AgRISTARS

YM-U2-04281
JSC-18229

A Joint Program for Agriculture and Resources Inventory Surveys Through Aerospace Remote Sensing

AUGUST 1981

Yield Model Development

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

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1. Report No. YM-U2-04281 JSC-18229	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle Winter Wheat: A Model for the Simulation of Growth and Yield in Winter Wheat		5. Report Date August 1981
		6. Performing Organization Code
7. Author(s) D. N. Baker, D. E. Smika, A. L. Black, W. O. Willis, and A. Bauer		8. Performing Organization Report No.
		10. Work Unit No.
9. Performing Organization Name and Address USDA/ARS P.O. Box 5367 Mississippi State, MS 39762		11. Contract or Grant No.
		13. Type of Report and Period Covered
12. Sponsoring Agency Name and Address Johnson Space Center/SK Houston, TX 77058		14. Sponsoring Agency Code

15. Supplementary Notes

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Published as a part of Major Project Element 2, Task 5, of the FY1981/82/83 Yield Model Development Plan

17. Key Words (Suggested by Author(s))	18. Distribution Statement
Winter Wheat RHIZOS Physiological Process	

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price*
Unclass.	Unclass.	163	

WINTER WHEAT

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

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USDA/ARS

August 24, 1981

acknowledgements

We wish to acknowledge, as follows, the assistance we received in this work.

Sammy Turner, Computer Specialist, Crop Simulation Research Unit, Mississippi State, flow charted the model and wrote the FORTRAN code.

Frank D. Whisler, Soil Physicist, Mississippi State University, and Jerry R.Lambert, Agricultural Engineer, Clemson University, consulted on adaptations for RHIZOS to WHEAT.

E. L. Klepper, Plant Physiologist, USDA-ARS, Pendleton, Oregon for many helpful discussions.

J. A. Morgan, Agronomist, USDA-ARS, Fort Collins for early testing and incorporation of provisions for the future development and improvement of the model.

Arnold Klute, Research Leader, USDA-SEA-AR, Fort Collins, provided soil physical properties data for the Akron, Colorado data set.

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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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.

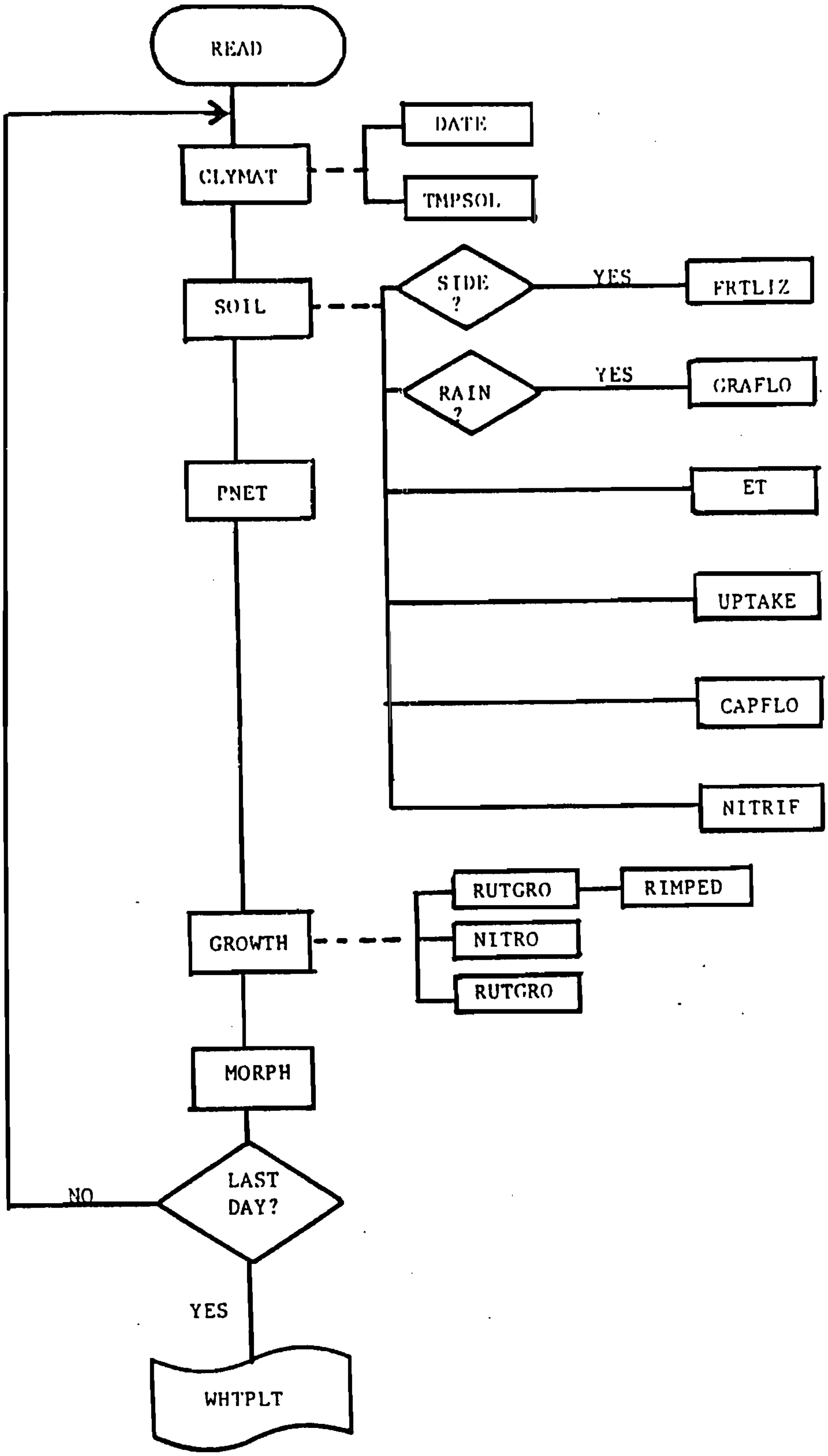
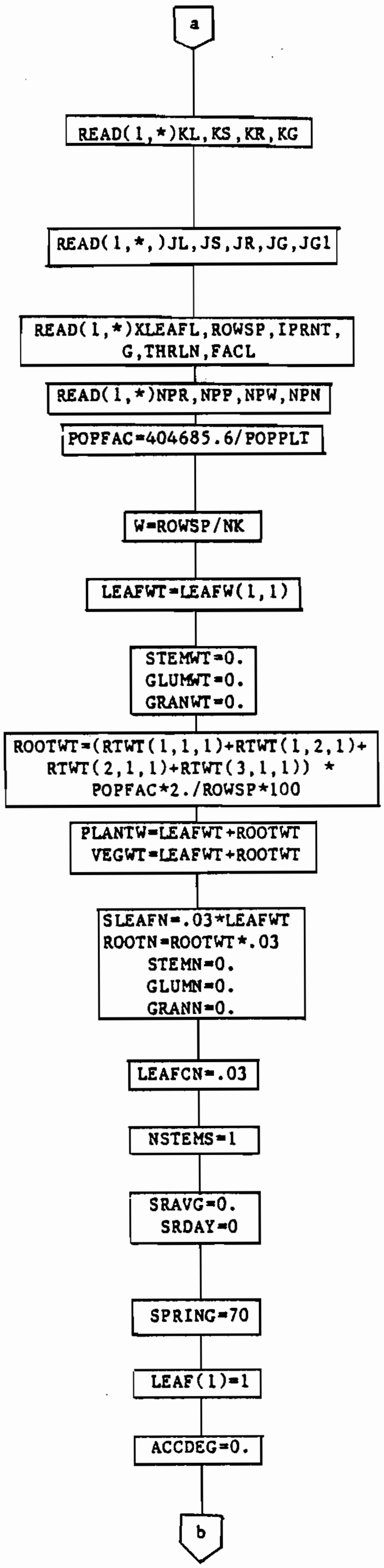


Figure 1. The subroutine structure of WINTER WHEAT.

MAIN Program

Flowchart	Notes
DIFREN=999 TILLER=999 Do 100 I = 1,10 JOINT(I)=999 BOOT(I)=999 HEAD(I)=999 ANTHES(I)=999	Initialize the variables which are set in the morphogenesis subroutine and are used to indicate state of development.
STEMW(I)=0. GLUMW(I)=0. GRANW(I)=0.	Initialize the variables where stem, glume, and grain weight for each stem are stored.
SPIKE(I)=0. FLORET(I)=0. LEAF(I)=0	Initialize the variables where number of spikelets, florets, and leaves for each stem are stored.
LTDAY(I)=0 LLDAY(I)=0 NTILL(I)=0	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.
ATTMP(I)=0. APTMP(I)=0.	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.
Do 100 J=1,6 LEAFW(I,J)=0. LIDATE(I,J)=0 ALTMP(I,J)=0.	For each leaf, variables set up to store weight, day of initiation, and accumulated temperature since initiation are set to zero.
100 CONTINUE	
AHTMP=0.	Accumulator for temperature after heading is set to zero.
SECOND=0	The variable for number of secondary roots is set to zero.
AREA=0.	Total leaf area is set to zero.
READ(1,*)LEAFW(1,1),RTWT(1,1,1), RTWT(1,2,1),RTWT(2,1,1),RTWT(3,1,1), PNFAC	Read in initial leaf weight, root weight, and minimum value for net photosynthesis.
READ(1,*)POPPLT,F2,LATUDE, LAI,NOITR,FACR	Read in plant population, nitrogen availability factor, latitude, initial leaf area index, number of iterations per half day, and a root growth calibration factor.
(a)	



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.

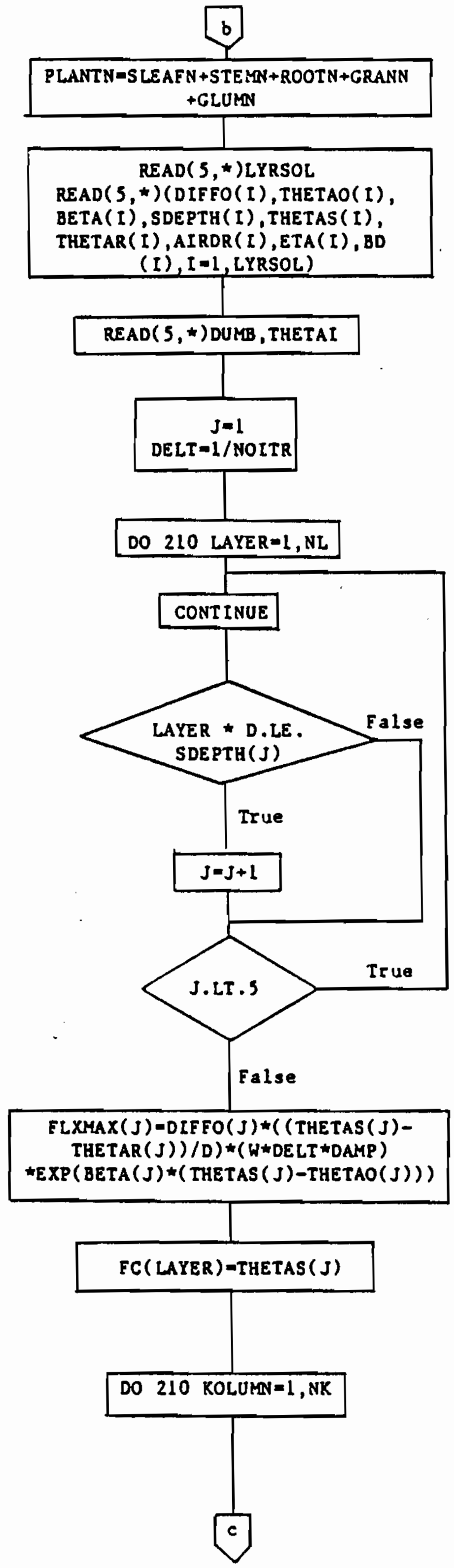
The accumulator for temperature since initiation of the last seconday root, and the day the last secondary root was initiated, are set to zero.

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.

MAIN Continued



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.

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

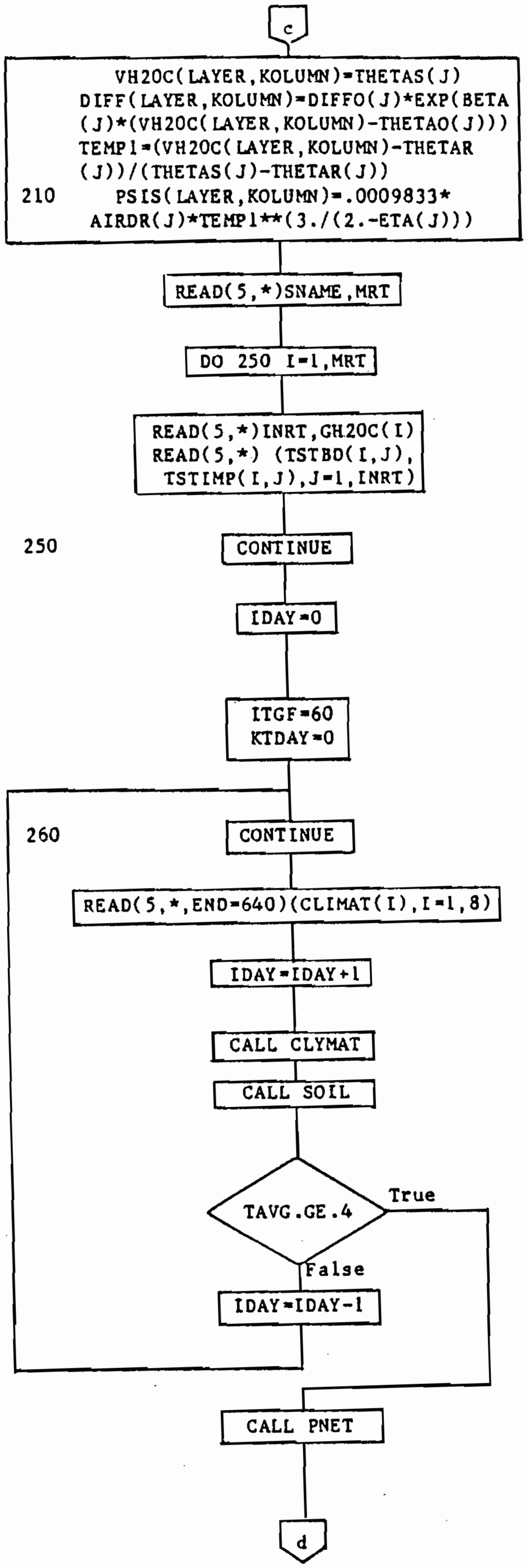
Do for each of the layers.

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.

MAIN Continued



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.

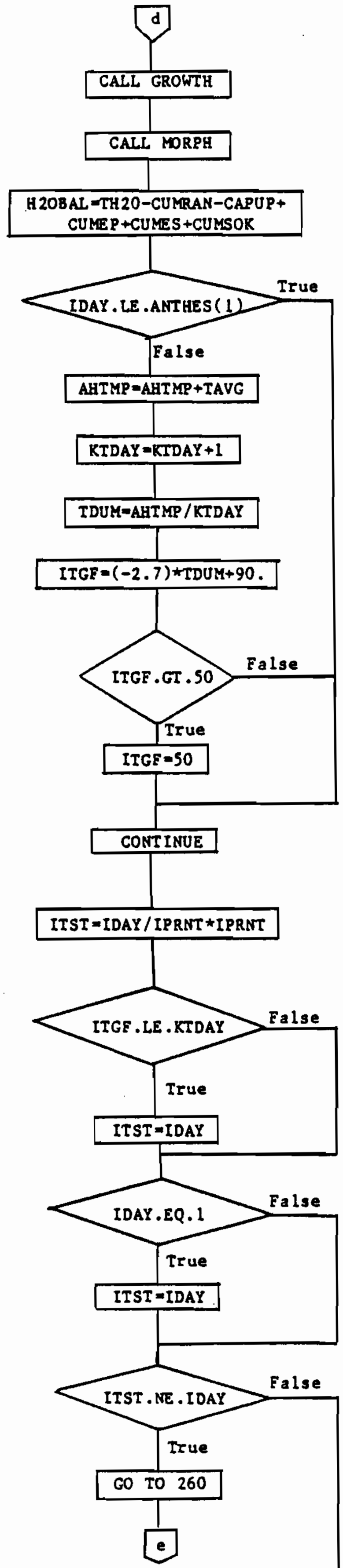
Increment the day counter.

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.

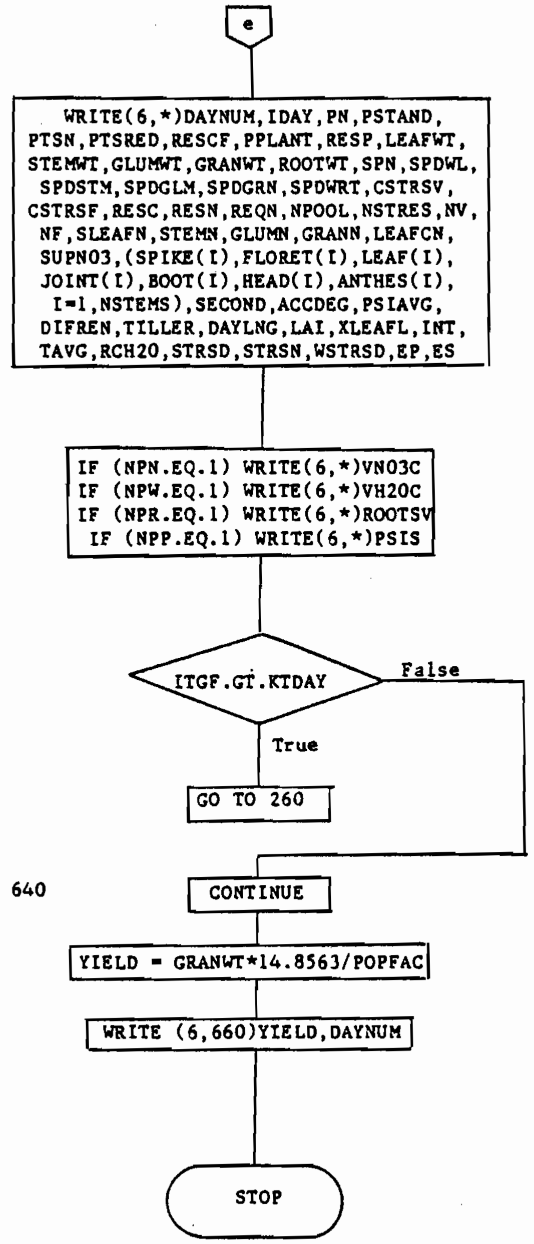
Limit the time for grain filling to be a maximum of 50 days.

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.



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.

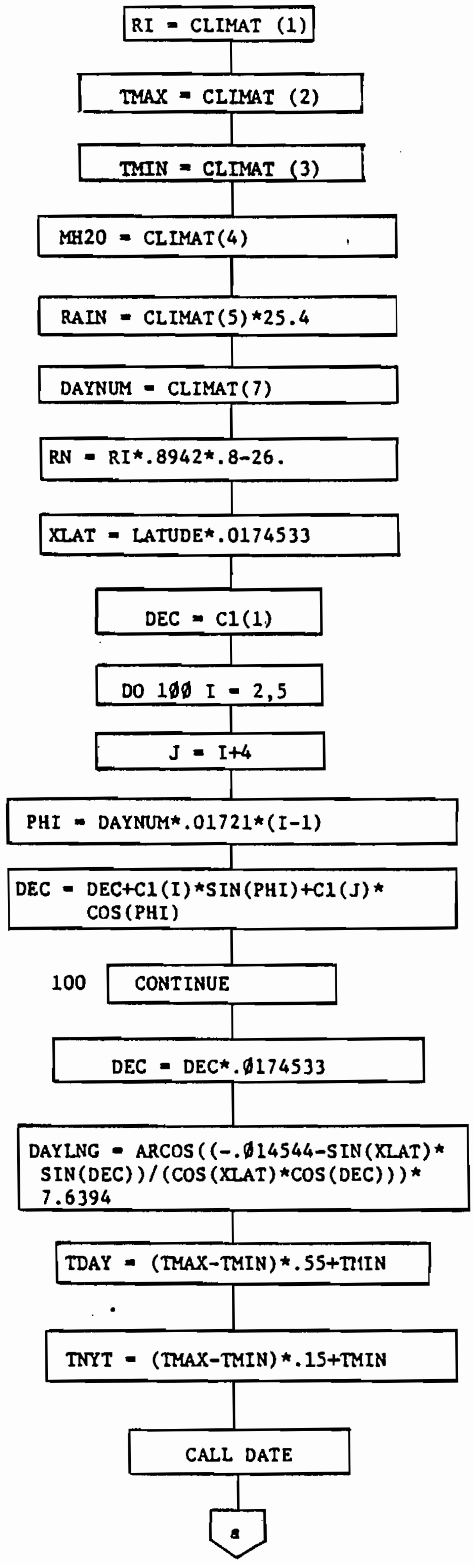
If we have not reached the last day of the simulation, then go to the beginning of the daily loop.

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.

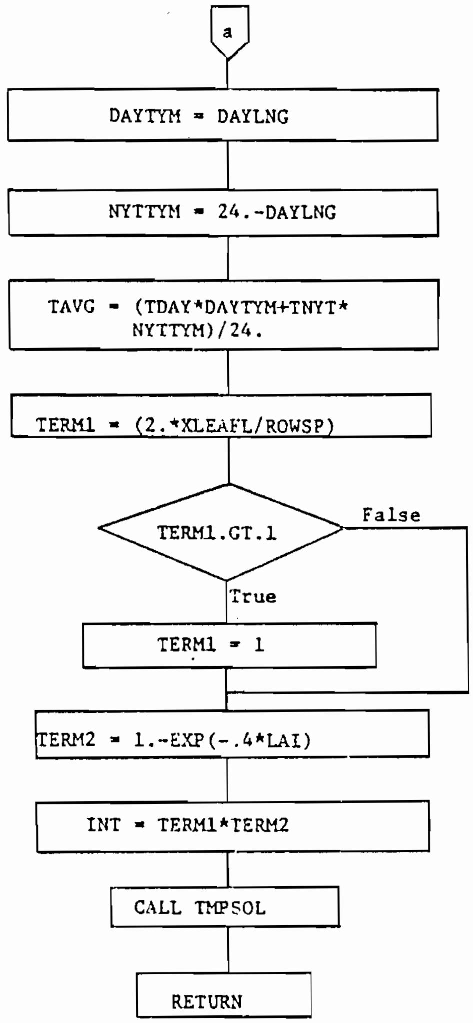
Solar radiation is converted to watts/meter**2.

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.

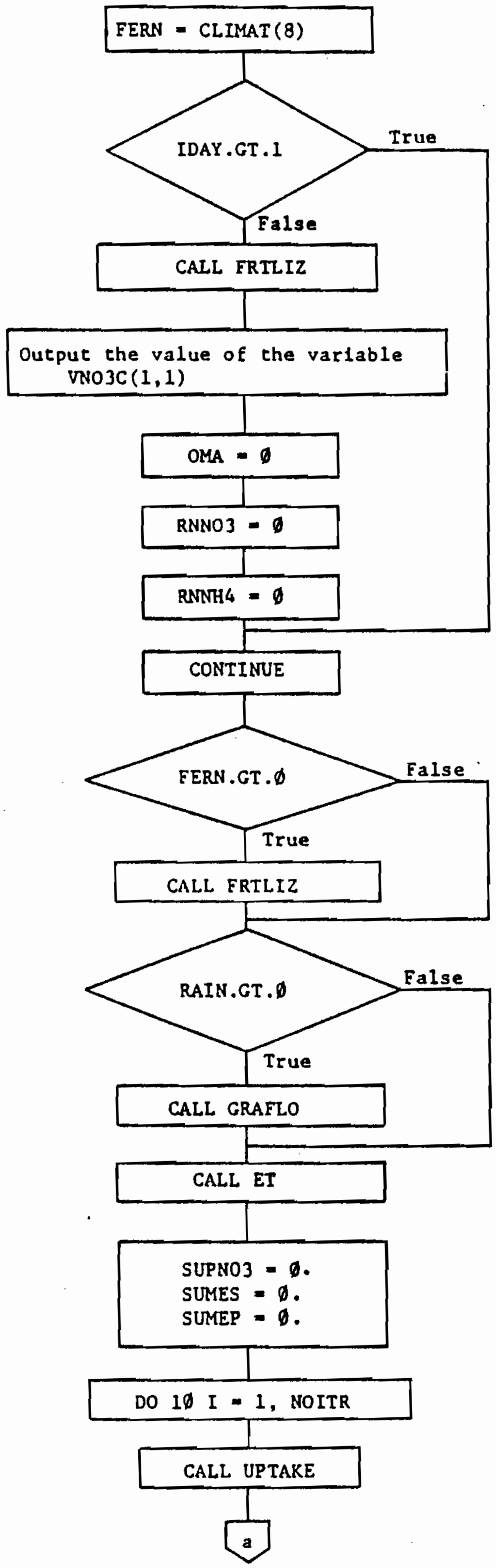
PNET

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).

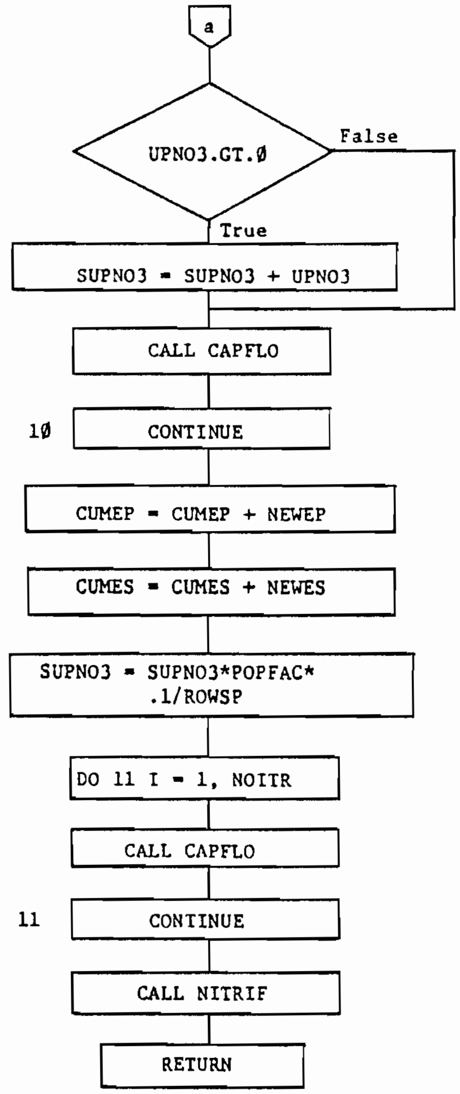
If rain or irrigation occurred, then call the gravitational flow subroutine (GRAFLO).

