CONTENT OF SOIL JULIAN DAY 120
AT THE END OF MAIN

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

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

TOTAL = 235.7825 MM WATER

ROOTS IN EACH CELL, TOTAL JULIAN DAY 120
AT THE END OF RUTGRO

UNITS - G/CM**3 SOIL LEGEND

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

TOTAL = 0.2721 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN JULIAN DAY 120
AT THE END OF MAIN

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

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

TOTAL = 235.7825 MM WATER

JULIAN DAY=149 IDAY=100

PN	PSTAND	PTSN	PTSRED	RESCF	PPLANT	RESP
0.238E-01	0.562E+02	0.100E+01	0.86CE+00	0.198E+00	0.639E-01	0.291E-01
LEAFWT	STMWT	GLUMWT	GRANWT	ROOTWT	SPN	
0.188E+01	0.764E-01	0.000E+00	0.000E+00	0.207E+01	0.396E+01	
SPDWL	SPDSTM	SPDGLM	SPDGRN	SPDWRT	CSTRSV	CSTRSF
0.000E+00	0.425E-02	0.000E+00	0.000E+00	0.306E-01	0.100E+01	0.100E+01
RESC	RESN	REQN	NPOOL	NSTRES	NV	NF
0.721E+00	0.255E-01	0.105E-02	0.256E-01	0.100E+01	0.100E+01	0.100E+01
SLEAFN	STMN	GLUMN	GRANN	LEAFCN	SUPNO3	
0.349E-01	0.215E-02	0.000E+00	0.000E+00	0.185E-01	0.741E-04	

SPIKE(I)	FLORET(I)	LEAF(I)	JOINT(I)	BOOT(I)	HEAD(I)	ANTHES(I)
0	0	6	87	999	999	999
0	0	6	87	999	999	999
0	0	6	88	999	999	999

SECOND	ACCDEG	PSIAVG	DIFREN	TILLER
10	927.53	-0.13399E+01	31	8

DAYLNG	LAI	XLEAFL	INT	TAVG	
0.147E+02	0.436E+01	0.320E+03	0.825E+00	0.162E+02	
RCH2O	STRSD	STRSN	WSTRSD	EP	ES
0.306E-01	0.100E+01	0.100E+01	0.630E+00	0.233E+00	0.330E+00

VOLUMETRIC NITRATE CONTENT OF SOIL JULIAN DAY 149
AT THE END OF MAIN

UNITS = MG/N PER CM**3

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

TOTAL = 63.5477 MG N

VOLUMETRIC WATER CONTENT OF SOIL JULIAN DAY 149
AT THE END OF MAIN

UNITS = CM**3/CM**3 SOIL

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

TOTAL = 244.5427 MM WATER

ROOTS IN EACH CELL, TOTAL
AT THE END OF RUTGRO

JULIAN DAY 149

UNITS = G/CM**3 SOIL

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

TOTAL = 0.3843 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN
AT THE END OF MAIN

JULIAN DAY 149

UNITS = CM**3/CM**3 SOIL

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

TOTAL = 244.5427 MM WATER

JULIAN DAY=174 IDAY=125

PN	PSTAND	PTSN	PTSRED	RESCF	PPLANT	RESP
0.241E-01	0.637E+02	0.100E+01	0.979E+00	0.194E+00	0.809E-01	0.455E-01
LEAFWT	STEMWT	GLUMWT	GRANWT	ROOTWT	SPN	
0.188E+01	0.346E+00	0.425E-02	0.000E+00	0.279E+01	0.516E+01	
SPDWL	SPDSTM	SPDGLM	SPDGRN	SPDWRT	CSTRSV	CSTRSF
0.000E+00	0.167E-01	0.805E-03	0.000E+00	0.373E-01	0.100E+01	0.100E+01
RESC	RESN	REQN	NPOOL	NSTRES	NV	NF
0.799E+00	0.311E-01	0.165E-02	0.313E-01	0.100E+01	0.100E+01	0.100E+01
SLEAFN	STEMN	GLUMN	GRANN	LEAFCN	SUPNO3	
0.318E-01	0.942E-02	0.125E-03	0.000E+00	0.169E-01	0.208E-03	

SPIKE(I)	FLORET(I)	LEAF(I)	JOINT(I)	BOOT(I)	HEAD(I)	ANTHES(I)
19	0	6	87	114	120	999
19	0	6	87	114	120	999
19	0	6	88	115	121	999