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.

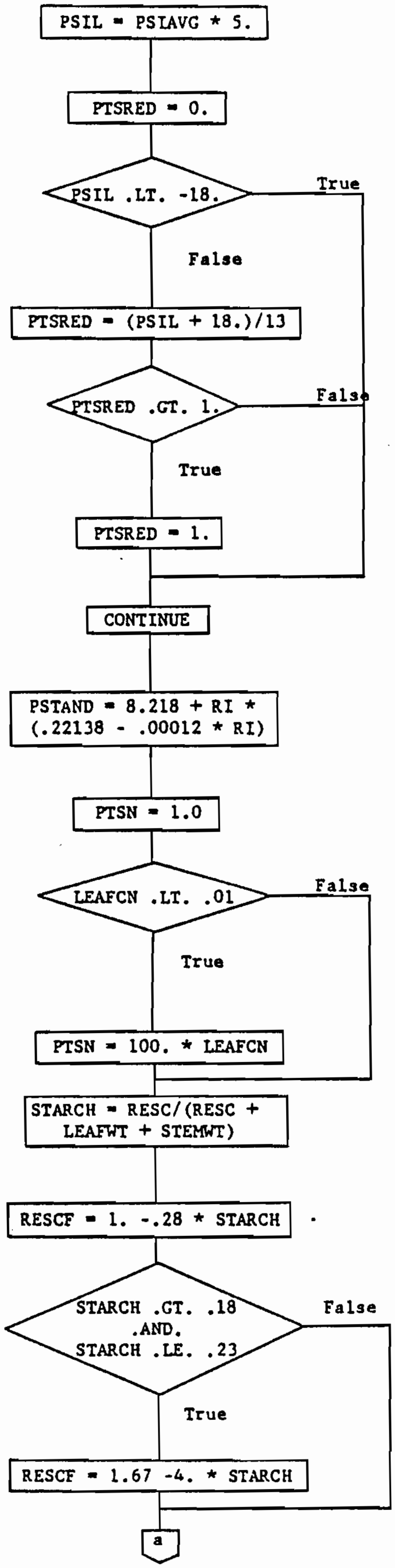
The static models of Monsi and Saeki (1953), deWit (1965), Duncan, et.al., (1967), and Tooming, (1967) consider the leaf as the basic photosynthetic element. They treat an exceedingly complex subject requiring a vast amount of input data describing the physical location, the climate and the angular orientation 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 nutritional status of each leaf element. All this can be provided in a model, but at considerable expense.

In addition to the complexity involved, these static leaf element models present 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.

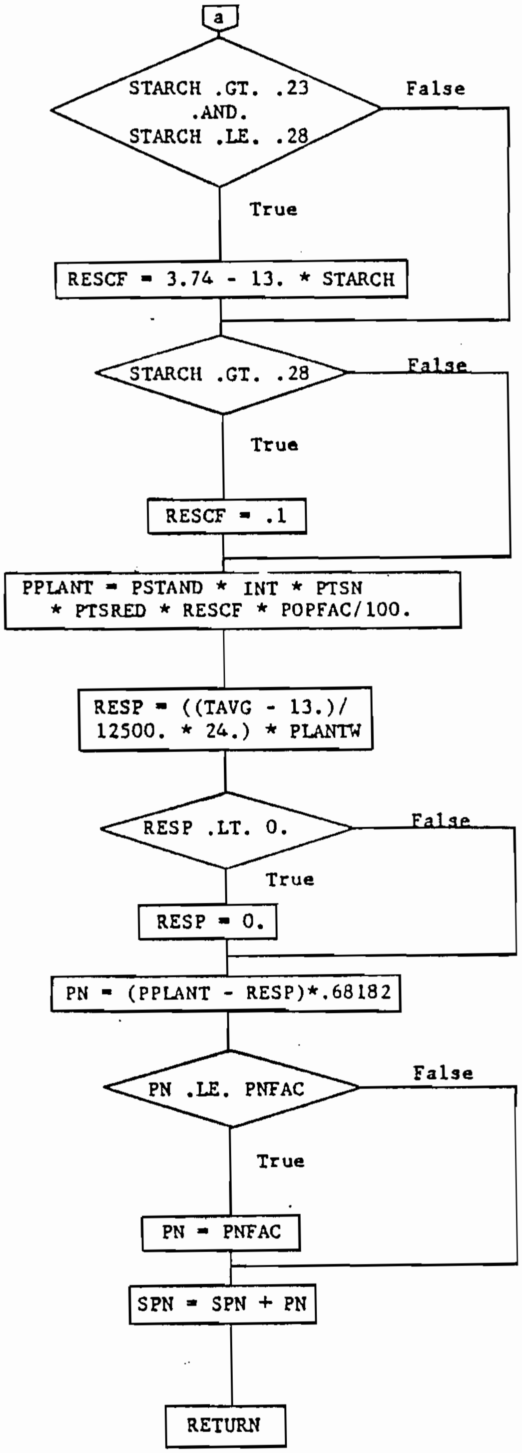
Potential canopy photosynthesis is a function of solar radiation.

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

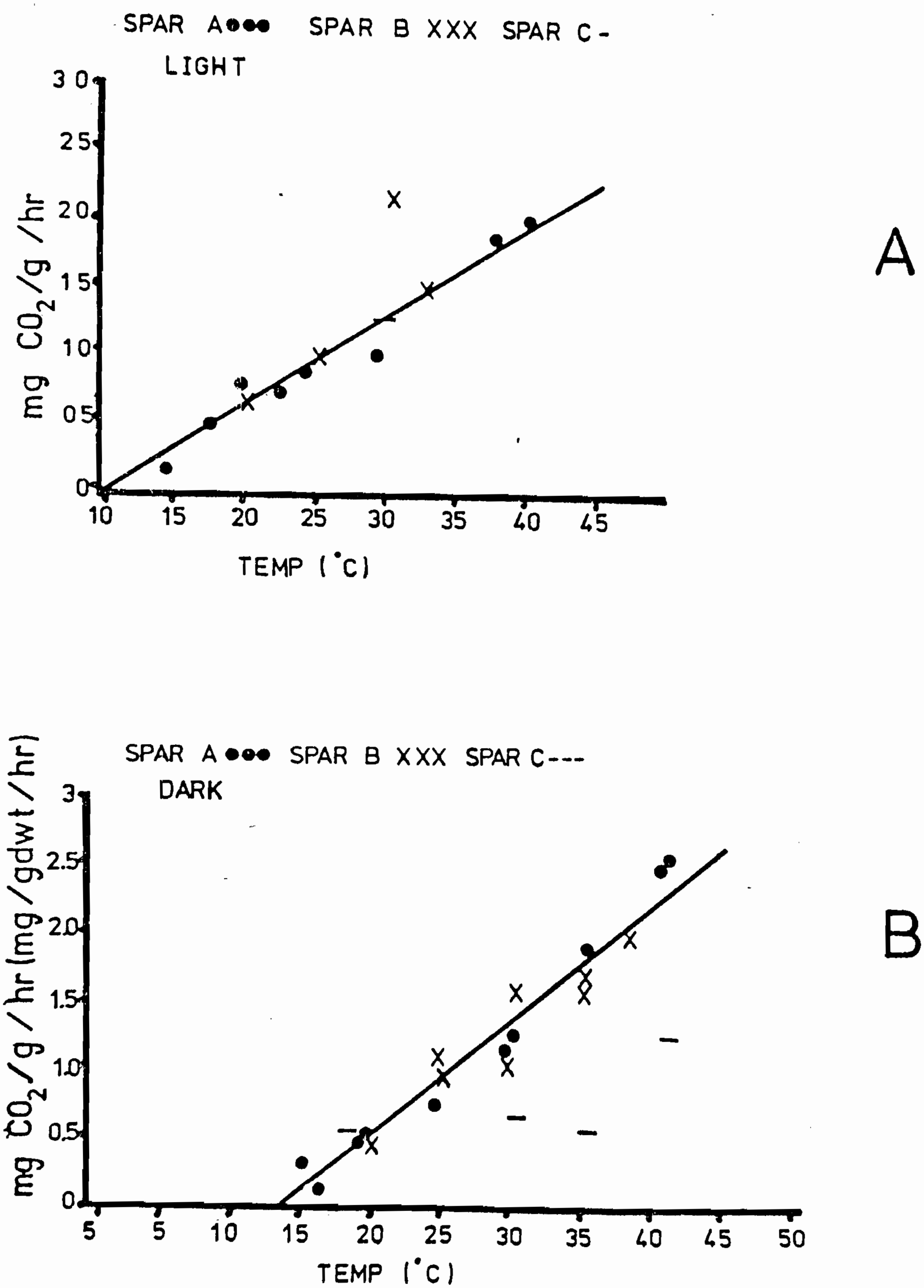


Figure 2. Canopy respiration rates (in mg. CO_2/gram dry plant weight/hour) vs. air temperature immediately after exposure to bright light (A) and after exposure to long periods of darkness (B).

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

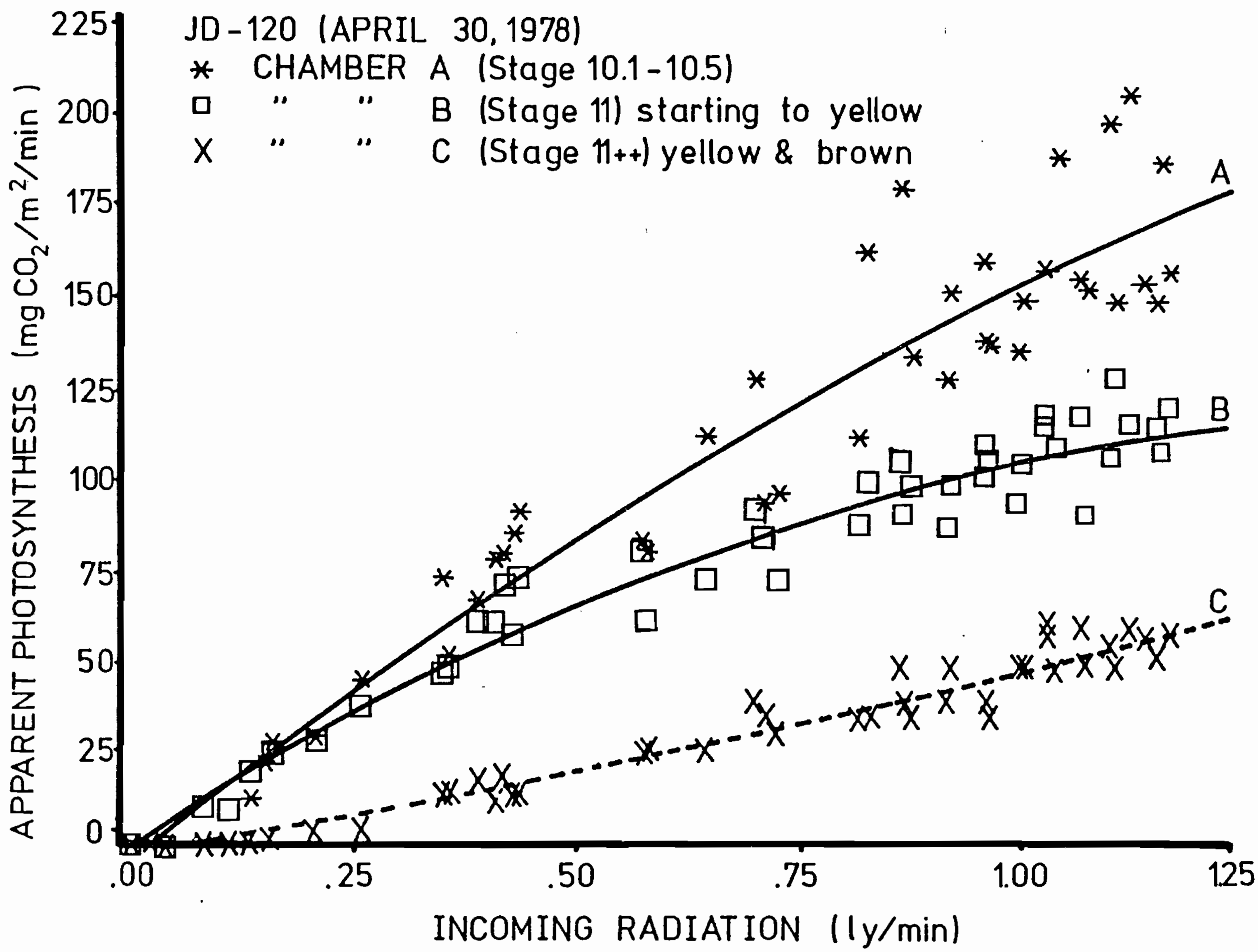


Figure 3. Apparent canopy photosynthesis vs. solar radiation flux density in three SPAR crops differing in maturity.

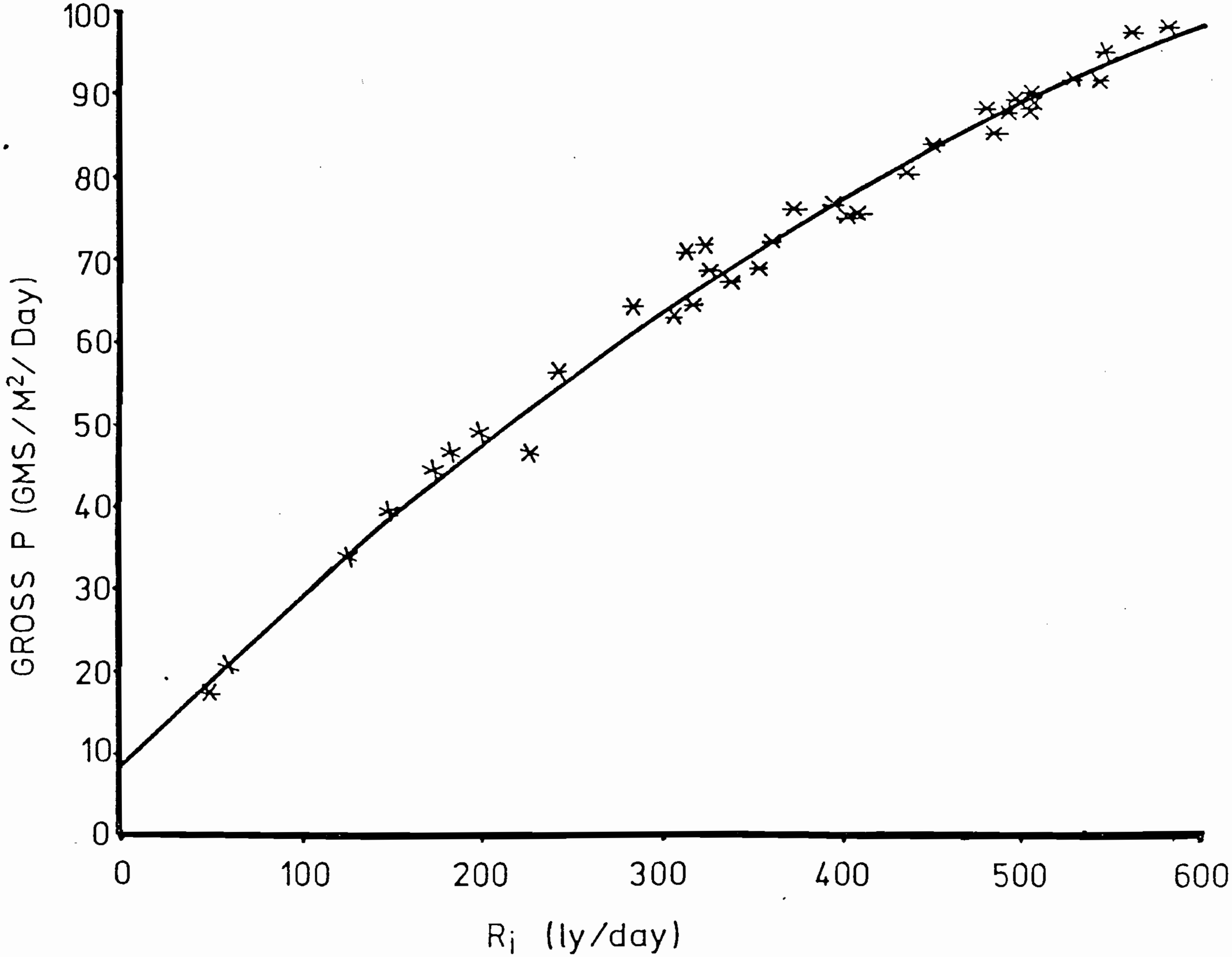


Figure 4. Daily total canopy photosynthesis vs. daily total solar radiation.

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:

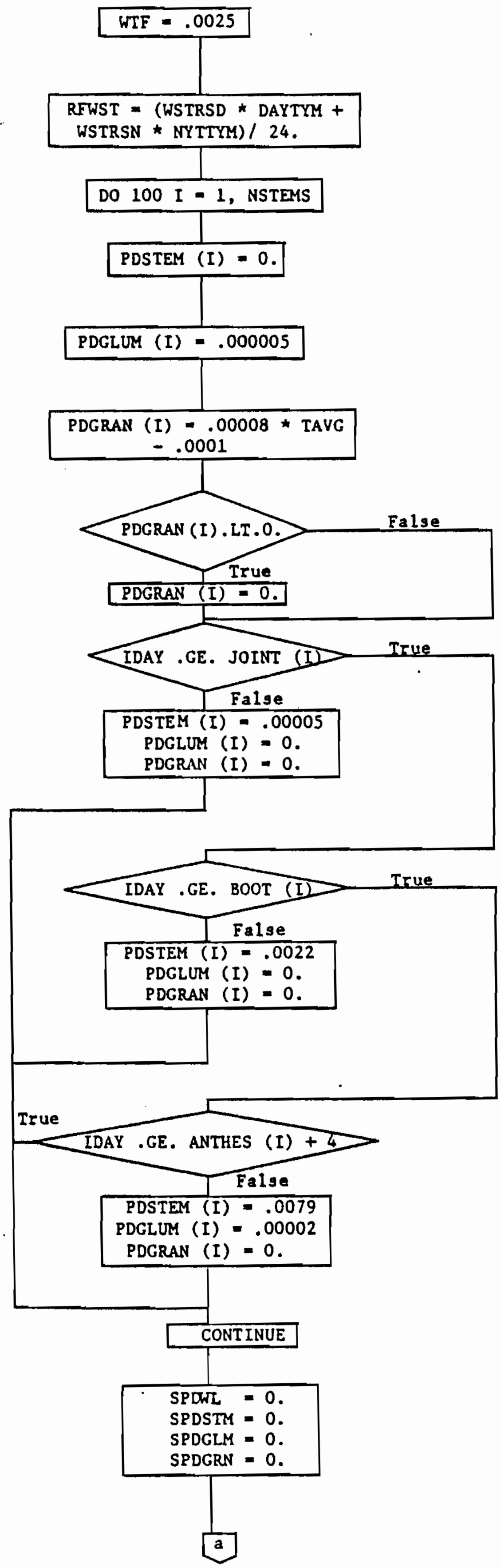
$$CPOOL = PN + RESC$$

$$CSTRES = CPOOL/CD$$

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)

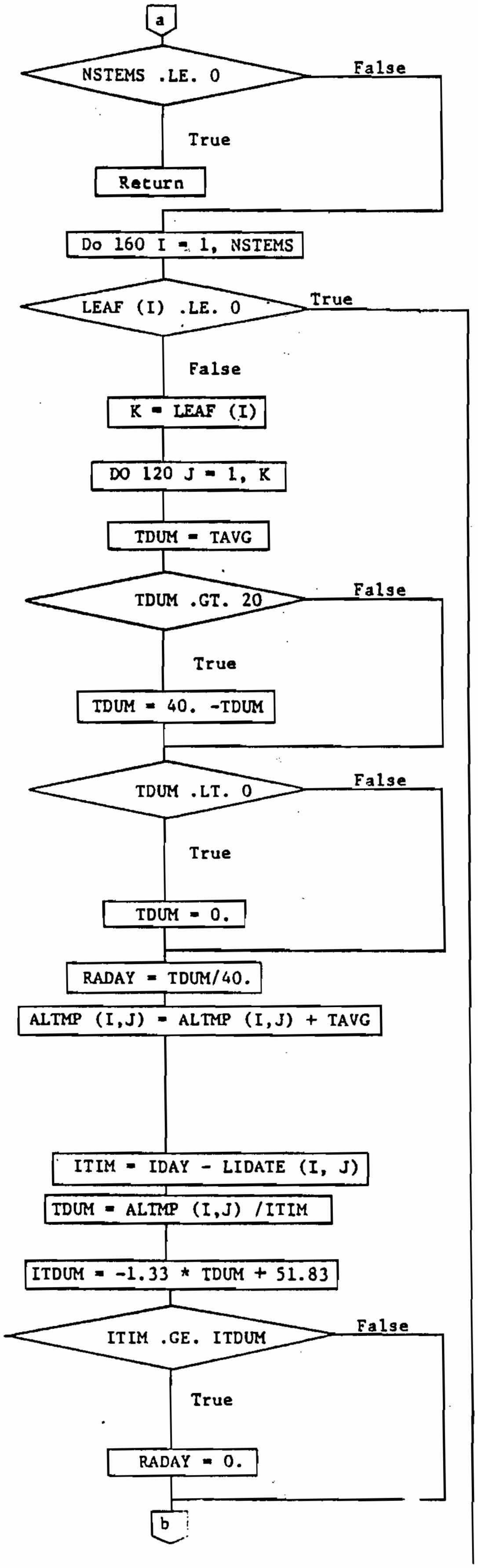
If the potential change in grain weight is calculated to be less than zero, then set it to zero.

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.

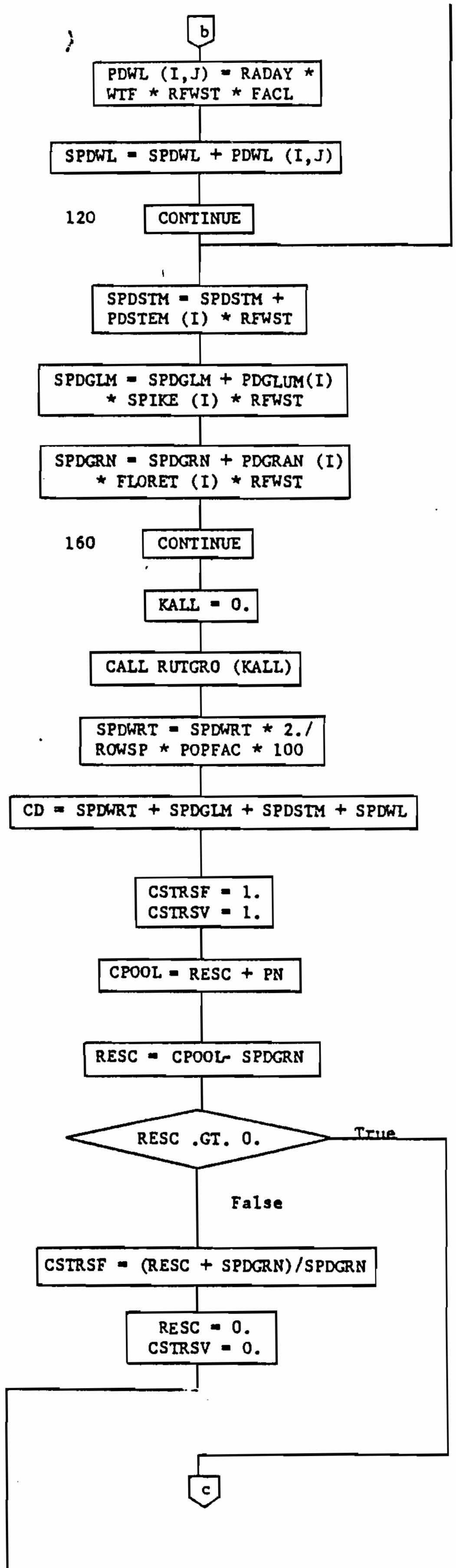
Do for each leaf on the stem.

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).

Calçulate 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.

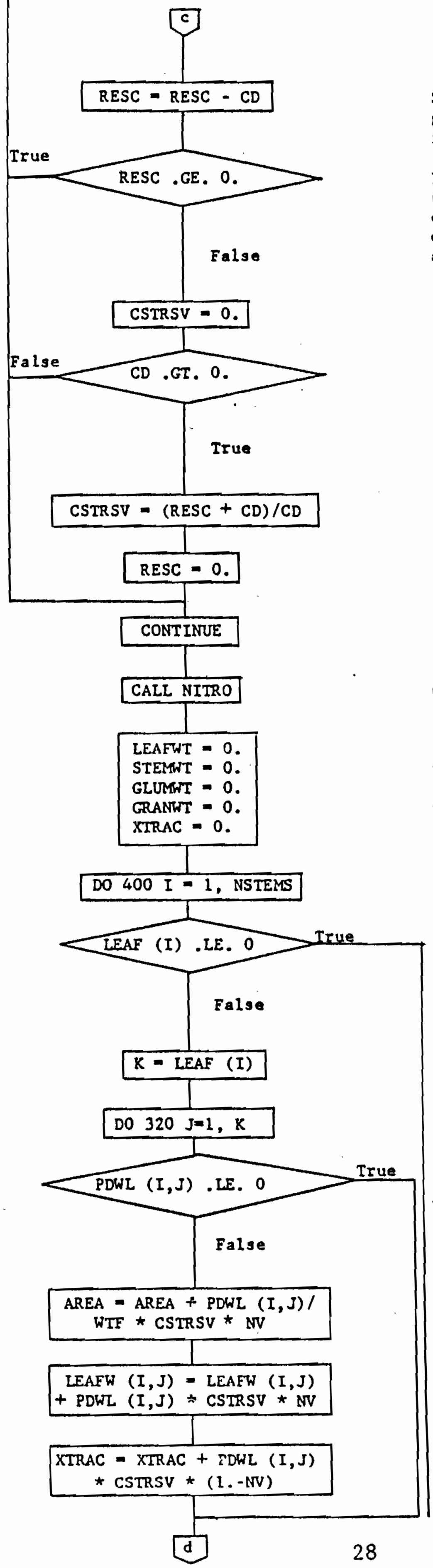
Total potential change in weight of all plant parts except grain to determine carbohydrate demand for these parts.

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.

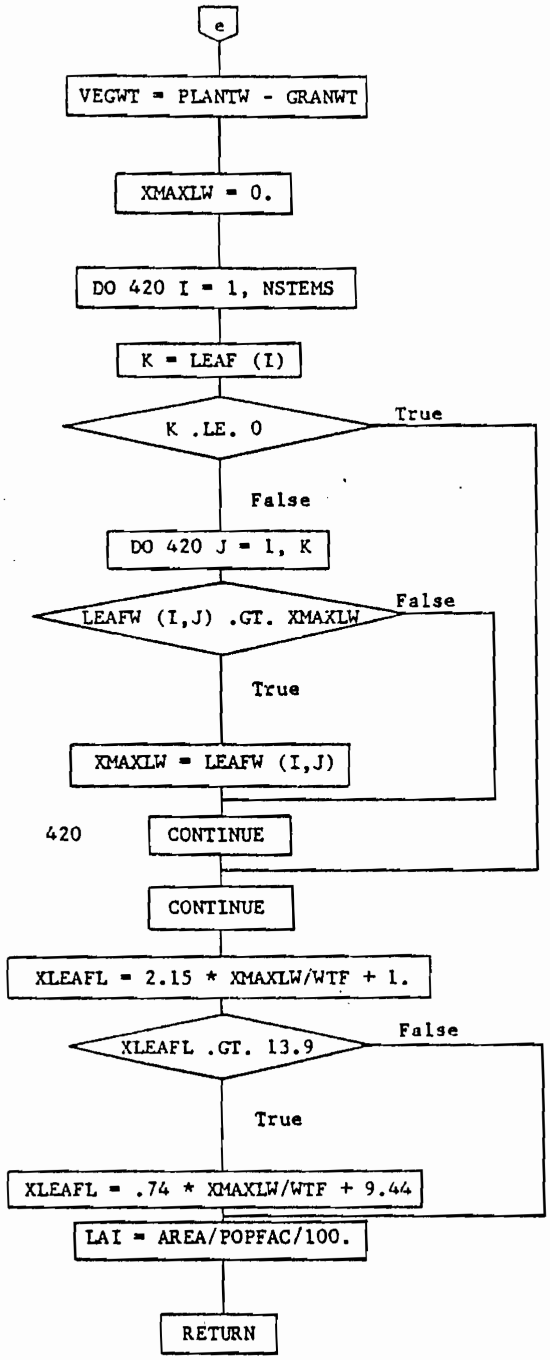
Determine the weight of leaf J on stem I.

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

(d)

Flowchart step	Description
LEAFWT = LEAFWT + LEAFW (I,J)	Accumulate the weight of leaves on plant.
320 CONTINUE	
STEMW(I) = STEMW(I) + PDSTEM (I) * RFWST * CSTRSV * NV	Determine weight of stem I by adding change in stem weight to the accumulator.
XTRAC = XTRAC + PDSTEM (I) * RFWST * CSTRSV * (1.-NV)	Accumulate the extra carbohydrate which was needed for stem growth but not used because of nitrogen stress.
STEMWT = STEMWT + STEMW (I)	Accumulate the total weight of all stems on plant.
GLUMW (I) = GLUMW (I) + PDGLUM (I) * RFWST * CSTRSV * SPIKE (I) * NV	Determine weight of glumes on stem I by adding change in glume weight to the accumulator.
XTRAC = XTRAC + PDGLUM (I) * SPIKE (I) * RFWST * CSTRSV * (1.-NV)	Accumulate the extra carbohydrate which was needed for glume growth but not used because of nitrogen stress.
GLUMWT = GLUMWT + GLUMW (I)	Accumulate the total weight of all glumes on plant.
GRANW (I) = GRANW (I) + PDGRAN (I) * RFWST * CSTRSF * NF * FLORET (I)	Determine the weight of grain of stem I by adding grain weight to the accumulator.
XTRAC = XTRAC + PDGRAN (I) * FLORET (I) * RFWST * CSTRSF * (1.-NF)	Accumulate the extra carbohydrate which was needed for grain growth but not used because of nitrogen stress.
GRANWT = GRANWT + GRANW (I)	Accumulate the total weight of all grain on the plant.
400 CONTINUE	
RCH2O = SPDWRT * CSTRSV * NV	Determine the amount of carbohydrate going to the roots of the plant.
XTRAC = XTRAC + SPDWRT * CSTRSV * (1.-NV)	Accumulate the extra carbohydrate which was allocated for root growth, but not used because of nitrogen stress.
KALL = 1.	
CALL RUTGRO (KALL)	Call the RUTGRO subroutine to grow the roots.
RESC = RESC + XTRAC	The extra carbohydrate is added to reserve carbohydrate.
PLANTW = LEAFWT + STEMWT + GLUMWT + GRANWT + ROOTWT + RESC	Total plant weight is weight of individual plant parts plus the reserve carbohydrate which is mainly stored in the leaves.

(e)



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

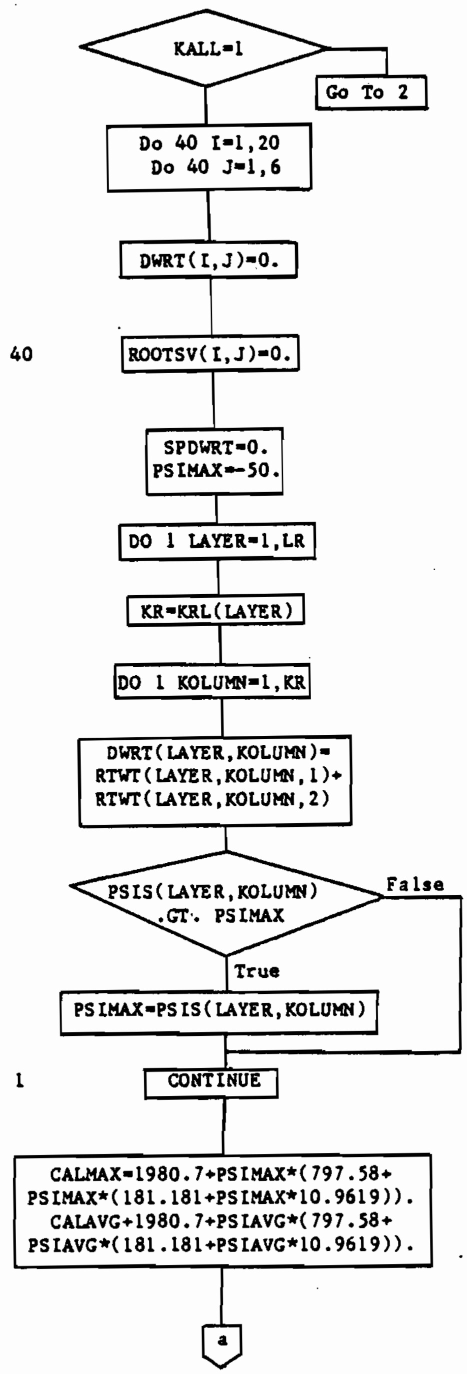
This subroutine calculates potential and actual dry matter in the various parts of the root system. It also calculates water stress parameters which are used in GROWTH to adjust potential growth of above ground plant parts.

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.



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

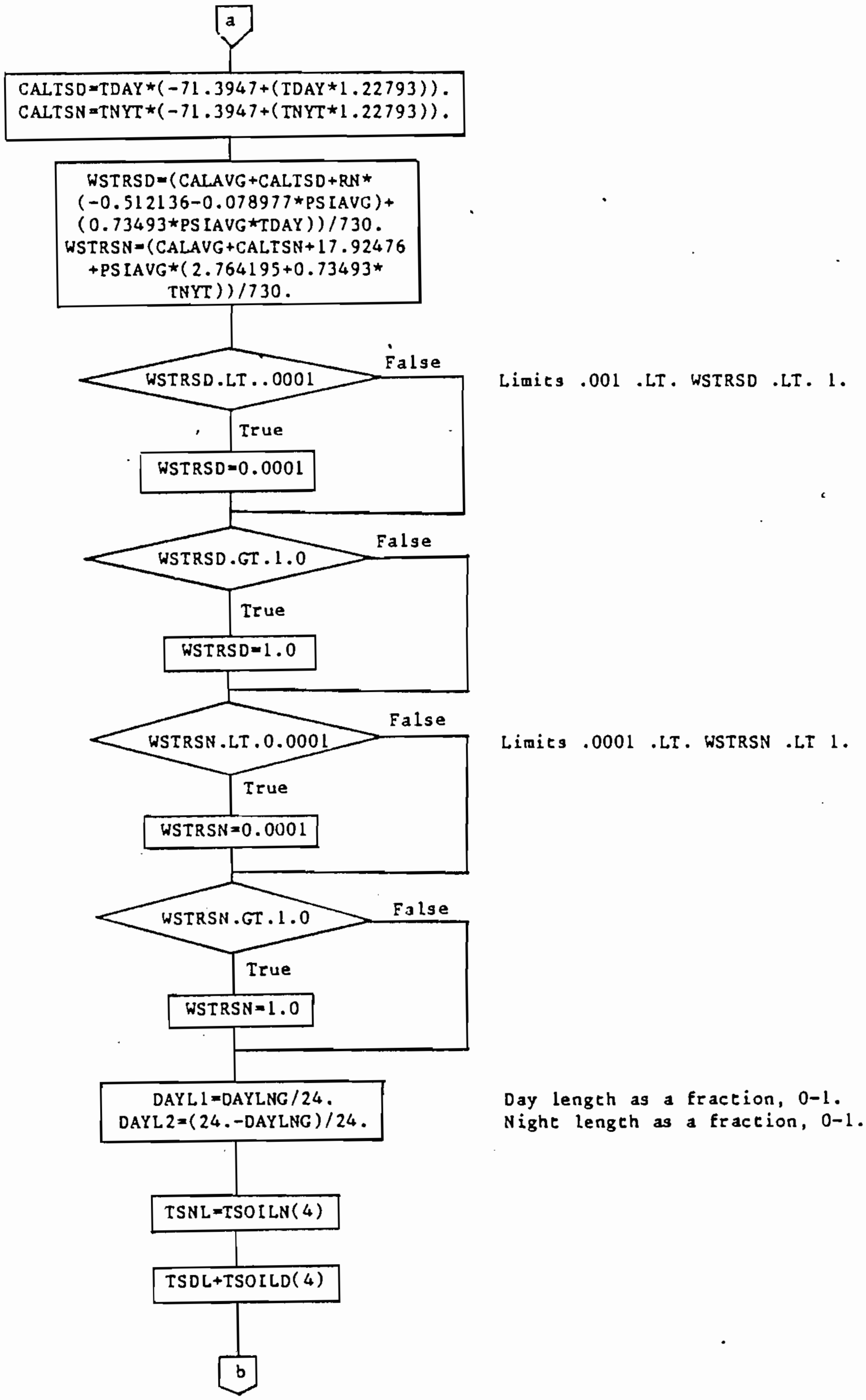
Initialize the arrays DWRT and ROOTSV each day.

Initialize these variables.

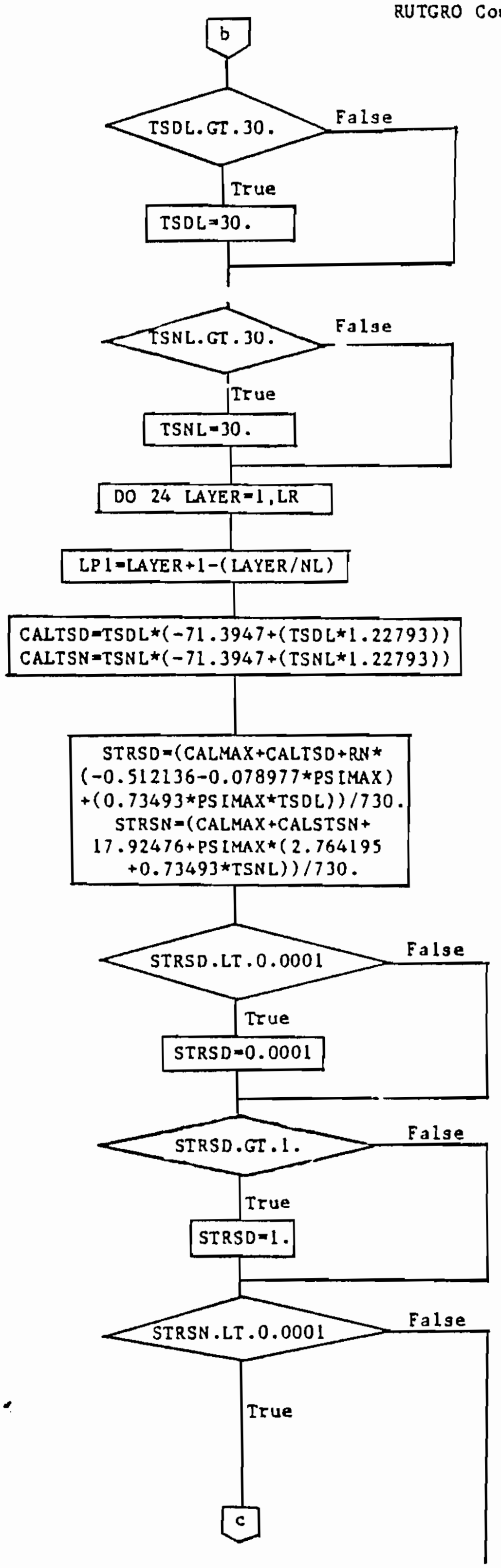
Traverses all soil cells occupied by roots.

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.


a
CALTSD=TDAY*(-71.3947+(TDAY*1.22793)).
CALTSN=TNYT*(-71.3947+(TNYT*1.22793)).
WSTRSD=(CALAVG+CALTSD+RN*
(-0.512136-0.078977*PSIAVG)+
(0.73493*PSIAVG*TDAY))/730.
WSTRSN=(CALAVG+CALTSN+17.92476
+PSIAVG*(2.764195+0.73493*
TNYT))/730.
WSTRSD.LT..0001
False
True
Limits .001 .LT. WSTRSD .LT. 1.
WSTRSD=0.0001
WSTRSD.GT.1.0
False
True
WSTRSD=1.0
WSTRSN.LT.0.0001
False
True
Limits .0001 .LT. WSTRSN .LT 1.
WSTRSN=0.0001
WSTRSN.GT.1.0
False
True
WSTRSN=1.0
DAYL1=DAYLNG/24.
DAYL2=(24.-DAYLNG)/24.
Day length as a fraction, 0-1.
Night length as a fraction, 0-1.
TSNL=TSOILN(4)
TSDL+TSOILD(4)
b

RUTGRO Continued



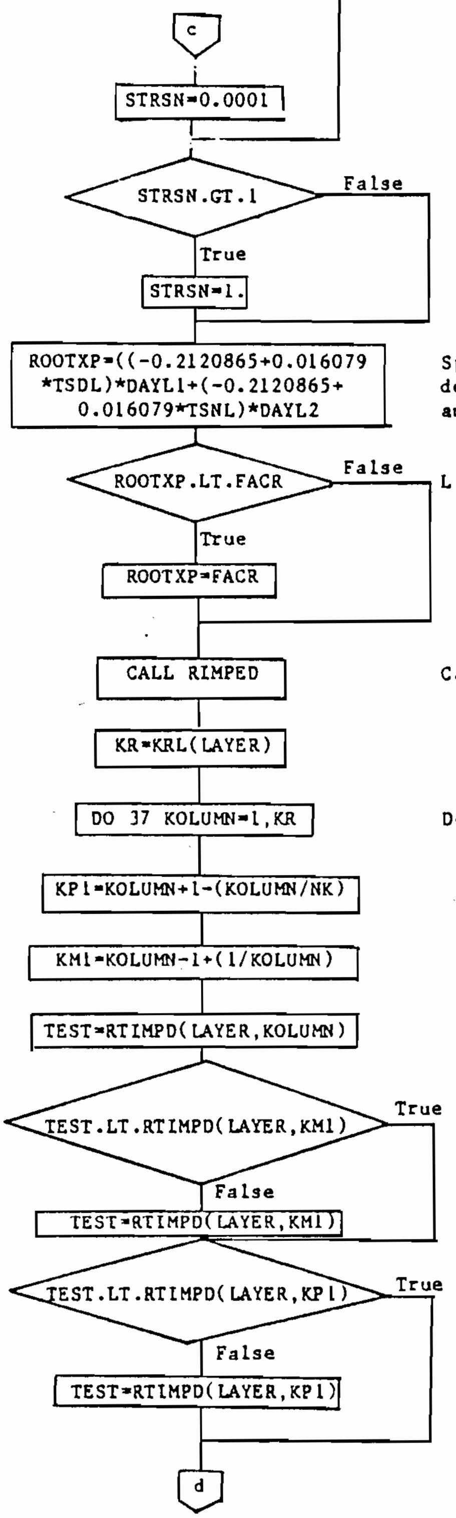
Limit TSDL and TSNL to a maximum of 30° C.

Traverses all layers occupied by roots.

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

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

RUTGRO Continued

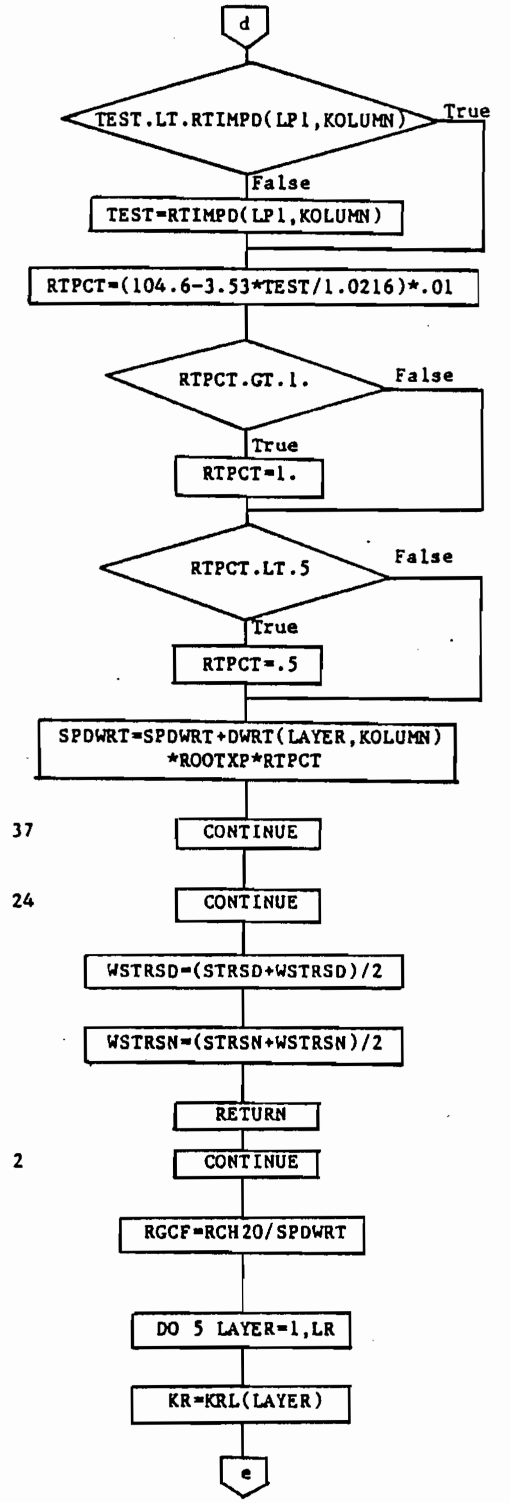


Specific root growth rate within soil cell, dependent on daylength, layer temperature, and water stress based on PSIMAX.

Limit ROOTXP to an input minimum amount.

Call the RIMPED subroutine.

Do for all the columns containing roots.

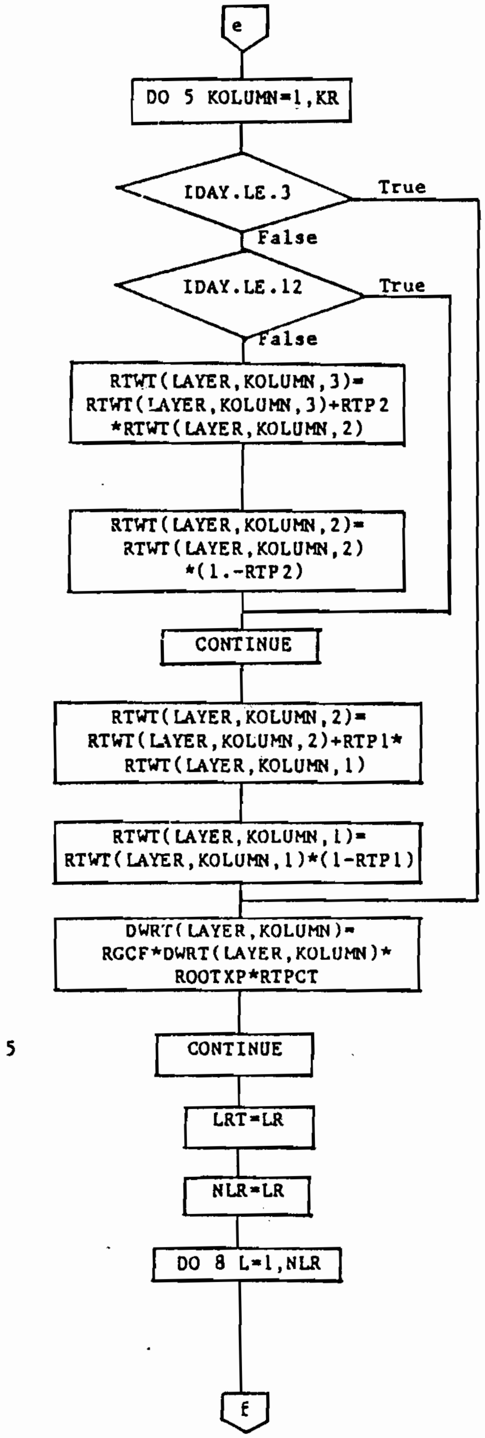


Sum potential root growth over the entire profile.

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. RTP! is 1/3.

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

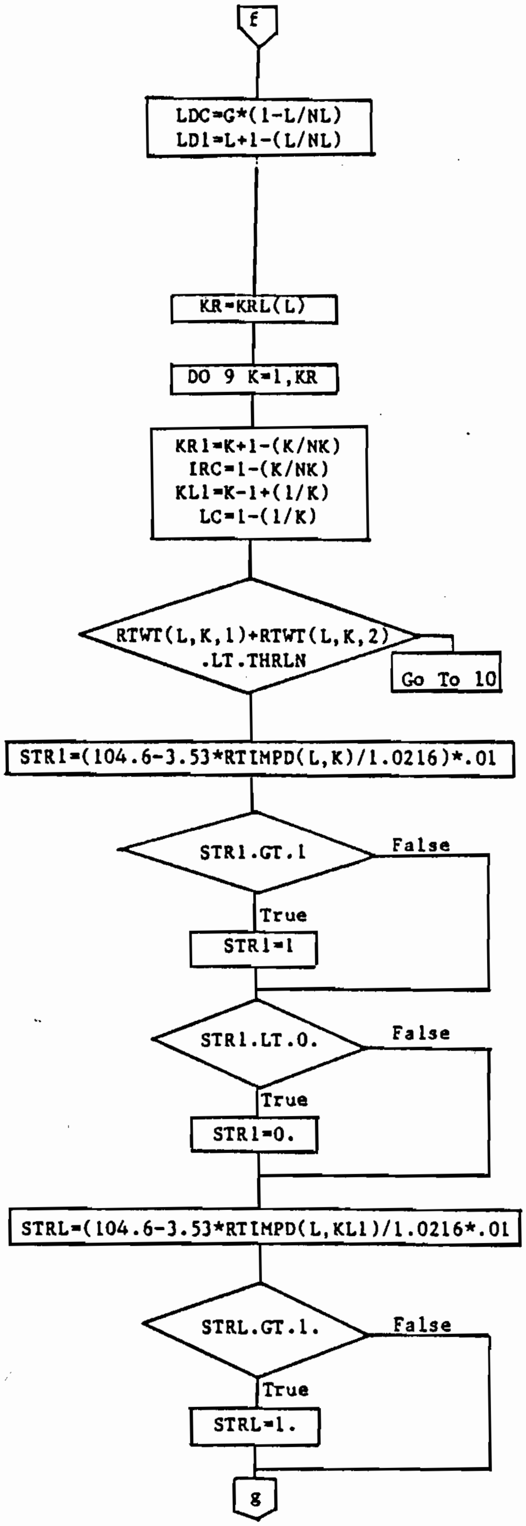
The actual root weight increase in the soil cell. Note that DWRT=RCH2O.

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

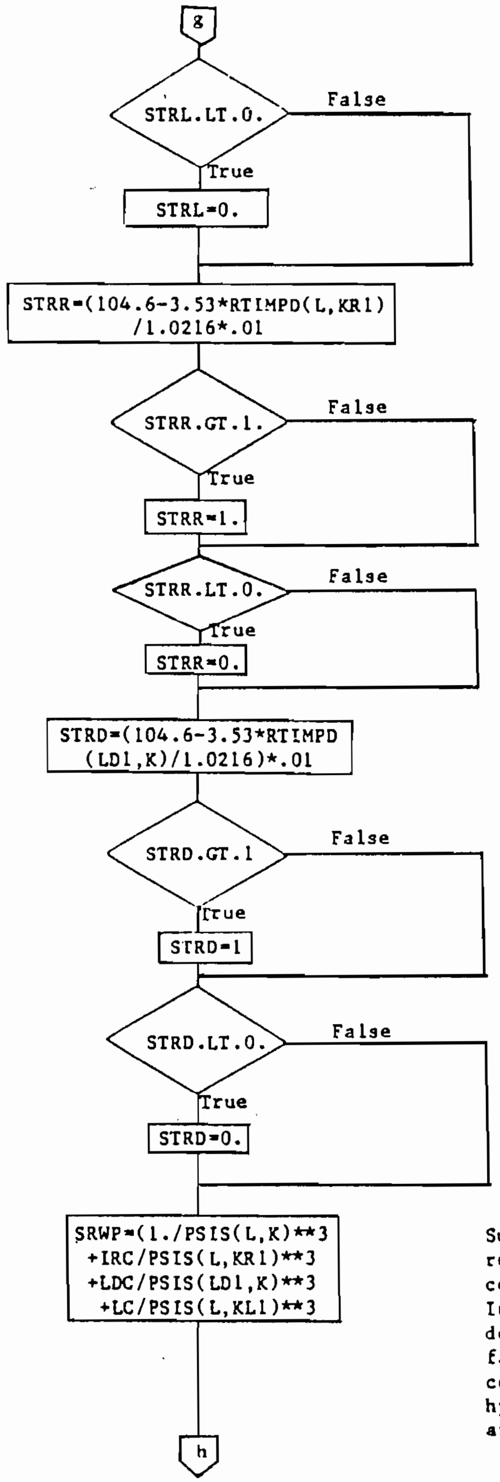


Number of "Layer down" (below) for use in SRWP equations below.
=L+1 1 .LE. L .LT. NL
=L L = NL
The effect of LDC and LD1 in the SRW and subsequent statements is to prohibit roots from growing onto the bottom of the root zone.