SECOND	ACCDEG	PSIAVG	DIFREN	TILLER		
14	1290.87	-0.10578E+01	31	8		
DAYLNG	LAI	XLEAFL	INT	TAVG		
0.150E+02	0.436E+01	0.320E+03	0.825E+00	0.171E+02		
RCH2O	STRSD	STRSN	WSTRSD	EP	ES	
0.373E-01	0.100E+01	0.100E+01	0.729E+00	0.826E+00	0.401E+00	

VOLUMETRIC NITRATE CONTENT OF SOIL JULIAN DAY 174
AT THE END OF MAIN

UNITS = MG/N PER CM**3

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

TOTAL = 58.6074 MG N

VOLUMETRIC WATER CONTENT OF SOIL JULIAN DAY 174
AT THE END OF MAIN

UNITS = CM**3/CM**3 SOIL

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

TOTAL = 242.4756 MM WATER

ROOTS IN EACH CELL, TOTAL JULIAN DAY 174
AT THE END OF RUTGRO

UNITS = G/CM**3 SOIL

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

TOTAL = 0.5180 GM. DRY WEIGHT

VOLUMETRIC WATER CONTENT OF SOIL JULIAN DAY 199
AT THE END OF MAIN

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

TOTAL = 230.2652 MM WATER

ROOTS IN EACH CELL, TOTAL JULIAN DAY 199
AT THE END OF RUTGRO

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

TOTAL = 0.6707 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN JULIAN DAY 199
AT THE END OF MAIN

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

TOTAL = 230.2652 MM WATER

JULIAN DAY=212 IDAY=163

PN	PSTAND	PTSN	PTSRED	RESCF	PPLANT	RESP
0.238E-01	0.873E+02	0.100E+01	0.904E+00	0.241E+00	0.127E+00	0.921E-01
LEAFWT	STEMWT	GLUMWT	GRANWT	ROOTWT	SPN	
0.188E+01	0.415E+00	0.936E-02	0.245E+01	0.359E+01	0.876E+01	
SPDWL	SPDSTM	SPDGLM	SPDGRN	SPDWRT	CSTRSV	CSTRSF
0.000E+00	0.000E+00	0.180E-03	0.154E+00	0.818E-02	0.100E+01	0.100E+01
RESC	RESN	REQN	NPOOL	NSTRES	NV	NF
0.852E+00	0.141E-04	0.251E-03	0.542E-03	0.111E+00	0.000E+00	0.117E+00
SLEAFN	STEMN	GLUMN	GRANN	LEAFCN	SUPNO3	
0.188E-01	0.415E-02	0.936E-04	0.735E-01	0.100E-01	0.528E-03	

SPIKE(I)	FLORET(I)	LEAF(I)	JOINT(I)	BOOT(I)	HEAD(I)	ANTHES(I)
19	60	6	87	114	120	126
19	60	6	87	114	120	126
19	60	6	88	115	121	127

SECOND	ACCDEG	PSIAVG	DIFREN	TILLER
14	2028.31	-0.12551E+01	31	8

DAYLNG	LAI	XLEAFL	INT	TAVG		
0.143E+02	0.436E+01	0.320E+03	0.825E+00	0.182E+02		
RCH2O	STRSD	-STRSN	WSTRSD	EP	ES	
0.000E+00	0.824E+00	0.100E+01	0.511E+00	0.167E+01	0.663E+00	

VOLUMETRIC NITRATE CONTENT OF SOIL JULIAN DAY 212
AT THE END OF MAIN

UNITS = MG/N PER CM**3

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

TOTAL = 55.1046 MG N

VOLUMETRIC WATER CONTENT OF SOIL JULIAN DAY 212
AT THE END OF MAIN

UNITS = CM**3/CM**3 SOIL

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

TOTAL = 227.8863 MM WATER

ROOTS IN EACH CELL, TOTAL
AT THE END OF RUTGRO.

JULIAN DAY 212

UNITS - G/CM**3 SOIL

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

TOTAL = 0.6646 GM. DRY WEIGHT

PSIS FOR EACH LAYER AND COLUMN
AT THE END OF MAIN

JULIAN DAY 212

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

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

TOTAL = 227.8863 MM WATER

*** FINAL YIELD (BU/ACRE) IS 44.94 ON DAY 212

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