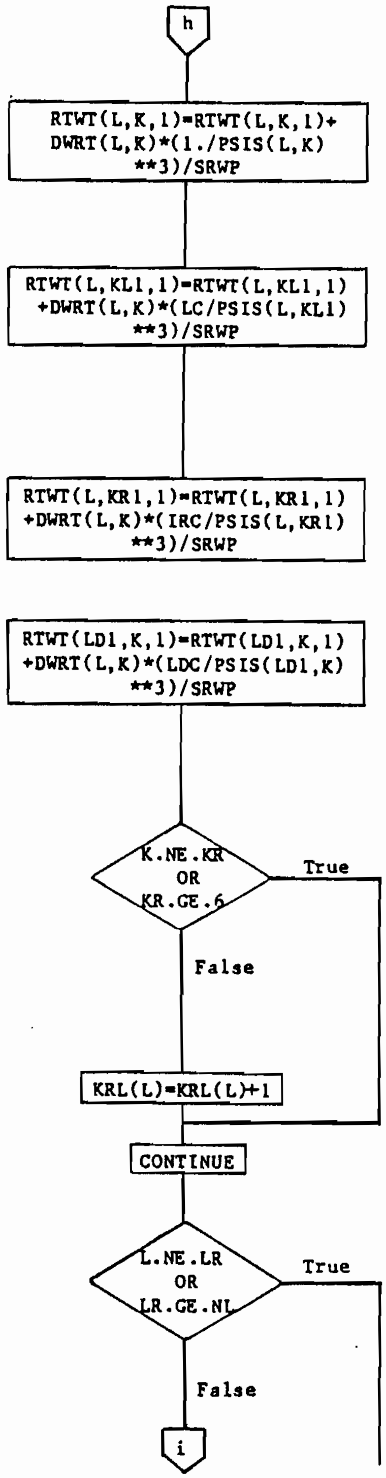
The number of columns occupied by roots in layer L.

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.

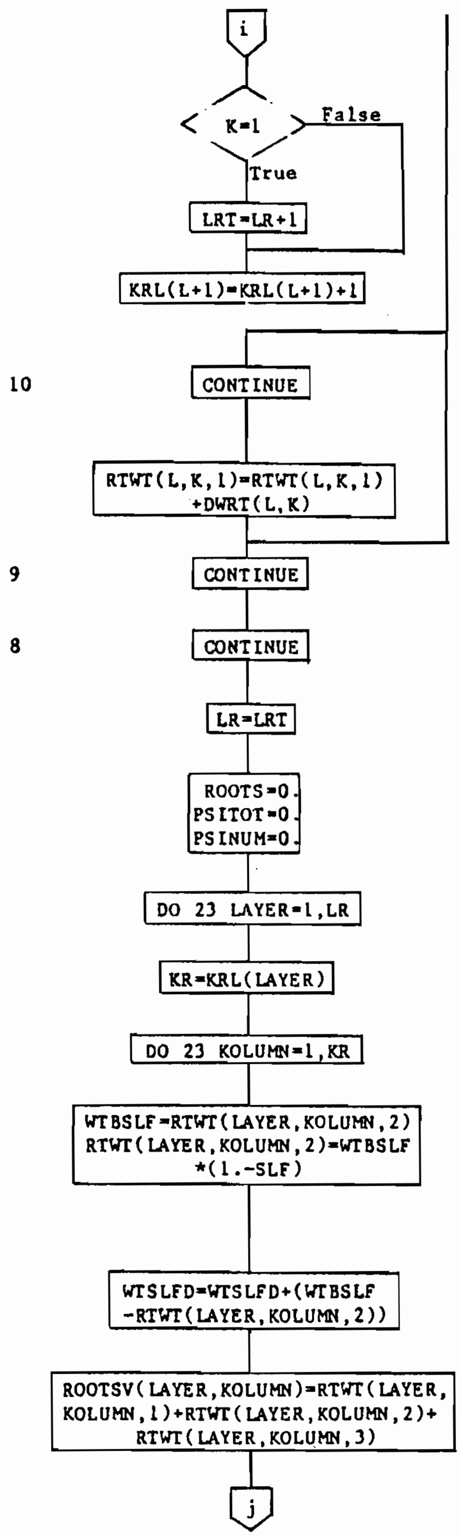
To the current young root weight in the cell to the right of cell L, K is added the fraction of the root growth occurring from the cell L, K into the righthand cell. Note that if K=NK, IRC=0 and the boundary condition of no growth across the plane under the next row is satisfied.

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.

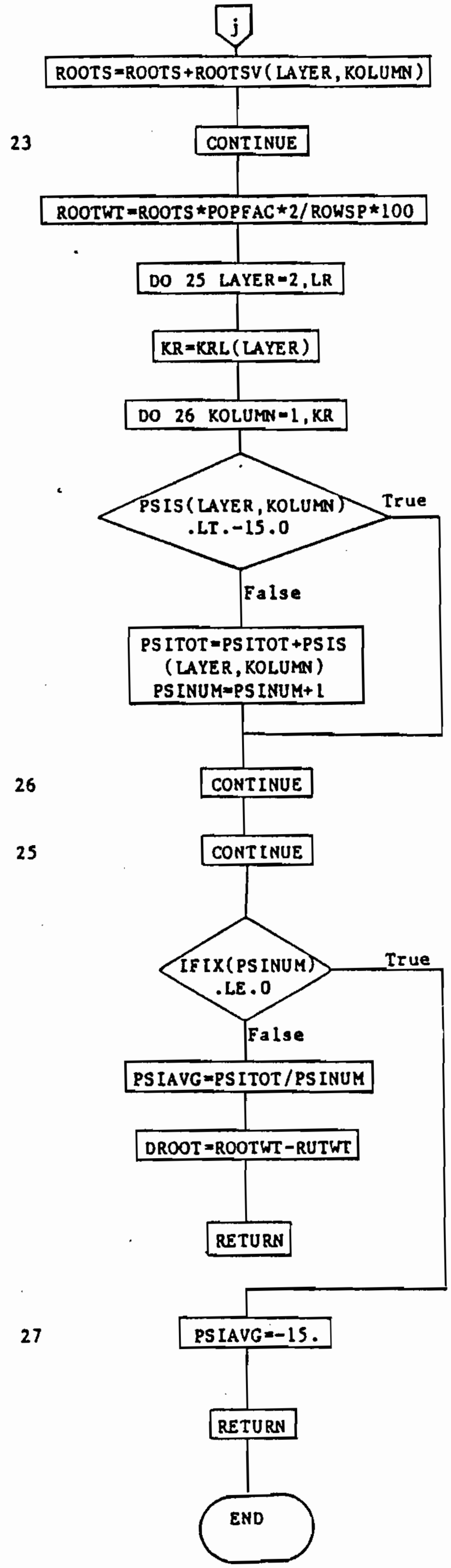
Traverse all soil cells occupied by roots.

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.

RUTGRO Continued



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.

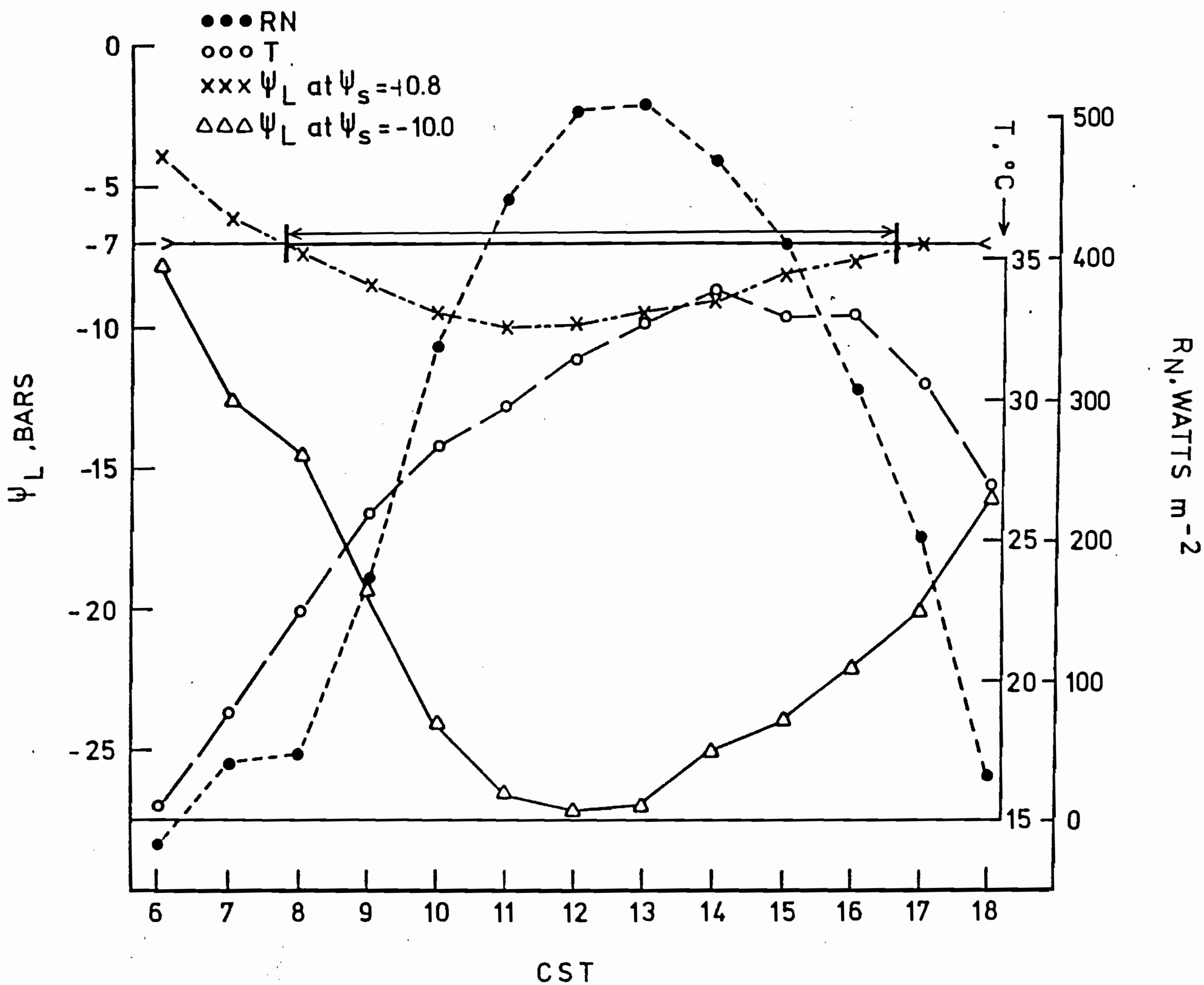


Figure 5. Typical daily time courses of net radiation, air temperature and leaf water potential at soil water potentials of -0.8 and -10.0 bar.

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.

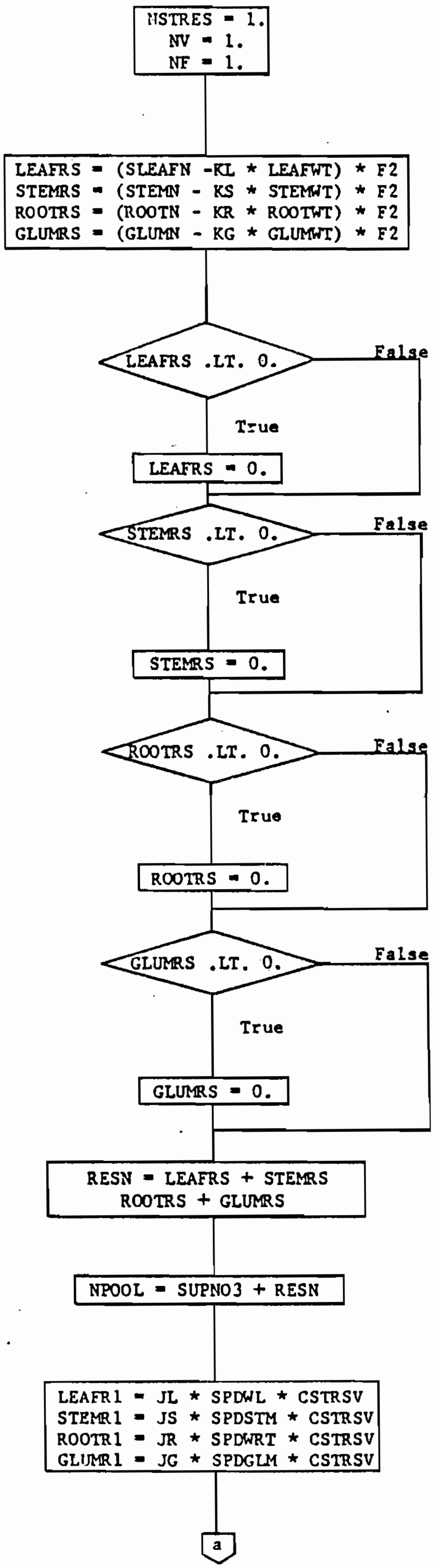
NITRO is flow charted on pages 49-51. Organ weights and nitrogen contents are brought in. Also brought in (from GROWTH) are potential growth increments. The nitrogen supply:demand ratios are initialized, and, reserves are calculated as the difference between the tissue nitrogen content and the content 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 availability 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.

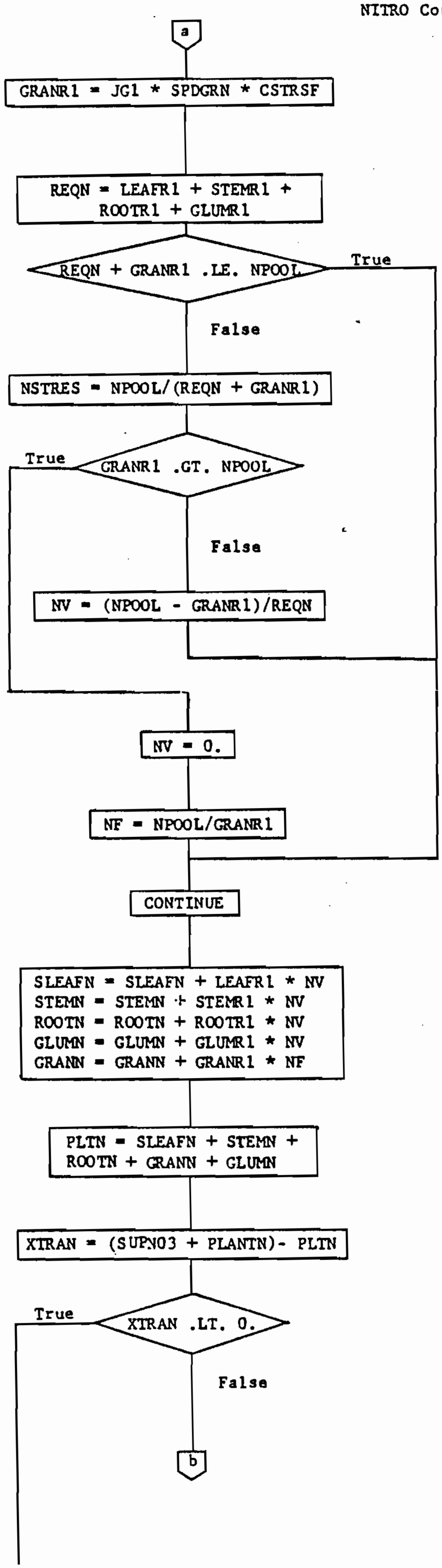
If root reserves are calculated be less than zero, then they are set to zero.

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.

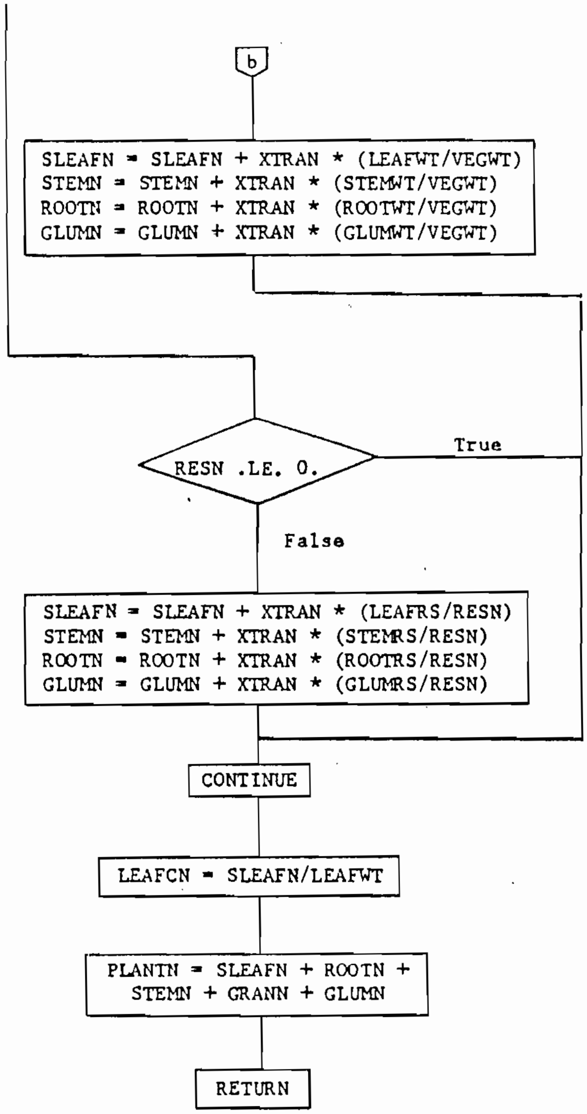
If the nitrogen requirement for maximum grain growth is less than or equal to the available nitrogen then calculate a reduction factor for vegetative growth.

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.



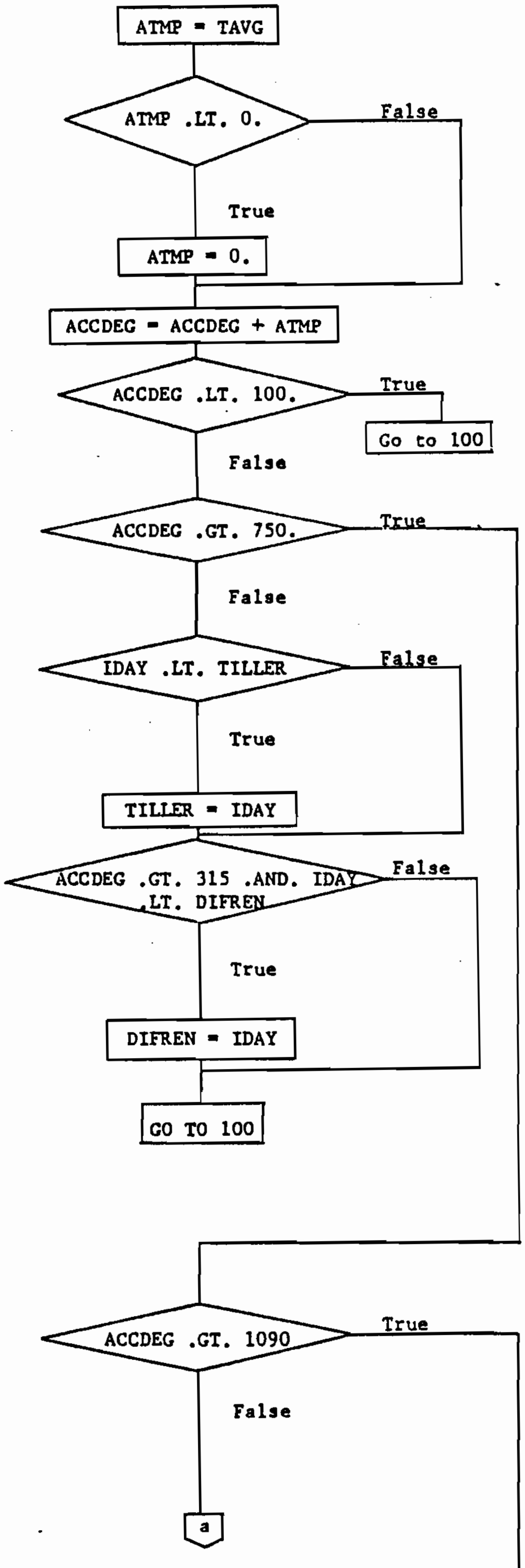
Allocate the excess to the various vegetative structures in proportion to their dry weights.

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.

MORPH Subroutine



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.

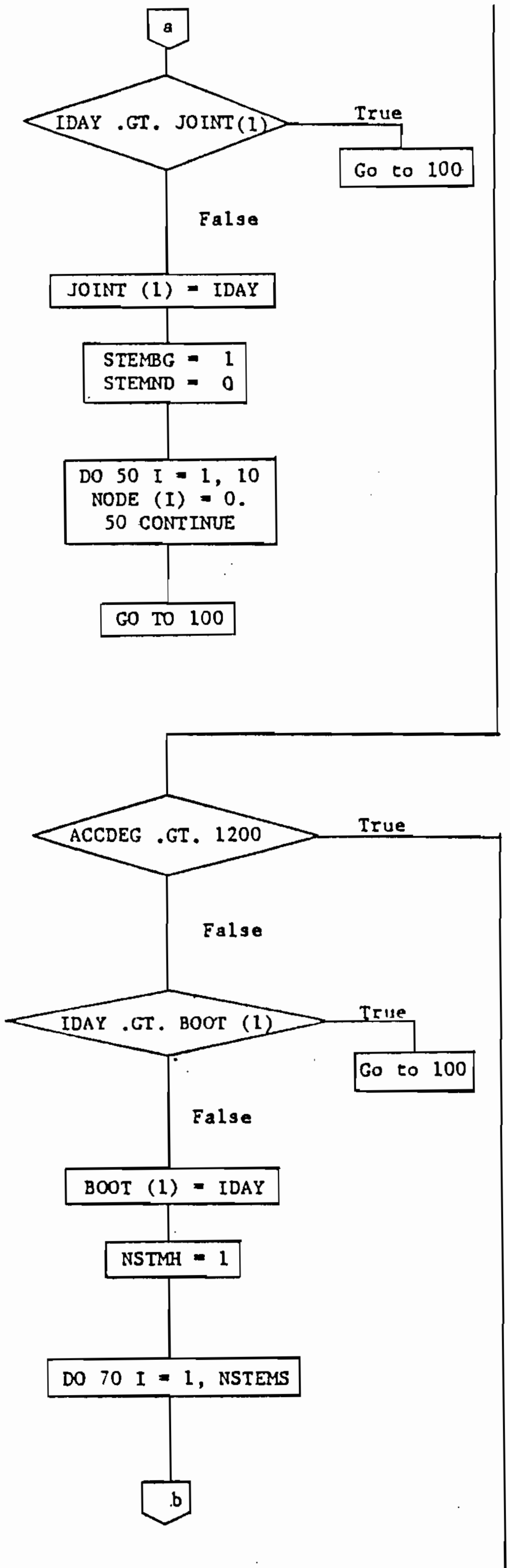
If the accumulated degrees are greater than 750, then beyond the tillering stage.

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.

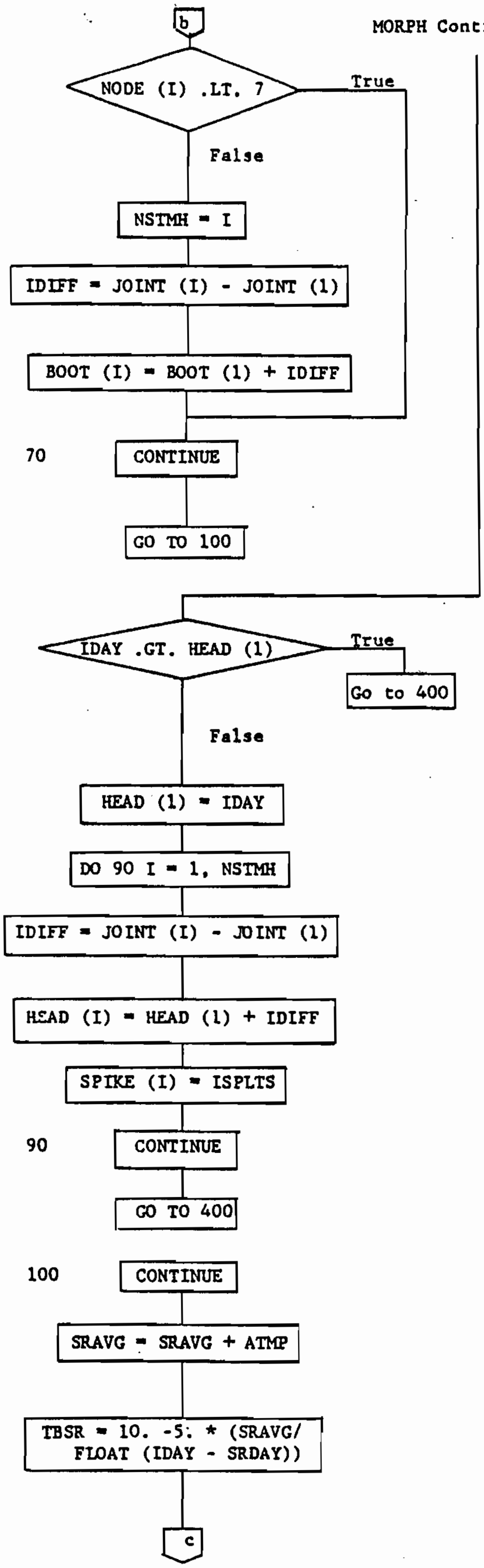
If the accumulated number of degrees is greater than 1090 and less than or equal to 1200 then the plant is in the boot stage.

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.

MORPH Continued



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).

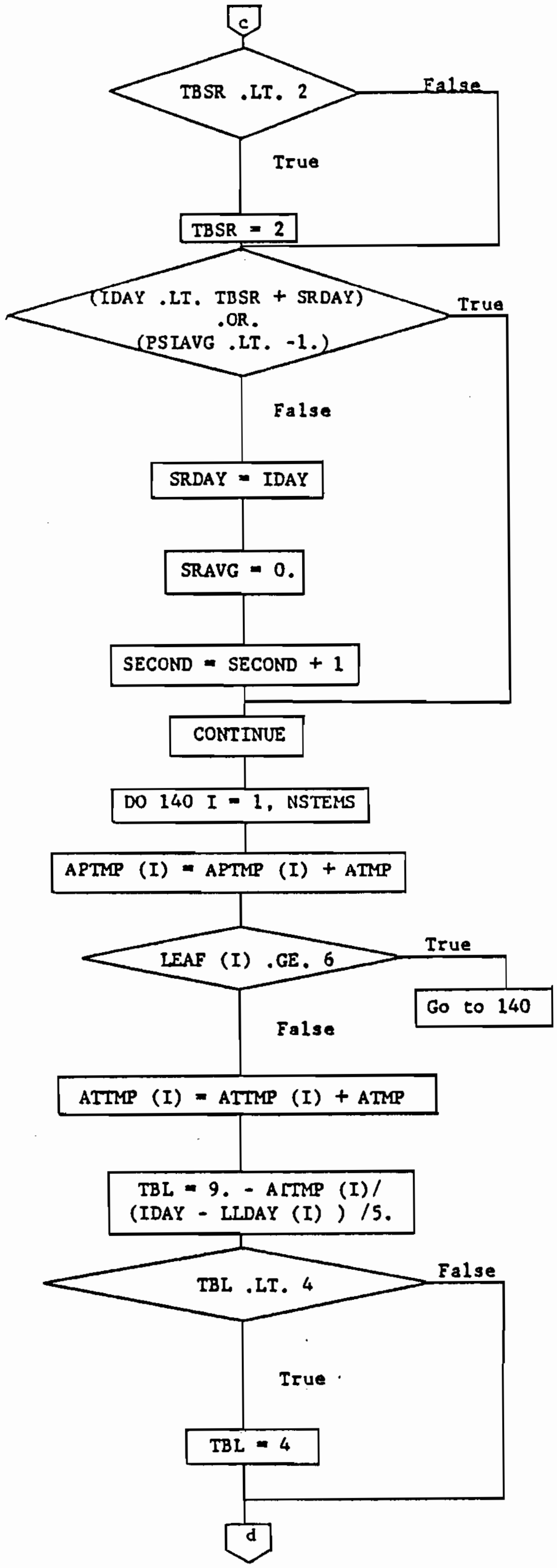
The difference between the heading of STEM 1 and STEM I is defined to be the same as that of JOINT 1 and JOINT I. This difference added to the Day Stem 1 began heading gives the Day heading begins for the other stems.

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.

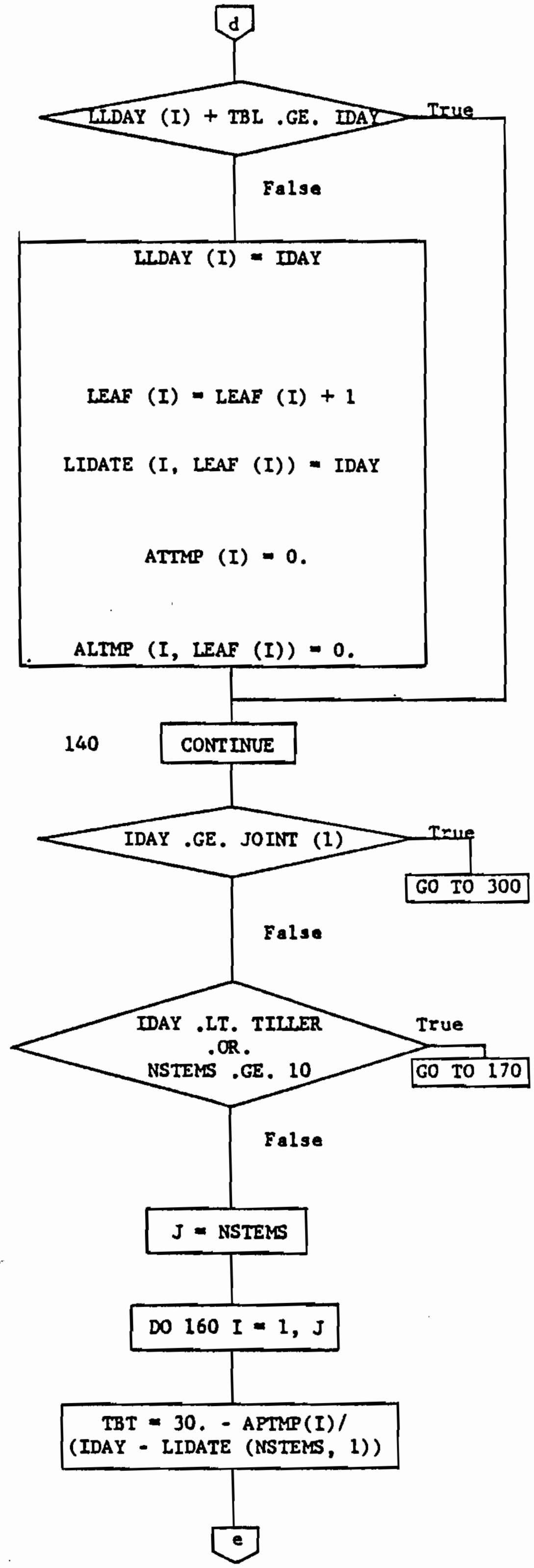
The variable APTMP contains the accumulated temperature for each stem since initiation of that stem.

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.

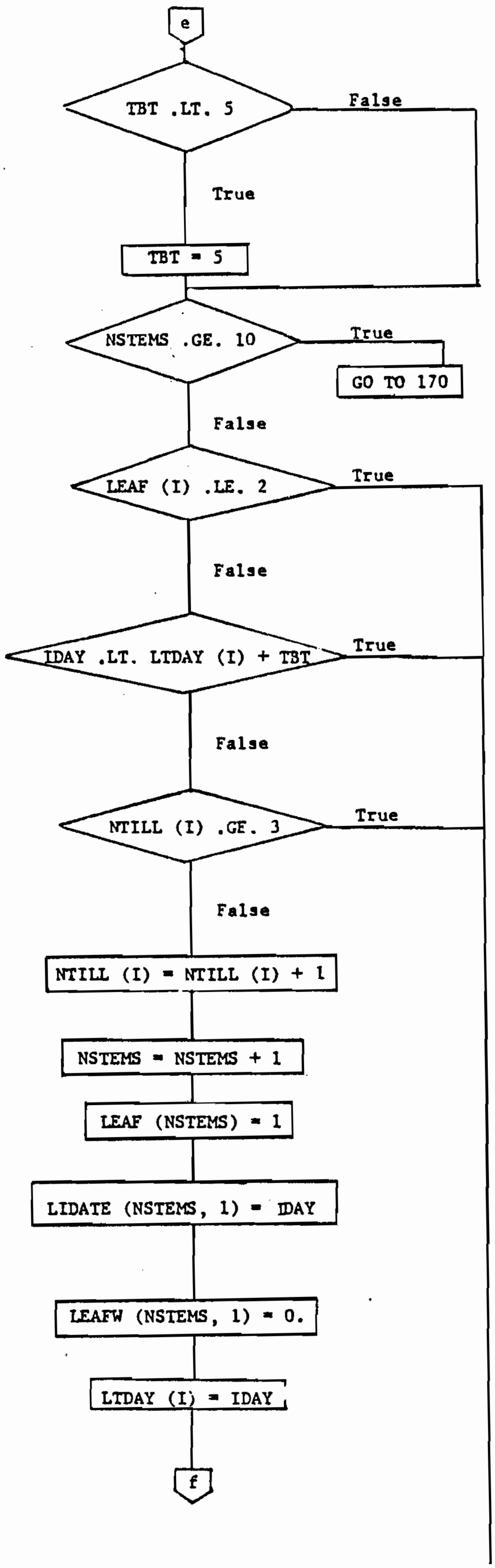
If jointing has begun, skip to jointing routine; there is no more tillering.

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.

MORPH Continued



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.

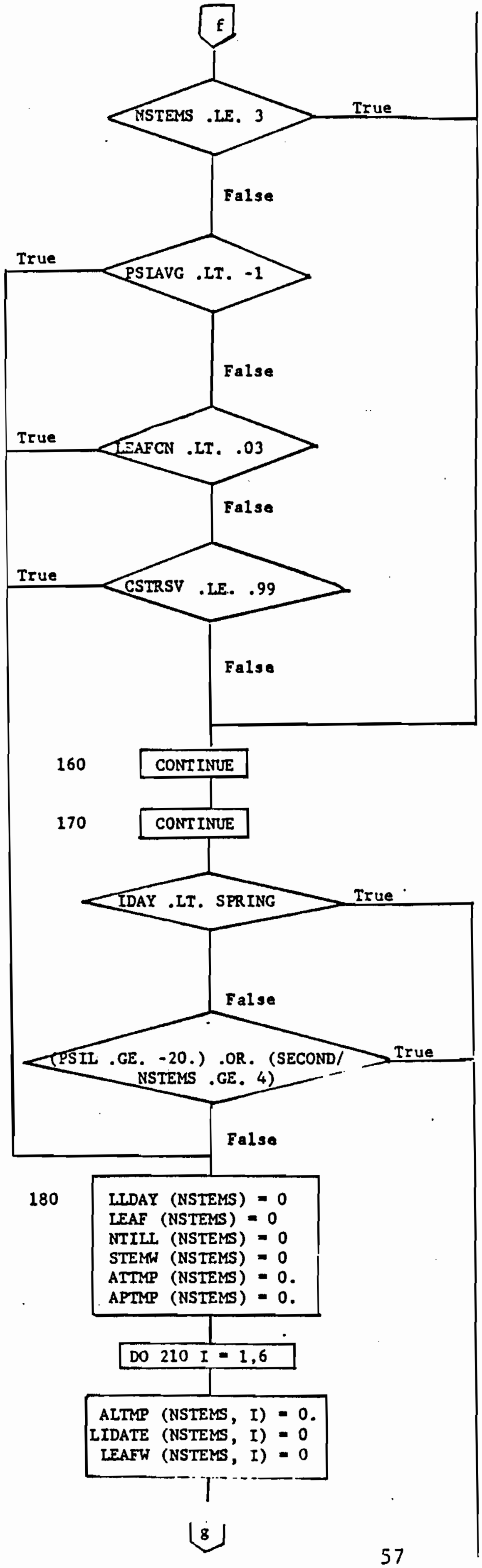
The total number of stems is incremented.

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.

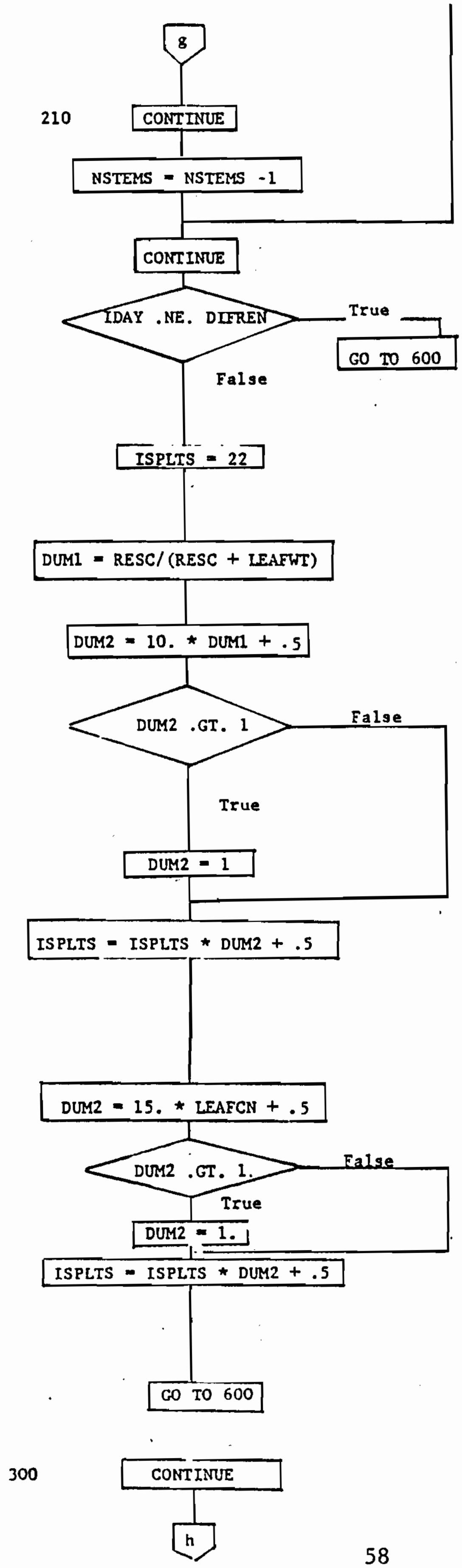
If the nitrogen concentration of the leaves is less than 3% then abort the new tiller.

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.

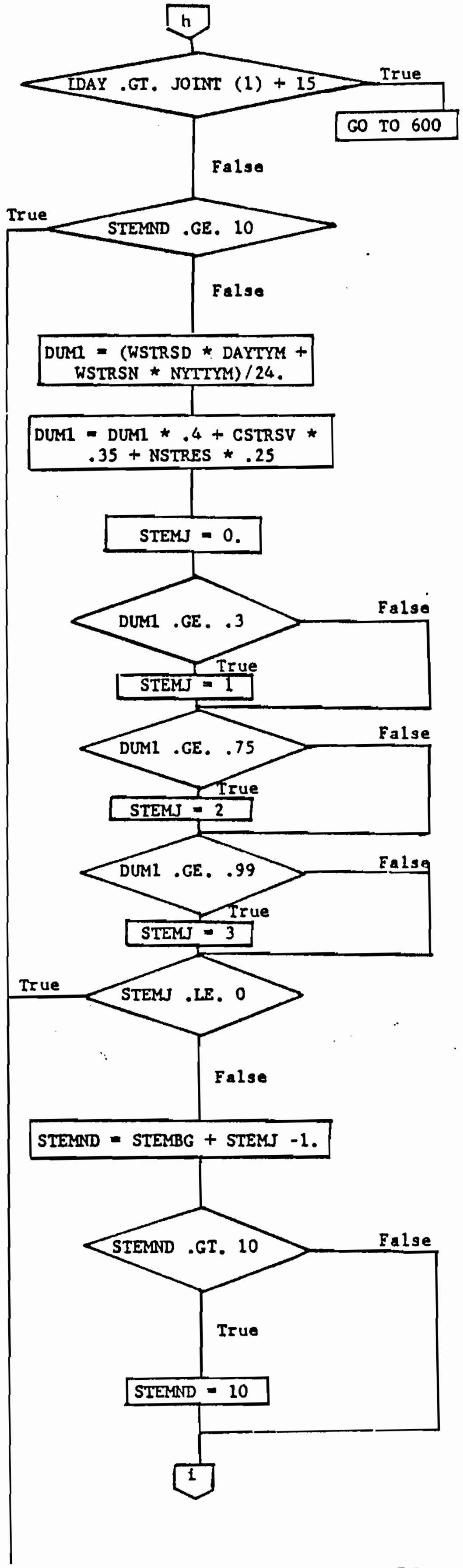
A second dummy variable is set equal to 10 times the first plus 0.5.

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.

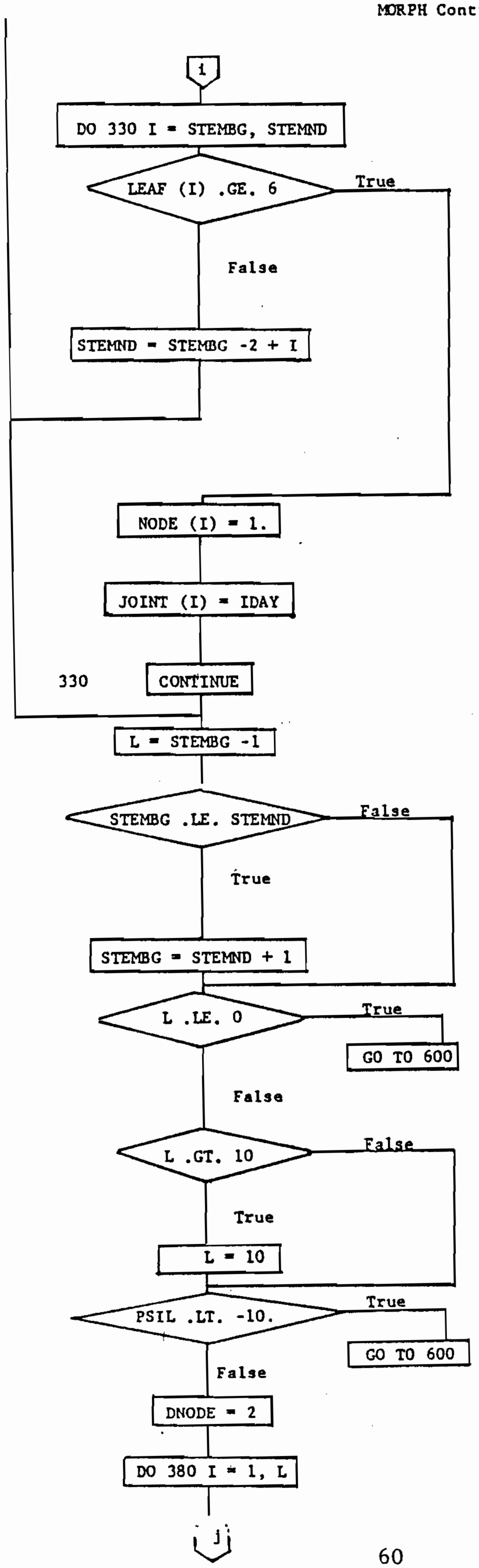
The number of stems to begin jointing on IDAY is set to zero initially.

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.

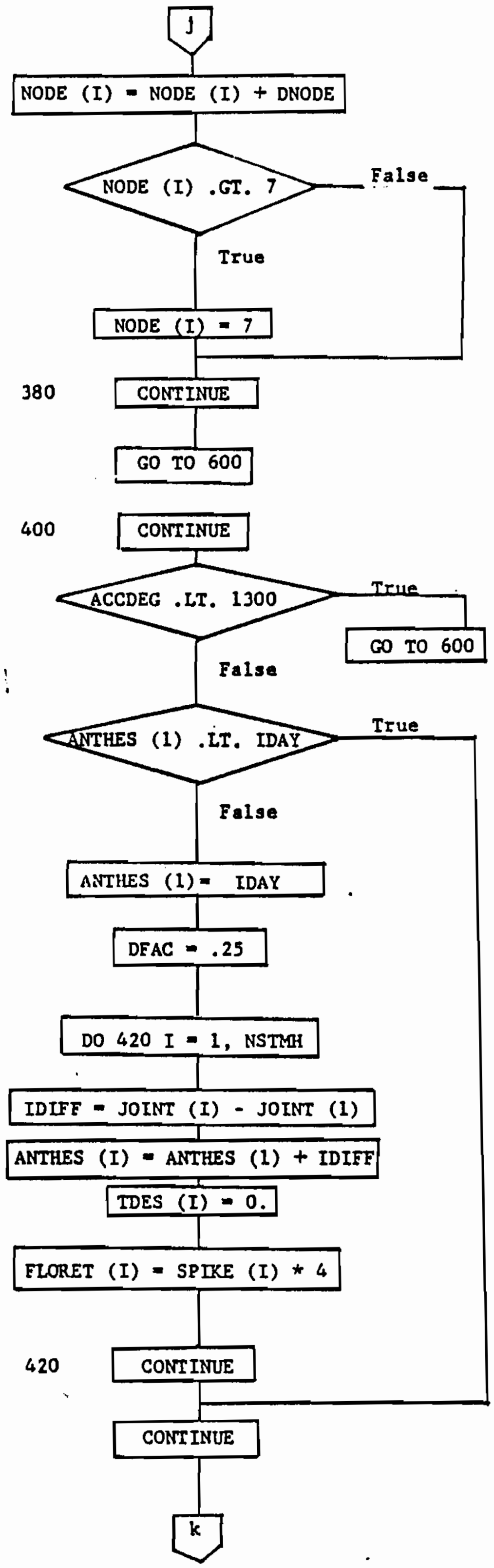
If stems begin jointing on IDAY, then the stem to begin jointing on IDAY plus one must be set.

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.

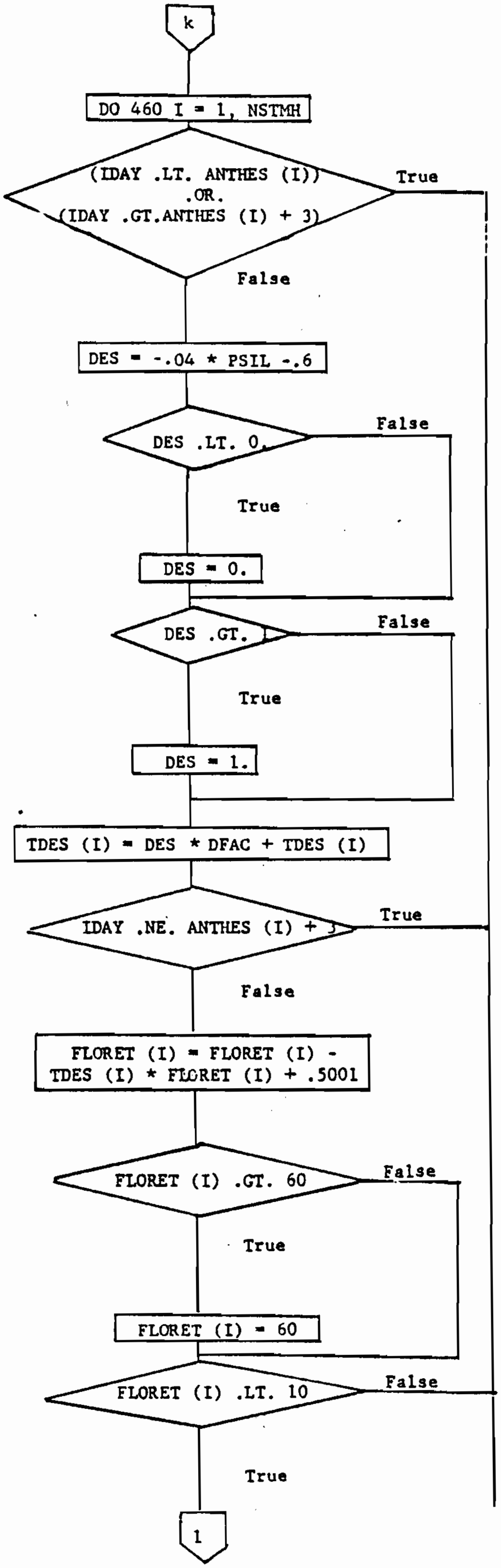
The first day the accumulated temperature becomes 1300 is set to be the beginning of Anthesis for stem 1.

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.

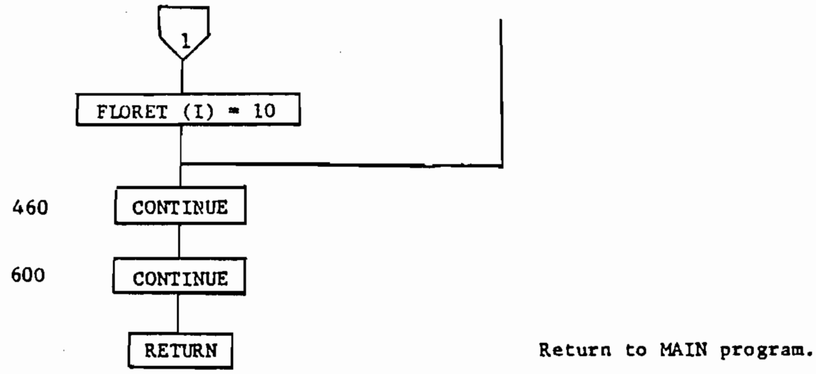
The florets dessicated on stem I are accumulated during anthesis. Only DFAC are eligible for dessication each day.

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.


1
FLORET (I) = 10
460
CONTINUE
600
CONTINUE
RETURN
Return to MAIN program.

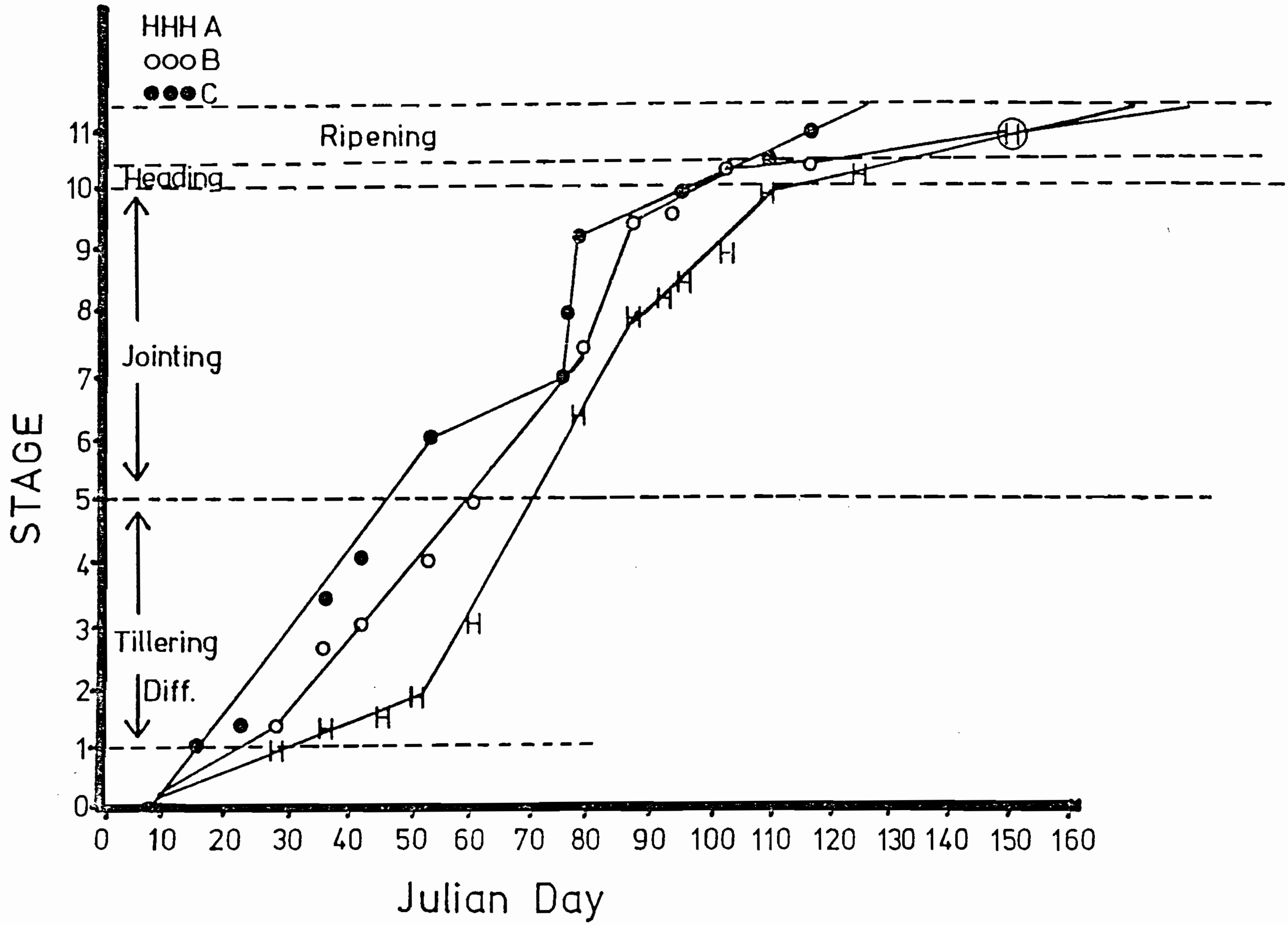


Figure 6. Developmental stage vs. Julian date for wheat crops maintained in three different temperature regimes.

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

```
      COMMON /PHYTIM/ TILLER,JOINT(10),DIFREN,BOOT(10),HEAD(10),
     . ANTHES(10),SPRING,ACCDEG
      COMMON /PLOTS / NPN, NPP, NPR, NPW
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN
      COMMON /PS    / PSIS(20,6)
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC
      COMMON /ROOTIM/ RTIMPD(20,6),SNAME(3),TSTBD(9,20),INRT,MRT
     .     ,TSTIMP(9,20),GH2OC(9),FACR
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN
      COMMON /SROOT / SRAVG,SRDAY,SECOND
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,
     . STRSD,STRSN,FACL
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TIMEBD/ THETAI
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)
      COMMON /UPS   / SUPNO3,UPNO3
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C                                                                   0000
C  VARIABLES OF 1 CHARACTER                                         0000
      DATA D/10./, G/1./, T/0./
C  VARIABLES OF 2 CHARACTERS                                        0000
      DATA EP/0./, ES/0./, FC/20*.267/, LR/3/, NK/6/, NL/20/,
     . C1/.3964,3.631,.03838,.07659,0.0,-22.97,-.3885,-.1587,-.01021/
      DATA KA/' ','0','1','2','3','4','5','6','7','8','9','*'/
      DATA KHAR/120*' '/
C  VARIABLES OF 3 CHARACTERS                                        0000
      DATA KRL/2,1,1,17*0/,OMA/600./,SLF/.02/,SPN/0./,VNC/12*0./
C  VARIABLES OF 4 CHARACTERS                                        0000
      DATA DIFF/120*258.3/,DAMP/.002/,FNH4/0./,FNO3/1./,PSIS/120*-.175/
     .     ,RESC/0./, RTP1/.3/, RTP2/.1/, SESI/0./, RTWT/360*0./
C  VARIABLES OF 5 CHARACTERS                                        0001
      DATA CAPUP/0./, CUMEP/0./, CUMES/0./, SUMES/0./, SUMEP/0./,
     .     DACNT/31,28,31,30,31,30,31,31,30,31,30,31/, DTAVG/7*20./, 0001
     .     MH2O/0./, RNNH4/60./, RNNO3/40./, ROOTN/.0045/, ROOTS/0./,
     .     SESII/0./,THRLN/.3E-4/,VH2OC/120*.267/,VNH4C/12*0./,
     .     VNO3C/120*0./
C  VARIABLES OF 6 CHARACTERS                                        0001
      DATA CUMRAN/0./, CUMSOK/0./, PSIAVG/-.175/, PSIMAX/-.175/,
     .     ROOTWT/.005/, SLEAFN/.0003/, ROOTCN/.037/, ROOTSV/120*0./
      DATA STEMWT/0./, SUPNO3/0./, TSOILD/20*0./, TSOILN/20*0./,
     .     TSOLAV/2*0./, WSTRSD/1./, WSTRSN/1./, WTSLFD/0./
      DATA ALPHA/3.5/,GAMMA/.653/,LAMDAC/.23/,LAMDAS/.3/,
     .     U/6./,WND/120./
      END                                                           0001
```

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

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

```
      BOOT(I)=999
      HEAD(I)=999
      ANTHES(I)=999
      STEMW(I)=0.
      GLUMW(I)=0.
      GRANW(I)=0.
      SPIKE(I)=0
      FLORET(I)=0
      LEAF(I)=0
      LTDAY(I)=0
      LLDAY(I)=0
      NTILL(I)=0
      ATTMP(I)=0.
      APTMP(I)=0.
      DO 100 J=1,6
      LEAFW(I,J)=0.
      LIDATE(I,J)=0
      ALTMP(I,J)=0.
  100 CONTINUE
      AHTMP=0.
      SECOND=0
      AREA=0.
      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)
  130 FORMAT(' INPUT POPPLT F2 LATUDE LAI NOITR FACR')
      READ(1,*) POPPLT,F2,LATUDE,LAI,NOITR,FACR
      WRITE(2,140)
  140 FORMAT(' INPUT KL KS KR KG')
      READ(1,*) KL,KS,KR,KG
      WRITE(2,150)
  150 FORMAT(' INPUT JL JS JR JG JG1')
      READ(1,*) JL,JS,JR,JG,JG1
      WRITE(2,160)
  160 FORMAT(' INPUT LEAFLGTH ROWSPACE PRINT G THRLN FACL')
      READ(1,*) XLEAFL,ROWSP,IPRNT,G,THRLN,FACL
      WRITE(2,170)
  170 FORMAT(' TO SEE PLOT TYPE 1 UNDER FIRST LETTER OTHERWISE TYPE 0'/
     . '  ROOTS PSIS VH2OC VNO3C ')
      READ(1,*) NPR, NPP, NPW, NPN
      POPFAC=404685.6/POPPLT
      W=ROWSP/NK
```

```
      LEAFWT=LEAFW(1,1)
      STEMWT=0.
      GLUMWT=0.
      GRANWT=0.
      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.
      GLUMN=0.
      GRANN=0.
      LEAFCN=.03
      NSTEMS=1
      SRAVG=0.
      SRDAY=0
      SPRING=70
      LEAF(1)=1
      ACCDEG=0.
      PLANTN=SLEAFN+STEMN+ROOTN+GRANN+GLUMN
C
      READ(5,*) LYRSOL
C  LYRSOL = NUMBER OF SOIL LAYERS OF DIFFERENT CHARACTERISTICS
C  -- UP TO 5 ALLOWED
C  LPT1 = PRINT SOILS INFORMATION IF = 0; OTHERWISE NOT.
C  SOIL DIFFUSIVITY WATER CONTENT FUNCTIONS ARE IN :
C   GARDNER,W.R. AND M.S.MAYHUGH. 1958. SSSAP 22:197-201.
C
C  SOIL WATER CONTENT PSI FUNCTION FROM:
C   BROOKS,R.H. AND A.T.COREY. 1964.HYD.PAPERS CSU 3:1-27. FOW.
C
      READ(5,*)(DIFFO(I),THETAO(I),BETA(I),SDEPTH(I),THETAS(I),
     . THETAR(I),AIRDR(I),ETA(I),BD(I),I=1,LYRSOL)
      WRITE(6,180)LYRSOL
  180 FORMAT(' NUMBER OF SOIL LAYERS',I2 //
     .' LAYER   MAX.DEPTH     DO      THETA O     BETA'//
     .'    NO.',7X,'CM        CM       BAR/DAY    CC/CC')
      WRITE(6,185)(I,SDEPTH(I),DIFFO(I),THETAO(I),BETA(I),I=1,LYRSOL)
 185  FORMAT(' ',I4,5X,1P4E10.3)
C   SDEPTH = MAX. DEPTH OF LAYER
C   DIFFUSIVITY = DO EXP BETA*(VH2OC - THETAO) WHERE
C   DO AND THETAO ARE INITIAL OR 15 BAR DIFF. AND WATER CONTENT ;
C   BETA = SLOPE OF LOG D - THETA CURVE.
C*****WARNING***** WATCH UNITS OF DIFF. CM BAR/DAY *******
```

```
C    PSIS = AIRDR*((VH2OC-THETAR)/(THETAS-THETAR))**(3/(2-ETA))
C    WHERE AIRDR = THE AIR ENTRY PRESSURE: THETAR = RESIDUAL
C    WATER CONTENT ; THETAS = SATURATED WATER CONTENT ;
C    ETA = SLOPE OF SEMI-LOG PLOT. FDW.
C    BD  = BULK DENSITY OF LAYER
C
      READ(5,*) DUMB,THETAI
C
C    MAKE BOTTOM LAYER TIME DEPENDENT BOUNDARY WHERE :
C     VH2OC = THETAI FOR TIME LESS THEN TO
C     VH2OC = THETAI - 0.00385*(TIME - TO)
C OR VH2OC = 0.65*THETAI , WHICHEVER IS LEAST ;
C    SLOPES AND RESIDUAL WATER CONTENT ARE FROM :
C     GERARD,C.D. AND L.N.NAMKEN. 1966. AGRON.J. 58:39-42. FDW.
C
      WRITE(6,190) THETAI
 190  FORMAT(' INITIAL VH2O AT BOTTOM BOUNDARY =',1PE10.3)
C
      J = 1
      DELT = 1/NOITR
C
      DO 210 LAYER =1,NL
  200 CONTINUE
      IF(LAYER*D.LE.SDEPTH(J)) GO TO 205
      J = J+1
      IF(J.LT.5) GO TO 200
  205 FLXMAX(J)=DIFFO(J)*((THETAS(J)-THETAR(J))/D)*(W*DELT*DAMP)*
     .EXP(BETA(J)*(THETAS(J)-THETAO(J)))
      FC(LAYER) = THETAS(J)
      DO 210 KOLUMN = 1,NK
      VH2OC(LAYER,KOLUMN) = THETAS(J)
      DIFF(LAYER,KOLUMN)=DIFFO(J)*EXP(BETA(J)*(VH2OC(LAYER,KOLUMN)-
     .THETAO(J)))
      TEMP1 = (VH2OC(LAYER,KOLUMN)-THETAR(J))/(THETAS(J)-THETAR(J))
  210 PSIS(LAYER,KOLUMN) = 0.0009833*AIRDR(J)*TEMP1**(3./(2.-ETA(J)))
C    READ IN DATA TABLE OF H2O,BD, AND SOIL STRENGTH                 NASA
      READ(5,215)SNAME,MRT
  215 FORMAT(3A4,2I2)                                                NASA
C    PRINT DATA TABLE                                                NASA
      WRITE(6, 220)SNAME,MRT
  220 FORMAT(' SOIL ID.',3A4,'  NO.OF CURVES',I2)
C                                                                    NASA
      DO 250 I=1,MRT
      READ(5,*)INRT,GH2OC(I)
      READ(5,*) (TSTBD(I,J),TSTIMP(I,J),J=1,INRT)
```

```
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
    WRITE(6,360)
360 FORMAT('     RESC        RESN        REQN        NPOOL       ',
   . 'NSTRES        NV          NF')
    WRITE(6,310) RESC,RESN,REQN,NPOOL,NSTRES,NV,NF
    WRITE(6,380)
380 FORMAT('     SLEAFN      STEMN       GLUMN       GRANN       ',
   . 'LEAFCN      SUPNO3')
    WRITE(6,310) SLEAFN,STEMN,GLUMN,GRANN,LEAFCN,SUPNO3
    WRITE(6,390)
390 FORMAT('    SPIKE(I)    FLORET(I)    LEAF(I)    JOINT(I)    ',
   . 'BOOT(I)     HEAD(I)     ANTHES(I)')
    DO 400 I=1,NSTEMS
    WRITE(6,410) SPIKE(I),FLORET(I),LEAF(I),JOINT(I),BOOT(I),
   . HEAD(I),ANTHES(I)
400 CONTINUE
410 FORMAT(10(I8,3X))
    WRITE(6,420)
420 FORMAT('    SECOND        ACCDEG      PSIAVG        DIFREN     TILLER')
    WRITE(6,430) SECOND,ACCDEG,PSIAVG,DIFREN,TILLER
430 FORMAT(I8,4X,F9.2,3X,E12.5,I8,4X,I8)
    WRITE(6,460)
460 FORMAT('    DAYLNG          LAI         XLEAFL        INT',
   . '         TAVG')
    WRITE(6,310) DAYLNG,LAI,XLEAFL,INT,TAVG
    WRITE(6,480)
480 FORMAT('    RCH2O        STRSD        STRSN         WSTRSD',
   . '       EP           ES')
    WRITE(6,310) RCH2O,STRSD,STRSN,WSTRSD,EP,ES
    IF(NPN.EQ.1) CALL OUT(VNO3C,TTL5,TTL3,VNOSCA,
   .  VNOUNI,TNNO3,NITUNT)
    IF(NPW.EQ.1) CALL OUT(VH2OC,TTL1,TTL3,CAPSCA,
   .  VH2UNI,TH2O,UNITST)
    IF(NPR.EQ.1) CALL OUT(ROOTSV,TTL1R,TTL2R,
   .  ROOSCA,UNITS,ROOTS,UNITSR)
    IF(NPP.EQ.1) CALL OUT(PSIS,TTL4,TTL3,PSISCA,
   .  VH2UNI,TH2O,UNITST)
    IF(ITGF.GT.KTDAY) GO TO 260
640 CONTINUE
    YIELD=GRANWT*14.8563/POPFAC
    WRITE(6,660) YIELD,DAYNUM
660 FORMAT(///' *** FINAL YIELD (BU/ACRE) IS',F8.2,'   ON DAY',I4)
    STOP


    END
```

```
      SUBROUTINE CLYMAT
C  ***********************************************************
C  *                                                         *
C  *                  CLIMATE SUBROUTINE                     *
C  *                                                         *
C  ***********************************************************
      REAL INT,LATUDE,LAI,NYTTYM
      INTEGER DAZE, YR, DACNT, DAYNUM
C
C
      COMMON /CALEN / DACNT(12), DAZE, MO, YR
      COMMON /CLIM  / CLIMAT(8),C1(9)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C
C
C
      RI = CLIMAT(1)
      TMAX =  CLIMAT(2)
      TMIN =  CLIMAT(3)
      MH2O=CLIMAT(4)
      RAIN=CLIMAT(5)*25.4
      DAYNUM = CLIMAT(7)
      RN = RI * .8942 * .8 - 26.
C NET RADIATION IN WATTS/M**2
      XLAT=LATUDE*.0174533
      DEC=C1(1)
      DO 100 I=2,5
      J=I+4
      PHI=DAYNUM*.01721*(I-1)
      DEC=DEC+C1(I)*SIN(PHI)+C1(J)*COS(PHI)
  100 CONTINUE
      DEC=DEC*.0174533
      DAYLNG=ARCOS((-.014544-SIN(XLAT)*SIN(DEC))/(COS(XLAT)*COS(DEC)))
     . *7.6394
      TDAY=(TMAX-TMIN)*.55+TMIN
      TNYT=(TMAX-TMIN)*.15+TMIN
C
      CALL DATE
C
      DAYTYM=DAYLNG



      NYTTYM=24.-DAYLNG
      TAVG=(TDAY*DAYTYM+TNYT*NYTTYM)/24.
C
C    PHOTOSYNTHESIS MUST BE CORRECTED TO REFLECT % SOLAR RADI-
C     ATION INTERCEPTED. TWO TERMS USED, THE FIRST CORRECTS FOR
C     AREA BETWEEN ROWS WITH NO COVER, THE SECOND IS TAKEN FROM
C     PAPER (LIGHT AND CROP PRODUCTION BY J L MONTEITH - FIELD
C     CROP ABSTRACTS NOVEMBER 1965)
C
      TERM1=(2.*XLEAFL/ROWSP)
      IF(TERM1.GT.1.) TERM1=1.
      TERM2=1.-EXP(-.4*LAI)
      INT=TERM1*TERM2
C
      CALL TMPSOL
C
      RETURN
      END
```

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

```
      SUBROUTINE TMPSOL
C*************************************************************
C   THIS SUBROUTINE CALCULATES A TEMPERATURE PROFILE IN THE*
C SOIL. ASSUMES HORIZONTAL HOMOGENEITY OF TEMPERATURE &     *
C DISREGARDS MOISTURE CONTENT EFFECTS.                      *
C FIRST, MAXIMUM (H) & MINIMUM (L) TEMPERATURES ARE         *
C CALCULATED AT 2, 4, 8, & 16 INCH DEPTHS BY MULTIPLE       *
C REGRESSION EQUATIONS OF                                   *
C J. C. MCWHORTER & B. P. BROOKS, JR.  1965. CLIMATOLOGICAL*
C AND SOLAR RADIATION RELATIONSHIPS. BULL. 715, MISS.       *
C AGRI. EXP. STA., STARKVILLE.                              *
C NOTE THAT THE GRID SIZE (D*W) IS NOT VARIABLE IN THIS     *
C SUBROUTINE, BUT THE LAYER THICNESS IS FIXED AT 5 CM.      *
C   MAX & MIN SOIL TEMPS FOR EACH OF THE LAYERS ARE THEN    *
C OBTAINED BY INTERPOLATION & EXTRAPOLATION OF THE 2, 4,    *
C 8, & 16 INCH TEMPS.                                       *
C    FINALLY, DAYTIME AND NIGHTIME TEMPS(TSMX & TSMN)       *
C ARE OBTAINED AS AVERAGE HOURLY VALUES FROM 7 A.M. THRU    *
C SUNSET, & SUNSET THRU 7 A.M., RESPECTIVELY, USING AN      *
C ALGORITHM FOR AIR TEMP PUBLISHED BY H. N. STAPLETON,      *
C D. R. BUXTON, F. L. WATSON, D. J. NOLTING, AND D          *
C D. N. BAKER.  UNDATED.  COTTON: A COMPUTER SIMULATION OF *
C COTTON GROWTH.  TECH. BULL. 206, ARIZONA AGRI. EXP. STA. *
C TUCSON.                                                   *
C*************************************************************
      INTEGER DAYNUM
      REAL LATUDE,NYTTYM
      DIMENSION TSMX(20), TSMN(20), RECDAT(24)
C
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSON  / TSOILD(20), TSOILN(20), TSOLAV(2)
C
      J=8
      DO 1 I = 1,6
      J=J-1
    1 DTAVG(J) = DTAVG(J-1)
      DTAVG(1) = TAVG
      WTAVG = 0.
      J=7
      IF(IDAY.LT.7) J=IDAY
      DO 2 I = 1,J
    2 WTAVG = WTAVG +  DTAVG(I)
      WTAVG = WTAVG/J
      WTAVGF = WTAVG*1.8 + 32.
```

```
C THE NEXT EIGHT EQUATIONS ARE FROM MCWHORTER AND BROOKS.
        T2H  = 1.1962*WTAVGF + 0.27389
        T2L  = 0.960*WTAVGF + 1.4404
        T4H  = 1.1493*WTAVGF + 1.1452
        T4L  = 0.9126*WTAVGF + 2.9961
        T8H  = 0.9655*WTAVGF + 8.3121
        T8L  = 0.8700*WTAVGF + 7.9217
        T16H = 0.8409*WTAVGF + 13.988
        T16L = 0.8341*WTAVGF + 13.029
C GET TEMP OF SOIL ( MAX ) BY INTERPOLATION OR EXTRAPOLATION.
      T24 = T2H - T4H
      T48 = T4H - T8H
      TSMX(1)=(T2H+T4H+T24*1.031)/2.
      TSMX(2)=T8H+(T48*1.048)/2.
      T816 = .0492126 * (T8H - T16H)
      DO 6 I= 3,20
      J=I-3
        TSMX(I) = T8H - (2.18+(1+J*4)*5.) * T816/2.
 6    CONTINUE
C GET TEMP OF SOIL (MIN) BY INTERPOLATION OR EXTRAPOLATION.
      T24 = T2L - T4L
      T48 = T4L - T8L
      TSMN(1) = (T2L+T4L+T24*1.031)/2.
      TSMN(2) = T8L+(T48*1.048)/2.
      T816 = .0492126 * (T8L - T16L)
      DO 7 I=3,20
      J=I-3
      TSMN(I) = T8L - (2.18+(1+J*4)*5.) * T816 / 2.
        IF(TSMN(I).LT.TSMX(I)) GO TO 7
        TSMN(I) = (TSMN(I) + TSMX(I))/2.
        TSMX(I) = TSMN(I)
 7    CONTINUE
      DO 8 I=1,20
C CONVERT TEMPS TO CENTIGRADE.
        TSMX(I) = (TSMX(I)-32.)*.555556
        TSMN(I) = (TSMN(I)-32.)*.555556
 8    CONTINUE
      ISR = 12 - IFIX(DAYLNG*.5)
      ISS = ISR + IFIX(DAYLNG+0.5)
C HOUR OF SUNSET.
C SEE PP 37 OF STAPLETON, ET AL. FOR EQUATIONS DETERMINING RECDAT.
      DO 9 LAYER = 1,20
      TMEAN = (TSMX(LAYER)+TSMN(LAYER)) * .5
      SWINGH = (TSMX(LAYER)-TSMN(LAYER)) * .5
      DO 11 IH=7,15
      RECDAT(IH) = TMEAN - SWINGH*COS(0.3927*(IH-7.))
      IH9 = IH + 9
      RECDAT(IH9) = TMEAN + SWINGH*COS(0.19635*(IH9-15.))
 11   CONTINUE
      DO 12 IH=1,6
 12   RECDAT(IH) = TMEAN - SWINGH*COS(0.19635*(6-IH))
      SHRTD = 0.
      SHRTN = 0.
      DO 13 IH=7,ISS
      SHRTD = SHRTD + RECDAT(IH)
C SUM OF HOURLY TEMPS IN DAYTIME.
 13   CONTINUE
      TSOILD(LAYER) = SHRTD/(ISS-6)
C AVERAGE TEMP OF SOIL DURING DAYTIME, DEG C.
      ISS1 = ISS + 1
      DO 14 IH=ISS1,24
      SHRTN = SHRTN + RECDAT(IH)
C SUM OF HOURLY TEMPS IN NIGHTIME.
 14   CONTINUE
      DO 15 IH=1,6
      SHRTN = SHRTN + RECDAT(IH)
 15   CONTINUE
      TSOILN(LAYER) = SHRTN/(30-ISS)
C AVERAGE TEMP OF SOIL DURING NIGHTIME.
 9    CONTINUE
      DO 16 LAYER = 1, 2
      TSOLAV(LAYER)= (TSOILD(LAYER)*DAYLNG+TSOILN(LAYER)*(24.-DAYLNG))
     . /24.
C AVERAGE SOIL TEMPERATURE, DEG C.
 16   CONTINUE
      RETURN
      END
```

```
      SUBROUTINE SOIL
C   ************************************************************
C   *                                                          *
C   *      SOIL SUBROUTINE.  CALLS FRTLIZ, GRAFLO, ET,         *
C   *        UPTAKE, CAPFLO, AND NITRIF.                       *
C   *                                                          *
C   ************************************************************
      REAL LATUDE,LAI,MH2O,NEWES,NEWEP,NYTTYM,INT
      INTEGER DAYNUM
C
      COMMON /CLIM   / CLIMAT(8),C1(9)
      COMMON /DIFFU  / DIFF(20,6)
      COMMON /ETPARM/ ALPHA,GAMMA,LAMDAC,LAMDAS,U,WND
      COMMON /EVTR   / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP
      COMMON /FERT   / FERN,FNH4,FNO3,OMA,RNNH4,RNNO3
      COMMON /FIELD  / FC(20)
      COMMON /GEOM   / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /H2ONO3/ VH2OC(20,6) , VNO3C(20,6)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /MATR   / KRL(20), LR
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)
      COMMON /PS     / PSIS(20,6)
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /SOILID/ DIFF0(5),THETA0(5),BETA(5),SDEPTH(5),THETAS(5),
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP   / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TIME80/ THETAI
      COMMON /TOTS   / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /TSDN   / TSOILD(20), TSOILN(20), TSOLAV(2)
      COMMON /UPS    / SUPNO3,UPNO3
      COMMON /WETS   / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C
      FERN=CLIMAT(8)
      IF(IDAY.GT.1) GO TO 2
      CALL FRTLIZ
      WRITE(6,1000) VNO3C(1,1)
 1000 FORMAT(' VNO3C(1,1) = ',F10.4)
C  ALL FERTILIZER IS NO3.
      OMA = 0.
      RNNO3 = 0.
      RNNH4 = 0.
    2 CONTINUE


      IF(FERN.GT.0.) CALL FRTLIZ
C
      IF(RAIN.GT.0.) CALL GRAFLO
C
      CALL ET
C
      SUPNO3 = 0.
      SUMES=0.
      SUMEP=0.
C
      DO 10 I=1,NOITR
      CALL UPTAKE
      IF(UPNO3.GT.0.) SUPNO3 = SUPNO3 +  UPNO3
      CALL CAPFLO
 10   CONTINUE
      CUMEP = CUMEP + NEWEP
      CUMES = CUMES + NEWES
C
      SUPNO3 = SUPNO3*POPFAC*.1/ROWSP
C
      DO 11 I=1,NOITR
      CALL CAPFLO
 11   CONTINUE
      CALL NITRIF
C
      RETURN
      END
```

```
      SUBROUTINE FRTLIZ
C*****************************************************************
C  ****  MODIFIED BY A. MARANI  MARCH 1980   ***************
C*****************************************************************
C SUBROUTINE ADDS FERTILIZER TO PROFILE. MUST BE CALLED AT       *
C PLANTING DATE TO INITIALIZE NITROGEN & ORGANIC MATTER          *
C PROFILE.  MAY BE CALLED FOR SIDE DRESSING.  INPUTS ARE:        *
C FERN:  FERTILIZER INORGANIC NITROGEN, LBS N/ACRE.              *
C FNH4:  FRACTION OF INORGANIC N  IN AMMONIA FORM. C TO 1        *
C FNO3:  FRACTION OF INORGANIC N  IN NITRATE FORM. C TO 1        *
C OMA:  ORGANIC MATTER PLOWED AT BEGINNING OF SEASON, LBS/ACRE,  *
C        MUST BE .GT. 0 TO INITIALIZE N & ORGANIC MATTER ARRAYS. *
C RNNO3: RESIDUAL N  AS NITRATE IN UPPER 2 LAYERS, LBS/ACRE.       *
C RNNH4: RESIDUAL N AS AMMONIUM IN UPPER 2 LAYERS, LBS/ACRE.       *
C*****************************************************************
C
      COMMON /FERT  / FERN,FNH4,FNO3,OMA,RNNH4,RNNO3
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)
      WRITE(6,1000)
 1000 FORMAT('  FERTILIZER SUBROUTINE CALLED  ################## ')
      IF(OMA.LE.0.) GO TO 2
C OMA .GT. 0. IMPLIES INITIAL FERTILIZATION AT PLANTING DATE &
C PLOWDOWN OF ORGANIC MATTER.
      DO 3 L=1 , 2
      DO 3 K=1 ,NK
      VNC(L,K) = OMA * .01122/(D*2.) * .01
      VNO3C(L,K) = RNNO3 * .01122/(D*2.)
      VNH4C(L,K) = RNNH4 * .01122/(D*2.)
C
C    CHG LB/ACRE TO MG/CC IN TOP 2 LAYERS (.01122 LB/ACRE = 1 MG/CM**2)
C
  3   CONTINUE
  2   CONTINUE
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
      DO 5 KOLUMN = 1,NK
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + DUMY08
C     ADDITION OF BROADCAST NITRATE FERTILIZER.
      VNH4C(LAYER,KOLUMN) = VNH4C(LAYER,KOLUMN) + DUMY09
C ADDITION OF BROADCAST AMMONIUM FERTILIZER.
 5    CONTINUE



      RETURN
      END
```

```
      SUBROUTINE GRAFLO
C   **************************************************************
C   *                                                            *
C   *   GRAVITY FLOW OF NO3 AND H2O, AFTER RAIN OR IRRIGATION.   *
C   *                                                            *
C   **************************************************************
C RAIN OR IRRIGATION IS IN MM.
      REAL MH2O
      DIMENSION SOAKW(21), SOAKN(21)
C WATER SOAKING INTO LAYER.
C NITROGEN SOAKING INTO LAYER BY MASS FLOW OF H2O.
C
      COMMON /FIELD / FC(20)
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C
C VH2OC: VOLUMETRIC WATER CONTENT, CM**3/CM**3.
C FC:  FIELD CAPACITY, BY LAYER, CM**3/CM**3.
C VNO3C: VOLUMETRIC NITROGEN CONTENT AS NITRATE, MG N/CC SOIL.
C D:  DEPTH OF SOIL CELL, CM.
C NL: NUMBER OF LAYERS IN PROFILE.
C NK: NUMBER OF COLUMNS IN PROFILE.
      CUMRAN = CUMRAN + RAIN
      TSOAK = 0.
      DO 2 KOLUMN = 1, NK
      SOAKW(NL+1) = 0.
      SOAKW(1) = RAIN*.10
C H2O SOAKING INTO TOP LAYER, IN CM**3/CM**2.
      SOAKN(1) = 0.
C NITROGEN SOAKING INTO LAYER, IN MG/CM**2.
C IF NITROGEN IN RAINFALL IS TO BE ADDED, DO IT HERE.
      DO 3 LAYER = 1, NL
      H2O = SOAKW(LAYER) + VH2OC(LAYER,KOLUMN)*D
C TOTAL TEMPORARY AND RESIDUAL VOLUME OF H2O IN SOIL
C CELL, IN CM**3/CM**2.
      SOAKW(LAYER+1) = AMAX1(0., H2O-FC(LAYER)*D)
C H2O SOAKING INTO LAYER BENEATH, IN CM**3/CM**2.
      SOAKN(LAYER+1) = AMAX1(0.,SOAKW(LAYER+1)*(VNO3C(LAYER,KOLUMN) /
     .(VH2OC(LAYER,KOLUMN)+SOAKW(LAYER)/D)))
C NITROGEN SOAKING INTO LAYER BENEATH, IN MG/CM**2.
 3    CONTINUE
      TSOAK = TSOAK + SOAKW(NL+1)
      DO 4 LAYER = 1, NL
      IF(SOAKW(LAYER).LE.0.) GO TO 4
C WHEN SOAKW .LT. 0, NO GRAVITY PERCOLATION OCCURS.
      VH2OC(LAYER,KOLUMN) = VH2OC(LAYER,KOLUMN) + (SOAKW(LAYER) -
     . SOAKW(LAYER+1))/D
C VOLUMETRIC MOISTURE CONTENT OF SOIL CELL, IN CM**3/CM**3.
      VNO3C(LAYER,KOLUMN) = AMAX1(0.,VNO3C(LAYER,KOLUMN)+(SOAKN(LAYER)
     .-SOAKN(LAYER+1))/D)
C VOLUMETRIC NITROGEN CONTENT OF SOIL CELL, IN MG/CM**3.
 4    CONTINUE
 2    CONTINUE
      CUMSOK = CUMSOK + 10.*TSOAK/FLOAT(NK)
      RETURN
      END
```

```
      SUBROUTINE ET
C   ***************************************************************
C   *                                                             *
C   *              EVAPOTRANSPIRATION SUBROUTINE                  *
C   *                                                             *
C   ***************************************************************
C SUBROUTINE TAKEN ALMOST ENTIRELY FROM RITCHIE, A MODEL
C  FOR PREDICTING EVAPORATION FROM A ROW CROP WITH INCOMPLETE COVER.
C  WATER RESOURCES RESEARCH VOL. 8:1204.
C
      REAL LAMDAC,LAMDAS,LAMDA,INT,MH2O,NEWES,NEWEP
C
      COMMON /ETPARM/ ALPHA,GAMMA,LAMDAC,LAMDAS,U,WND
      COMMON /EVTR  / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C
      VP(TMP) = EXP(1.8282+TMP*(0.07046136-TMP*0.000215743))
      P = RAIN
      RS = RI*.0169491525
C RS = SOLAR RADIATION IN MM H2O/DAY.
      TAVM1 = TAVG-1.
      DEL = VP(TAVG) - VP(TAVM1)
C DEL=SLOPE OF SATURATION VAPOR PRESSURE CURVE AT MEAN AIR TEMP.
      LAMDA = INT*LAMDAC + (1.-INT)*LAMDAS
C LAMDAC & LAMDAS = ALBEDOS OF CROP & SOIL.
C INT=INTERCEPTION (FRACTION OF INCIDENT RS)
C RNO=NET RADIATION ABOVE CANOPY (MM/DAY)
      RNO=(RS-LAMDA*RS)
C TD & TW = DRY AND WET BULB TEMPERATURES.
      TD = TAVG
      VPO = VP(TD)
      TW = TMIN
C EO=POTENTIAL EVAPORATION RATE ABOVE CANOPY (MM/DAY)
C MODIFIED PENMAN EQ.
C W=WINDSPEED AT 2 METERS (MILES/DAY)
C GAMMA=PSYCHROMETER CONSTANT
      VPA = VP(TW)
      EO=(RNO*DEL/GAMMA+.262*(1.+0.0061*WND)*(VPO-VPA))/(DEL/GAMMA+1.)
C THE FOLLOWING CALCULATES ESO(POTENTIAL EVAP. RATE AT SOIL SURFACE1
C RNS=NET RADIATION AT SOIL SURFACE BELOW CANOPY
      RNS=((1.-INT)-(1.-INT)*LAMDAS)*RS
      ESO=DEL*RNS/(DEL+GAMMA)
```

```
C STAGE I DRYING
C SESI=CUMULATIVE STAGE ONE EVAPORATION FROM SOIL SURFACE
C U=UPPER LIMIT OF SESI
      IF(SESI.GT.U)GOTO 100
C P=RAINFALL
      IF(P.GE.SESI)GOTO 101
      SESI=SESI-P
99    SESI=SESI+ESO
      IF(SESI.GE.U)GOTO 102
      ES=ESO
      GOTO 110
102   ES=ESO-.4*(SESI-U)
      SESII=.6*(SESI-U)
      DUMY01 = SESII / ALPHA
      T = DUMY01 * DUMY01
      GO TO 110
101   SESI=0.
      GO TO 99
C STAGE II DRYING
100   IF(P.GE.SESII)GO TO 103
      T=T+1.
      ES = ALPHA * (SQRT(T)-SQRT(T-1.))
      IF(P.GT.0.)GO TO 104
      IF(ES.GT.ESO)GO TO 105
106   SESII=SESII+ES-P
      DUMY02 = SESII / ALPHA
      T = DUMY02 * DUMY02
      GO TO 110
105   ES=ESO
      GO TO 106
104   ESX=0.8*P
      IF(ESX.LT.ES)GO TO 107
111   IF(ESX.GT.ESO)GO TO 108
109   ES=ESX
      GO TO 106
108   ESX=ESO
      GO TO 109
107   ESX=ES+P
      GO TO 111
103   P=P-SESII
      SESI=U-P
      IF(P.GT.U)GO TO 101
      GO TO 99
C TRANSPIRATION IS PROPORTIONAL TO LIGHT INTERCEPTION (INT).
C  THIS REPRESENTS A MODIFICATION TO RITCHIE'S MODEL.

110   EP=INT*EO
      IF(EO-ES.LT.0.) EO=ES+EP
      IF(EP.GT.(EO-ES))EP=EO-ES
      AVGPSI = -1. * PSIAVG
      IF(AVGPSI.GT.9.0) AVGPSI = 9.0
      RN = RI*.71536-26.
C  RFEP = REDUCTION FACTOR FOR EVAPORATION FROM PLANT.  BASED ON
C  UNPUBLISHED DATA OF BAKER & HESKETH. 1969.
      RFEPN = 749.5831405 + 0.9659065*RN - 54.6600986*TAVG
     . - 194.6508431*AVGPSI - 0.0010226*RN*RN + 1.0153007*TAVG*TAVG +
     . 29.775978*AVGPSI*AVGPSI + 0.0293687*RN*TAVG
     . - 4.206856*TAVG*AVGPSI
      RFEPD = 749.5831405 + 0.9659065*RN
     . - 54.6600986*TAVG - 19.46508431 - 0.0010226*RN*RN +
     . 1.0153007*TAVG*TAVG + .29775978 + 0.0293687*RN*TAVG
     . - .4206856*TAVG
      RFEP = RFEPN/RFEPD
      IF(RFEP.LE.0.0) RFEP = 0.01
      EP = EP * RFEP
      RETURN
      END
```

```
      SUBROUTINE UPTAKE
C************************************************************
C   *********  MODIFIED FEB 22 1980  ******************
C   UPTAKE OF WATER FROM EACH SOIL CELL IS PROPORTIONAL TO *
C THE PRODUCT OF ROOT WEIGHT CAPABLE OF UPTAKE AND THE     *
C HYDRAULIC CONDUCTIVITY OF THE CELL.  THE SUM OF THE      *
C UPTAKE FROM THE CELLS EQUALS TRANSPIRATION.  ALL NO3 IN  *
C THE WATER TAKEN UP BY THE ROOTS IS ALSO TAKEN UP.        *
C************************************************************
C EP - TRANSPIRATION BY PLANTS, MM/DAY.
C SUPNO3 - SUPPLY OF NITRATE FROM SOIL, MG.
      DIMENSION UPF(20,6)
      INTEGER DAYNUM
      REAL NEWES , NEWEP, NYTTYM, LATUDE, INT
C UPF - UPTAKE FACTOR, GM CM/DAY.
C ROOT WEIGHT CAPABLE OF UPTAKE, GM/CELL.
C
      COMMON /DIFFU / DIFF(20,6)
      COMMON /EVTR  / EP,ES,SESI,SESII,T,NEWES,NEWEP,SUMES,SUMEP
      COMMON /FIELD / FC(20)
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /MATR  / KRL(20), LR
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)
      COMMON /SOILID/ DIFF0(5),THETA0(5),BETA(5),SDEPTH(5),THETAS(5),
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /UPS   / SUPNO3, UPNO3
C
C
      DELT = 1. / NOITR
      DUMY01 = (.10*NK*W*EP)*DELT
      DUMY02 = D * W
      DES = ES * 0.1 *DELT / D
C MODIFIED FOR ES REMOVED FROM ALL KOLUMNS
      DO 8 I=1,20
      DO 8 J=1,6
      UPF(I,J)=0.
    8 CONTINUE
      DO 7 KOLUMN = 1,NK
      DE = DES
      IF(DE.GT.VH2OC(1,KOLUMN) - .25 * FC(1) )
     .  DE =  VH2OC(1,KOLUMN) - .25 * FC(1)
```

```
        IF(DE.LT.0.)  DE = 0.
      VH2OC(1,KOLUMN) = VH2OC(1,KOLUMN) - DE
       SUMES = SUMES + DE * 10. *D
  7   CONTINUE
       NEWES=SUMES/ NK
      DO 1 LAYER  =1, LR
      KR = KRL(LAYER)
      DO 1 KOLUMN =1, KR
      UPF(LAYER,KOLUMN) = (RTWT(LAYER,KOLUMN,1) +
     . .20 * RTWT(LAYER,KOLUMN,2) + RTWT(LAYER,KOLUMN,3) )
C SUMS THE WEIGHT OF ROOTS 15 DAYS OLD OR LESS IN CELL.
 1    CONTINUE
      DO 4 LAYER  = 1, LR
      KR = KRL(LAYER)
      DO 4 KOLUMN = 1, KR
      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
C THE TOTAL WEIGHT OF ROOTS CAPABLE OF UPTAKE.
 4    CONTINUE
      NKH = NK/2
      SUPF = 0.
      DO 5 LAYER  = 1, LR
      KR = KRL(LAYER)
      IF (KR.GT.NKH) KR=NKH
      DO 5 KOLUMN = 1, KR
      UPF(LAYER,KOLUMN)=UPF(LAYER,KOLUMN)*DIFF(LAYER,KOLUMN)
C   **** NO DEPTH FACTOR FOR CALCULATING UPF ***** MODIFIED FEB 22
C UPTAKE FACTOR FOR EACH CELL, HAS UNITS OF GM CM/DAY.
C    MODIFIED BY DIVISION TO MEAN DEPTH OF LAYER
      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
C UPTAKE AMONG CELLS.
 5    CONTINUE
      UPNO3 = 0.
      J = 1
      DO 6 LAYER  = 1, LR
  21  IF(LAYER*D.LE.SDEPTH(J)) GO TO 20
      J = J + 1
      IF(J.LT.5) GO TO 21
 20   KR = KRL(LAYER)
      IF (KR.GT.NKH) KR=NKH
      DO 6 KOLUMN = 1, KR
      UPTH2O = (UPF(LAYER,KOLUMN)/SUPF) * DUMY01 / 2.
```

```
      H2OUPT=UPTH2O/DUMY02
C UPTAKE OF WATER FROM EACH CELL, CM**3/DAY.
C EP HAS UNITS OF MM/DAY.
      IF(VH2OC(LAYER,KOLUMN).GT.THETAR(J) ) GO TO 23
      H2OUPT = 0.
      GO TO 24
   23 IF (H2OUPT.GT.VH2OC(LAYER,KOLUMN)-THETAR(J) ) H2OUPT=
     *             VH2OC(LAYER,KOLUMN)-THETAR(J)
   24  CONTINUE
      UPTH2O=H2OUPT*DUMY02
      VH2OC(LAYER,KOLUMN)=VH2OC(LAYER,KOLUMN)-H2OUPT
      SUMEP=SUMEP+H2OUPT
C VOLUMETRIC WATER CONTENT OF CELL IS DECREASED BY AMOUNT
C OF UPTAKE FROM CELL.
      IMGKOL = NK - KOLUMN + 1
C           IMAGE COLUMN, MIRRORED ABOUT CENTERLINE OF PLANE.
      VH2OC(LAYER,IMGKOL) = VH2OC(LAYER,IMGKOL) - H2OUPT
      SUMEP=SUMEP+H2OUPT
C           VOLUMETRIC WATER CONTENT OF IMAGE CELL IS ALSO REDUCED.
      UPNO3C=0.
      IF(VH2OC(LAYER,KOLUMN).LE.THETAR(J)) GO TO 31
      UPNO3C = UPTH2O*(VNO3C(LAYER,KOLUMN)/VH2OC(LAYER,KOLUMN))
C UPTAKE OF NO3 FROM CELL, MG N/DAY.
C ALL NO3 IN WATER UPTAKE STREAM IS TAKEN UP.
   31 CONTINUE
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) - UPNO3C/DUMY02
C VOLUMETRIC NITRATE CONTENT OF CELL IS DECREASED BY AMOUNT OF
C UPTAKE FROM CELL, MG N/CC SOIL.
      UPNO3 = UPNO3 + UPNO3C
C SUM OF UPTAKE OF NITROGEN AS NITRATE FROM THE SOIL PROFILE,
C MG FOR THE DAY.
      UPNO3I=0.
      IF(VH2OC(LAYER,IMGKOL).LE.THETAR(J)) GO TO 34
      UPNO3I = UPTH2O*(VNO3C(LAYER,IMGKOL)/VH2OC(LAYER,IMGKOL))
C           UPTAKE OF NO3 FROM IMAGE CELL, MG N/DAY.
   34 CONTINUE
      VNO3C(LAYER,IMGKOL) = VNO3C(LAYER,IMGKOL) - UPNO3I/DUMY02
C           VOLUMETRIC NITRATE CONTENT OF IMAGE CELL IS ALSO DECREASED.
      UPNO3 = UPNO3 + UPNO3I
 6    CONTINUE
      NEWEP=SUMEP*D/NK*10.
      RETURN
      END
```

```
      SUBROUTINE CAPFLO
C  ***********************************************************
C  *                                                         *
C  *  CAPILLARY FLOW OF NO3 AND H2O IN ALL DIRECTIONS.       *
C  *                                                         *
C  ***********************************************************
C
C
      REAL LAI
      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.
C FLUX OF H2O UPWARD OUT OF THE CELL, CM**3/CELL/DAY.
C FLUX OF NITROGEN TO THE LEFT OUT OF THE CELL, MG N/CELL/DAY.
C FLUX OF NITROGEN UPWARD OUT OF THE CELL, MG N/CELL/DAY.
C
      COMMON /DIFFU / DIFF(20,6)
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /HOHBAL/ CAPUP, CUMEP, CUMES, CUMRAN, CUMSOK
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)
      COMMON /PS    / PSIS(20,6)
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),
     *                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)
      COMMON /TOTS  / DAMP, NOITR, TH2O, TNNH4, TNNO3
      COMMON /TIMEBD/ THETAI
C
      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
      J = 1
      DELT = .5 / NOITR
      DO 4 LAYER  = 1, NL
 214  IF(LAYER*D.LE.SDEPTH(J))GO TO 15
      J=J+1
      IF(J.LT.5) GO TO 214
C ******************************************************************
C       COND IS SOIL CONDUCTIVITY .
  15    CONTINUE
      IF(LAYER.EQ.NL) THETAI=THETAS(J)
      DO 4 KOLUMN = 1, NK
```

```
      DIFF(LAYER,KOLUMN)=C.
      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 :
C    GARDNER AND MAYHUGH. 1966. SSSAP 22:197-201. FDW.
      COND(LAYER,KOLUMN)=0.
       IF(VH2OC(LAYER,KOLUMN).LE.THETAS(J) ) GO TO 4
       COND(LAYER,KOLUMN) = 0.12 * ((VH2OC(LAYER,KOLUMN)-THETAR(J) ) /
     . (THETAS(J)-THETAR(J)  ) )**(3.*ETA(J)/(ETA(J)-2.))
       IF(COND(LAYER,KOLUMN).GT.3.) COND(LAYER,KOLUMN) = 3.
C  ******************************************************************
C
 4    CONTINUE
      DUMY01 = D * DAMP * DELT
      J = 1
      DO 5 LAYER  = 1, NL
 302  IF(LAYER*D.LE.SDEPTH(J)) GO TO 303
      J = J + 1
      IF(J.LT.5) GO TO 302
 303  DO 5 KOLUMN = 1, NK
       KM1 = KOLUMN - 1
       IF(KM1.EQ.0) KM1 = NK
C  ********************************************************************
C  DIFL IS THE ARITHMETIC MEAN OF DIFF OF THE TWO CELLS.
      DIFL = (DIFF(LAYER,KOLUMN)+DIFF(LAYER,KM1)) /2.
      FWL(LAYER,KOLUMN) = DIFL
     .      *((VH2OC(LAYER,KOLUMN)-VH2OC(LAYER,KM1))/W) * DUMY01
C FLOW OF WATER TO THE LEFT, OUT OF CELL, CM**3/CELL/DAY.
C SIMPLY DARCY'S LAW USING MEAN CONDUCTIVITY.
       FWLMAX = (VH2OC(LAYER,KOLUMN)-VH2OC(LAYER,KM1))*W*D / 10.
       IF(ABS(FWL(LAYER,KOLUMN)).GT.ABS(FWLMAX))FWL(LAYER,KOLUMN)=FWLMAX
C  FWLMAX IS USED TO PREVENT EXCESSIVE WATER FLOW IN ONE ITERATION.
C  *********************************************************************
C  WHEN FLOW IS INTO THE CELL (NEGATIVE FWL) THE CORRECT CALCULATION
C  OF FNL IS BY USING VNO3C AND VH2OC VALUES OF THE OTHER CELL.
       IF(FWL(LAYER,KOLUMN).LT.0.) GO TO 304
      FNL(LAYER,KOLUMN) = FWL(LAYER,KOLUMN)*VNO3C(LAYER,KOLUMN)/
     . VH2OC(LAYER,KOLUMN)
         GO TO 51
  304 FNL(LAYER,KOLUMN) = FWL(LAYER,KOLUMN)*VNO3C(LAYER,KM1) /
     . VH2OC(LAYER,KM1)
C FLOW OF NO3 TO THE LEFT, OUT OF CELL, MG N/CELL/DAY.
C MASS FLOW OF NO3 IN H2O, GM/CELL.
C  ************************************************************************
C  ***  REDISTRIBUTION OF NITRATES CAUSED BY DIFFERENCES IN THEIR
```

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C       CONCENTRATIONS IN SOIL SOLUTION OF ADJACENT CELLS.  **********
   51   FNL(LAYER,KOLUMN) = FNL(LAYER,KOLUMN) + (VNO3C(LAYER,KOLUMN) /
       .VH2OC(LAYER,KOLUMN)-VNO3C(LAYER,KM1)/VH2OC(LAYER,KM1))*DELT*1.5
 5      CONTINUE
        J = 1
        DO 6 LAYER  = 2, NL
  2     IF(LAYER*D.LE.SDEPTH(J)) GO TO 203
        J = J + 1
        IF(J.LT.5) GO TO 2
 203    DO 6 KOLUMN = 1,NK
C   *******************************************************************
C   DIFU IS THE ARITHMETIC MEAN OF DIFF OF THE TWO CELLS
C   CONU IS THE CONDUCTIVITY OF THE UPPER CELL.
C   THE PROCEDURE ALLOWS FOR GRAVITY FLOW WHEN VH2OC OF UPPER CELL
C   IS HIGHER THAN FIELD CAPACITY.
        DIFU = (DIFF(LAYER,KOLUMN)+DIFF(LAYER-1,KOLUMN)) / 2.
        FWU(LAYER,KOLUMN)=(DIFU*(VH2OC(LAYER,KOLUMN)-VH2OC(LAYER-1,KOLUMN)
       . ) / D - COND(LAYER-1,KOLUMN) ) * W * DAMP *DELT
C FLOW OF WATER UPWARD, OUT OF CELL, CM**3/CELL/DAY.
          FWUMAX = (VH2OC(LAYER,KOLUMN)-VH2OC(LAYER-1,KOLUMN) ) *W*D / 10.
          IF(ABS(FWU(LAYER,KOLUMN)).GT.ABS(FWUMAX))FWU(LAYER,KOLUMN)=FWUMAX
C   FWUMAX IS USED TO PREVENT EXCESSIVE WATER FLOW IN ONE ITERATION.
C   *********************************************************************
C   WHEN FLOW IS DOWNWARD, VNO3C AND VH2OC OF UPPER CELL ARE USED.
          IF(FWU(LAYER,KOLUMN).LT.0.) GO TO 300
        FNU(LAYER,KOLUMN) = FWU(LAYER,KOLUMN)*VNO3C(LAYER,KOLUMN)/
       . VH2OC(LAYER,KOLUMN)
            GO TO 61
  300   FNU(LAYER,KOLUMN) = FWU(LAYER,KOLUMN)*VNO3C(LAYER-1,KOLUMN)/
       . VH2OC(LAYER-1,KOLUMN)
C FLOW OF NO3 UPWARD IN THE WATER, MG N/CELL/DAY.
C   ********************************************************************
C   *** REDISTRIBUTION OF NITRATES IN ADJACENT CELLS.  *************
   61   FNU(LAYER,KOLUMN) = FNU(LAYER,KOLUMN) + (VNO3C(LAYER,KOLUMN) /
       .VH2OC(LAYER,KOLUMN)-VNO3C(LAYER-1,KOLUMN)/VH2OC(LAYER-1,KOLUMN) )
       . * DELT * 1.5
 6      CONTINUE
        J=1
        DO 16 LAYER = 1,NLM1
  40    IF(LAYER*D.LE.SDEPTH(J)) GO TO 41
        J=J+1
        IF(J.LT.5) GO TO 40
 41     DO 16 KOLUMN = 1,NK
        KP1 = KOLUMN + 1
        IF(KOLUMN.EQ.NK) KP1 = 1
```

```
      FWICN = FWL(LAYER,KP1) - FWL(LAYER,KOLUMN) +
     . FWU(LAYER+1,KOLUMN) - FWU(LAYER,KOLUMN)
C FLUX OF H2O INTO THE CELL, NET, CM**3/CELL.
      VH2OC(LAYER,KOLUMN) = VH2OC(LAYER,KOLUMN) + FWICN/(D*W)
C
      IF(VH2OC(LAYER,KOLUMN).LE.AIRDR(J)) VH2OC(LAYER,KOLUMN)=AIRDR(J)
   15 CONTINUE
      DO 30 KOLUMN = 1, NK
C  ******************************************************************
C  THIS INSURES DRAINAGE AT THE BOTTOM LAYER.
      IF(VH2OC(NL,KOLUMN).LE.THETAI) GO TO 30
      CUMSOK = CUMSOK +(VH2OC(NL,KOLUMN)-THETAI)*D*W*10./ROWSP
      VH2OC(NL,KOLUMN) = THETAI
   30 CONTINUE
C   BOTTOM BOUNDARY FROM GERARD AND NAMKEN DATA
C
      DO 7 LAYER  = 1, NL
      DO 7 KOLUMN = 1,NK
       KP1 = KOLUMN + 1
       IF(KOLUMN.EQ.NK) KP1 = 1
        IF(LAYER.EQ.NL) GO TO 71
      FNICN = FNL(LAYER,KP1) - FNL(LAYER,KOLUMN) +
     . FNU(LAYER+1,KOLUMN) - FNU(LAYER,KOLUMN)
        GO TO 72
   71 FNICN = FNL(LAYER,KP1) - FNL(LAYER,KOLUMN) - FNU(LAYER,KOLUMN)
   72       CONTINUE
C FLUX OF NO3 INTO THE CELL, NET, MG N/CELL/DAY.
      VNO3C(LAYER,KOLUMN) = VNO3C(LAYER,KOLUMN) + FNICN/(D*W)
C VOLUMETRIC NITROGEN CONTENT OF SOIL CELL, MG N/CM**3.
 7    CONTINUE
      TH2O = 0.
       TNNO3 = 0.
      J=1
      DO 8 LAYER = 1,NL
C  *****************************************************************
C  PSIS IS CALCULATED AFTER CAPFLO. PSIS IS -0.3 BAR FOR THETAS,
C  -15.0 BAR FOR THETAR, AND ASYMPTOTIC FOR AIRDR.
   34 TEMP2= (THETAR(J)-AIRDR(J))/(THETAS(J)-AIRDR(J))
      TEMP3 = ALOG(50.) / ALOG(TEMP2)
      IF(LAYER*D.LE.SDEPTH(J)) GO TO 35
      J=J+1
      IF (J,LT.5) GO TO 34
   35 DO 8 KOLUMN = 1, NK
      IF(VH2OC(LAYER,KOLUMN).GT.THETAR(J)) GO TO 45
      PSIS(LAYER,KOLUMN) = -15.
      GO TO 50
   45  CONTINUE
      TEMP1 = (VH2OC(LAYER,KOLUMN)-AIRDR(J))/(THETAS(J)-AIRDR(J))
      PSIS(LAYER,KOLUMN) = -0.3 * TEMP1**TEMP3
C H2O POTENTIAL OF SOIL CELL, IN BARS.
C  *******************************************************************
C
 50   CONTINUE
      TH2O = TH2O + VH2OC(LAYER,KOLUMN)
      TNNO3 = TNNO3 + VNO3C(LAYER, KOLUMN)
 8    CONTINUE
      TH2O = TH2O * D * W *0.1
C TOTAL WATER PROFILE
      TNNO3 = TNNO3*D*W
      RETURN
      END
```

```
      SUBROUTINE NITRIF
C  ***********************************************************
C  *                                                         *
C  *   S U B R O U T I N E   N I T R I F I C A T I O N       *
C  *                                                         *
C  ***********************************************************
C
C    SIMPLIED VERSION BASED ON KAFKAF1,HADAS,BAR-YOSEF MODEL
      COMMON /FIELD / FC(20)
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /H2ONO3/ VH2OC(20,6),VNO3C(20,6)
      COMMON /NITLIZ/ VNH4C(2,6),VNC(2,6)
      COMMON /TOTS  / DAMP,NOITR,TH2O,TNNH4,TNNO3
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)
      TNNH4 = 0.
      DO 5 L=1,2
      T = TSOLAV(L)
      FMIN = 7300000. * 10.**(-2758. /(T+273.))
      FNIT = .05 * 10.**( 12. - 3573.  /(T+273))
      DO 5 K=1,NK
      WFMIN = VH2OC(L,K)/FC(L)
      DNMIN = VNC(L,K) * FMIN * WFMIN
      VNC(L,K) = VNC(L,K) - DNMIN
      VNH4C(L,K) = VNH4C(L,K) + DNMIN
      WFNIT = 0.7 - 1.30 * (FC(L)- VH2OC(L,K))/FC(L)
      IF(WFNIT.LT.0.) WFNIT =0.
      DNIT = VNH4C(L,K) * FNIT * WFNIT
      VNH4C(L,K) = VNH4C(L,K) -DNIT
      VNO3C(L,K) = VNO3C(L,K) + DNIT
      TNNH4 = TNNH4 + VNH4C(L,K)
    5 CONTINUE
      TNNH4 = TNNH4 * D * W
      RETURN
      END
```

```
      SUBROUTINE PNET
C  ************************************************************
C  *                                                          *
C  *                    PNET  SUBROUTINE                      *
C  *                                                          *
C  ************************************************************
      REAL INT,LEAFWT,LEAFCN,LEAFRS,MH2O,LAI
C
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT
C
C   LEAF WATER POTENTIAL IS FUNC OF SOLAR RADIATION, HUMIDITY
C     AND SOIL WATER POTENTIAL
C
      PSIL=PSIAVG*5.
C
C   CALCULATE PHOTOSYNTHESIS REDUCTION FACTOR FOR MOISTURE STRESS
C     CURVE TAKEN FROM PAPER BY D W LAWLOR IN PHOTOSYNTHETICA 1976
C     PAGES 378-387
C
      PTSRED=0.
      IF(PSIL.LT.-18.) GO TO 10
      PTSRED=(PSIL+18.)/13.
      IF(PTSRED.GT.1.) PTSRED=1.
   10 CONTINUE
C
C   POTENTIAL CANOPY PHOTOSYNTHESIS IS A FUNCTION OF SOLAR
C     RADIATION. CURVE FROM FLORENCE SPAR DATA 1979 UNPUBLISHED
C      (UNITS ARE GMS/M**2/DAY)
C
      PSTAND=8.218+RI*(.22138-.00012*RI)
C
C   IF LEAF NITROGEN CONC < 1% CALC PHOTOSYNTHESIS REDUCTION FACTOR
C
      PTSN=1.0
      IF(LEAFCN.LT..01) PTSN=100.*LEAFCN
C
C   CALC PHOTOSYNTHESIS REDUCTION FACTOR FOR LEAF LOADING FEEDBACK
C     AS FUNCTION OF LEAF CARBOHYDRATE LEVEL. CURVE FROM RESEARCH
C     BULLETIN 907 - SIMED
C
      STARCH=RESC/(RESC+LEAFWT+STEMWT)
      RESCF=1.-.28*STARCH
      IF(STARCH.GT..18.AND.STARCH.LE..23) RESCF=1.67-4.*STARCH
      IF(STARCH.GT..23.AND.STARCH.LE..28) RESCF=3.74-13.*STARCH
      IF(STARCH.GT..28) RESCF=.1
C
C   PHOTOSYNTHATE PRODUCED/PLANT = POTENTIAL CANOPY PHOTOSYNTHESIS
C     ADJ FOR LIGHT INTERCEPTION, PLANT POPULATION & REDUCTION FACTORS.
C     POPFAC/100 CONVERTS FROM G/M**2/DAY TO G/PLANT/DAY
C
      PPLANT=PSTAND*INT*PTSN*PTSRED*RESCF*POPFAC/100.
C
C   RESPIRATION LOSS IS A FUNCTION OF TEMPERATURE. THE CURVE IS
C     FROM FLORENCE SPAR DATA 1979 UNPUBLISHED
C
      RESP=((TAVG-13.)/12500.*24.)*PLANTW
      IF(RESP.LT.0.) RESP=0.
C
C   REDUCE PHOTOSYNTHATE BY RESPIRATORY L  S
C
      PN=(PPLANT-RESP)*.68182
      IF(PN.LE.PNFAC) PN=PNFAC
      SPN=SPN+PN
      RETURN
      END
```

```
      SUBROUTINE GROWTH
C
C     ***************************************************************
C     *                                                             *
C     *                   GROWTH  SUBROUTINE                        *
C     *                                                             *
C     ***************************************************************
C
      REAL INT,LAI,LATUDE,NF,NV,NSTRES,NYTTYM,MH2O,LEAFWT,LEAFRS,
     . LEAFW,LEAFCN,JL,KL,JR,KR,JG,KG,JS,KS,JG1,NPOOL
      INTEGER DAYNUM,TILLER,DIFREN,BOOT,HEAD,ANTHES,SPIKE,FLORET,
     . SPRING,SRDAY,SECOND
C
      DIMENSION PDWL(10,6),PDSTEM(10),PDGLUM(10),PDGRAN(10)
C
      COMMON /CONS   / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN
      COMMON /FRUIT  / SPIKE(10),FLORET(10)
      COMMON /GEOM   / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /GROW   / LEAFW(10,6),STEMW(10),GLUMW(10),GRANW(10)
      COMMON /LASTAD/ LTDAY(10),LLDAY(10),ALTMP(10,6),ATTMP(10)
     .        ,APTMP(10)
      COMMON /LIGHT  / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /LOST   / WTSLFD
      COMMON /MATR   / KRL(20), LR
      COMMON /NIT    / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRANN,GLUMN,PLANTN
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1
      COMMON /PARTS  / LEAF(10),LIDATE(10,6),NTILL(10),NSTEMS
      COMMON /PHYTIM/ TILLER,JOINT(10),DIFREN,BOOT(10),HEAD(10),
     . ANTHES(10),SPRING,ACCDEG
      COMMON /POP    / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN
      COMMON /PS     / PSIS(20,6)
      COMMON /RESV   / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC
      COMMON /RUTWT  / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)
      COMMON /SIZES  / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /SOLAR  / INT, RI, RN, PNFAC
      COMMON /SPD    / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN
      COMMON /SROOT  / SRAVG,SRDAY,SECOND
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,
     . STRSD,STRSN,FACL
      COMMON /TEMP   / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSDN   / TSOILD(20), TSOILN(20), TSOLAV(2)
      COMMON /UPS    / SUPNO3,UPNO3
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT
      COMMON /WETS   / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C
```

```
C     DETERMINE FACTOR TO CONVERT LEAF AREA TO WEIGHT. AREA IS IN CM**2
C      & WEIGHT IS IN GRAMS. FROM UNPUBLISHED DATA FURNISHED BY SMIKA
C
        WTF=.0025
C
C     DETERMINE FACTOR TO BE USED TO REDUCE POTENTIAL WEIGHT CHANGE
C      DUE TO WATER STRESS.
C
        RFWST=(WSTRSD*DAYTYM+WSTRSN*NYTTYM)/24.
C
C     POTENTIAL STEM GROWTH IS FUNCTION OF TEMPERATURE & AGE
C     POTENTIAL GLUME GROWTH IS FUNCTION OF TEMPERATURE & AGE
C     POTENTIAL GRAIN DRY MATTER ACCUMULATION FUNCTION OF AGE & TEMP
C
        DO 100 I=1,NSTEMS
C
C     POTENTIALS DURING HEADING
C
        PDSTEM(I)=0.
        PDGLUM(I)=.000005
        PDGRAN(I)=.00008*TAVG-.0001
        IF(PDGRAN(I).LT.0.) PDGRAN(I)=0.
        IF(IDAY.GE.JOINT(I)) GO TO 40
C
C     POTENTIALS PRIOR TO JOINTING
C
        PDSTEM(I)=.00005
        PDGLUM(I)=0.
        PDGRAN(I)=0.
        GO TO 100
   40 IF(IDAY.GE.BOOT(I)) GO TO 60
C
C     POTENTIALS DURING JOINTING
C
        PDSTEM(I)=.0022
        PDGLUM(I)=0.
        PDGRAN(I)=0.
        GO TO 100
   60 IF(IDAY.GE.ANTHES(I)+4) GO TO 100
C
C     POTENTIALS DURING BOOT AND THRU ANTHESIS
C
        PDSTEM(I)=.0079
        PDGLUM(I)=.00002
        PDGRAN(I)=0.
```

```
C
C   ZERO ACCUMULATORS FOR WEIGHT CHANGE POTENTIALS
C
  100 CONTINUE
      SPDWL=0.
      SPDSTM=0.
      SPDGLM=0.
      SPDGRN=0.
C
C   GO THRU LOOP FOR EACH STEM TO SUM POTENTIALS
C
      IF(NSTEMS.LE.0) RETURN
      DO 160 I=1,NSTEMS
      IF(LEAF(I).LE.0) GO TO 140
      K=LEAF(I)
      DO 120 J=1,K
C
C   CALCULATE POTENTIAL CHANGE IN LEAF AREA AS FUNCTION OF TIME
C    FROM UNPUBLISHED DATA FURNISHED BY SMIKA
C
C     ITIM=IDAY-LIDATE(I,J)
C     IF(ITIM.LE.25) RADAY=.2
C     IF((ITIM.GT.25).AND.(ITIM.LE.35)) RADAY=.6
C     IF((ITIM.GT.35).AND.(ITIM.LE.43)) RADAY=.8
C     IF((ITIM.GT.43).AND.(ITIM.LE.65)) RADAY=.07
C     IF(ITIM.GT.65) RADAY=0.
      TDUM=TAVG
      IF(TDUM.GT.20.) TDUM=40.-TDUM
      IF(TDUM.LT.0.) TDUM=0.
      RADAY=TDUM/40.
      ALTMP(I,J)=ALTMP(I,J)+TAVG
      ITIM=IDAY-LIDATE(I,J)
      TDUM=ALTMP(I,J)/ITIM
      ITDUM=-1.33*TDUM+51.83
      IF(ITIM.GE.ITDUM) RADAY=0.
C
C   CONVERT POTENTIAL AREA GROWTH TO POTENTIAL WEIGHT INCREMENT
C
      PDWL(I,J)=RADAY*WTF*RFWST*FACL
      SPDWL=SPDWL+PDWL(I,J)
  120 CONTINUE
C
C   IF PLANT IS HEADING STEM GROWTH = 0
C    SUM POTENTIAL DRY MATTER ACCUMULATION IN ALL STEMS
C
```

```
  140 SPDSTM=SPDSTM+PDSTEM(I)*RFWST
C
C   SUM POTENTIAL DRY MATTER ACCUMULATION IN ALL GLUMES
C
      SPDGLM=SPDGLM+PDGLUM(I)*SPIKE(I)*RFWST
C
C   SUM POTENTIAL DRY MATTER ACCUMULATION IN GRAIN
C
      SPDGRN=SPDGRN+PDGRAN(I)*FLORET(I)*RFWST
  150 CONTINUE
C
C   CALL ROOT GROWTH SUB TO GET TOTAL POTENTIAL DRY MATTER ACCUMULATION
C    IN ROOT SYSTEM
C
      KALL=0
      CALL RUTGRO(KALL)
C
C   PUT ON A PER PLANT BASIS
C
      SPDWRT=SPDWRT*2./ROWSP*POPFAC*100.
C
C   CARBOHYDRATE DEMAND IS SUM OF DEMAND COMPONENTS FROM ALL PLANT PARTS
C
      CD=SPDWRT+SPDGLM+SPDSTM+SPDWL
C
C   CSTRES (SUPLY DEMAND RATIO) IS INDEX OF NUTRITIONAL STATUS OF PLANT
C
      CSTRSF=1.
      CSTRSV=1.
      CPOOL=RESC+PN
      RESC=CPOOL-SPDGRN
      IF(RESC.GT.0.) GO TO 200
      CSTRSF=(RESC+SPDGRN)/SPDGRN
      RESC=0.
      CSTRSV=0.
      GO TO 220
  200 RESC=RESC-CD
      IF(RESC.GE.0.) GO TO 220
      CSTRSV=0.
      IF(CD.GT.0.) CSTRSV=(RESC+CD)/CD
      RESC=0.
C
C
  220 CONTINUE
C
```

```
C     CALL NITROGEN BUDGET SUB TO GET NSTRES, THE SUPPLY DEMAND RATIO FOR
C      NITROGEN (ANALOGOUS TO CSTRES)
C
      CALL NITRO
      LEAFWT=0.
      STEMWT=0.
      GLUMWT=0.
      GRANWT=0.
      XTRAC=0.
C
C     DISTRIBUTE DRY MATTER TO PLANT PARTS. CHANGE IN WEIGHT OF STEM =
C      POTENTIAL CHANGE IN WEIGHT * SUPPLY DEMAND RATIOS FOR CARBOHYDRATE
C      AND NITROGEN
C
      DO 400 I=1,NSTEMS
      IF(LEAF(I).LE.0) GO TO 340
      K=LEAF(I)
      DO 320 J=1,K
      IF(PDWL(I,J).LE.0.) GO TO 300
C
C     ACCUMULATE LEAF AREA AND LEAF WT
C
      AREA=AREA+PDWL(I,J)/WTF*CSTRSV*NV
      LEAFW(I,J)=LEAFW(I,J)+PDWL(I,J)*CSTRSV*NV
      XTRAC=XTRAC+PDWL(I,J)*CSTRSV*(1.-NV)
  300 LEAFWT=LEAFWT+LEAFW(I,J)
  320 CONTINUE
C
C     ACCUMULATE STEM WT
C
  340 STEMW(I)=STEMW(I)+PDSTEM(I)*RFWST*CSTRSV*NV
      XTRAC=XTRAC+PDSTEM(I)*RFWST*CSTRSV*(1.-NV)
      STEMWT=STEMWT+STEMW(I)
C
C     ACCUMULATE WEIGHT IN THE GLUMES
C
      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)
C
C     ACCUMULATE WEIGHT IN THE GRAIN
C
      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)
```

```
      SUBROUTINE NITRO
C  ****************************************************************
C  *                                                              *
C  *                     NITRO  SUBROUTINE                        *
C  *                                                              *
C  ****************************************************************
C
      REAL LEAFWT,LEAFCN,KL,KS,KR,KG,JL,JS,JR,JG,JG1,LEAFRS,
     . NF,NSTRES,NV,NPOOL,LEAFR1
C
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN
      COMMON /NIT   / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRANN,GLUMN,PLANTN
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,
     . STRSD,STRSN,FACL
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN
      COMMON /UPS   / SUPNO3,UPNO3
C
      NSTRES=1.
      NV=1.
      NF=1.
C
C   CALCULATE NITROGEN RESERVES IN EACH TISSUE FROM TISSUE NITROGEN,
C    MINIMUM POSSIBLE LEVELS & AN AVAILABILITY FACTOR (F2)
C
      LEAFRS=(SLEAFN-KL*LEAFWT)*F2
      STEMRS=(STEMN-KS*STEMWT)*F2
      ROOTRS=(ROOTN-KR*ROOTWT)*F2
      GLUMRS=(GLUMN-KG*GLUMWT)*F2
      IF(LEAFRS.LT.0.) LEAFRS=0.
      IF(STEMRS.LT.0.) STEMRS=0.
      IF(ROOTRS.LT.0.) ROOTRS=0.
      IF(GLUMRS.LT.0.) GLUMRS=0.
C
C   CALCULATE TOTAL NITROGEN RESERVE
C
      RESN=LEAFRS+STEMRS+ROOTRS+GLUMRS
C
C   THE NITROGEN POOL AVAILABLE IS SUM OF NITROGEN TAKEN UP TODAY +
C    RESERVES
C
      NPOOL=SUPNO3+RESN
C
```

```
C     CALCULATE NITROGEN REQUIRED FOR NEW (PROPOSED) DRY WT GROWTH OF
C      EACH ORGAN
C
        LEAFR1=JL*SPDWL*CSTRSV
        STEMR1=JS*SPDSTM*CSTRSV
        ROOTR1=JR*SPDWRT*CSTRSV
        GLUMR1=JG*SPDGLM*CSTRSV
        GRANR1=JG1*SPDGRN*CSTRSF
C
C     CALCULATE TOTAL REQUIREMENT OF NITROGEN FOR GROWTH
C
        REQN=LEAFR1+STEMR1+ROOTR1+GLUMR1
C
C     IF NITROGEN REQUIREMENT FOR GROWTH OF GRAIN & VEGETATIVE PARTS >
C      NITROGEN POOL, BUT < REQUIREMENT FOR GROWTH OF GRAIN ALONE THEN GET
C      FULL GRAIN GROWTH & AMT LEFT GOES TO GROWTH OF VEGETATIVE PARTS
C      (NF=1 & NV IS REDEFINED). IF REQUIREMENT > FOR GRAIN ALONE THEN
C      NO VEGETATIVE GROWTH & GRAIN GROWTH REDUCED (NF IS REDEFINED, NV=0)
C
        IF((REQN+GRANR1).LE.NPOOL) GO TO 60
        NSTRES=NPOOL/(REQN+GRANR1)
        IF(GRANR1.GT.NPOOL) GO TO 40
        NV=(NPOOL-GRANR1)/REQN
        GO TO 60
   40   NV=0.
        NF=NPOOL/GRANR1
   60   CONTINUE
C
C     IF NITROGEN REQUIREMENT IS = OR < NITROGEN POOL, THEN EACH ORGAN
C      RESERVES WHATEVER IS REQUIRED FOR GROWTH
C
        SLEAFN=SLEAFN+LEAFR1*NV
        STEMN=STEMN+STEMR1*NV
        ROOTN=ROOTN+ROOTR1*NV
        GLUMN=GLUMN+GLUMR1*NV
        GRANN=GRANN+GRANR1*NF
C
C     CALCULATE TOTAL PLANT NITROGEN CONTENT FOR CHECK ON THE BALANCE
C
        PLTN=SLEAFN+STEMN+ROOTN+GRANN+GLUMN
C
C     DIFFERENCE BETWEEN NEW & OLD NITROGEN IN SYSTEM ADDED TO THE DAYS
C      UPTAKE REPRESENTS EITHER ADDITION OR WITHDRAWAL FROM RESERVE
C
        XTRAN=(SUPNO3+PLANTN)-PLTN
C
C     ADD TO OR SUBTRACT FROM RESERVES IN PROPORTION TO WT OF VARIOUS
C      ORGANS
C
        IF(XTRAN.LT.0.) GO TO 80
        SLEAFN=SLEAFN+XTRAN*(LEAFWT/VEGWT)
        STEMN=STEMN+XTRAN*(STEMWT/VEGWT)
        ROOTN=ROOTN+XTRAN*(ROOTWT/VEGWT)
        GLUMN=GLUMN+XTRAN*(GLUMWT/VEGWT)
        GO TO 90
   80   IF(RESN.LE.0.) GO TO 90
        SLEAFN=SLEAFN+XTRAN*(LEAFRS/RESN)
        STEMN=STEMN+XTRAN*(STEMRS/RESN)
        ROOTN=ROOTN+XTRAN*(ROOTRS/RESN)
        GLUMN=GLUMN+XTRAN*(GLUMRS/RESN)
   90   CONTINUE
C
C     CALCULATE LEAF NITROGEN CONCENTRATION AS % OF LEAF WEIGHT
C
        LEAFCN=SLEAFN/LEAFWT
C
C     TOTAL THE PLANT NITROGEN
C
        PLANTN=SLEAFN+ROOTN+STEMN+GRANN+GLUMN
        RETURN
        END
```

```
      SUBROUTINE MORPH
C   ***************************************************************
C   *                                                             *
C   *                     MORPH  SUBROUTINE                       *
C   *                                                             *
C   ***************************************************************
C
      REAL INT,LAI,LATUDE,NF,NV,NSTRES,NYTTYM,MH2O,LEAFWT,LEAFRS,
     . LEAFW,LEAFCN,JL,KL,JR,KR,JG,KG,JS,KS,JG1,NPOOL
      INTEGER DAYNUM,TILLER,DIFREN,BOOT,HEAD,ANTHES,SPIKE,FLORET,
     . SPRING,STEMBG,STEMND,SRDAY,TBSR,SECOND,TBT,TBL,STEMJ,DNODE,ANTHND
C
      DIMENSION NODE(10),TDES(10)
C
      COMMON /CONS  / ROOTCN,STEMCN,LEAFCN,GLUMCN,GRANCN
      COMMON /FRUIT / SPIKE(10),FLORET(10)
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /GROW  / LEAFW(10,6),STEMW(10),GLUMW(10),GRANW(10)
      COMMON /LASTAD/ LTDAY(10),LLDAY(10),ALTMP(10,6),ATTMP(10)
     .        ,APTMP(10)
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /LOST  / WTSLFD
      COMMON /MATR  / KRL(20), LR
      COMMON /NIT   / NPOOL,REQN,ROOTN,SLEAFN,STEMN,GRANN,GLUMN,PLANTN
      COMMON /NITCON/ JL,KL,JR,KR,JG,KG,JS,KS,JG1
      COMMON /PARTS / LEAF(10),LIDATE(10,6),NTILL(10),NSTEMS
      COMMON /PHYTIM/ TILLER,JOINT(10),DIFREN,BOOT(10),HEAD(10),
     . ANTHES(10),SPRING,ACCDEG
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN
      COMMON /PS    / PSIS(20,6)
      COMMON /RESV  / F2,LEAFRS,ROOTRS,STEMRS,RESN,RESC
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN
      COMMON /SROOT / SRAVG,SRDAY,SECOND
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,
     . STRSD,STRSN,FACL
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)
      COMMON /UPS   / SUPNO3,UPNO3
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C
      ATMP=TAVG
```

```
      IF(ATMP.LT.0.) ATMP=0.
      ACCDEG=ACCDEG+ATMP
      IF(ACCDEG.LT.100.) GO TO 100
      IF(ACCDEG.GT.750.) GO TO 40
      IF(IDAY.LT.TILLER) TILLER=IDAY
      IF(ACCDEG.GT.315..AND.IDAY.LT.DIFREN) DIFREN=IDAY
      GO TO 100
   40 IF(ACCDEG.GT.1090.) GO TO 60
      IF(IDAY.GT.JOINT(1)) GO TO 100
      JOINT(1)=IDAY
      STEMBG=1
      STEMND=0
      DO 50 I=1,10
      NODE(I)=0
   50 CONTINUE
      GO TO 100
   60 IF(ACCDEG.GT.1200.) GO TO 80
      IF(IDAY.GT.BOOT(1)) GO TO 100
      BOOT(1)=IDAY
      NSTMH=1
      DO 70 I=1,NSTEMS
      IF(NODE(I).LT.7) GO TO 70
      NSTMH=I
      IDIFF=JOINT(I)-JOINT(1)
      BOOT(I)=BOOT(1)+IDIFF
   70 CONTINUE
      GO TO 100
   80 IF(IDAY.GT.HEAD(1)) GO TO 400
      HEAD(1)=IDAY
      DO 90 I=1,NSTMH
      IDIFF=JOINT(I)-JOINT(1)
      HEAD(I)=HEAD(1)+IDIFF
      SPIKE(I)=ISPLTS
   90 CONTINUE
      GO TO 400
C
C
  100 CONTINUE
      SRAVG=SRAVG+ATMP
      TBSR=10.-.5*(SRAVG/FLOAT(IDAY-SRDAY))
      IF(TBSR.LT.2) TBSR=2
C
C    IF H2O IS OK AND ENOUGH TIME HAS PASSED SINCE LAST SECONDARY ROOT
C     WAS FORMED, THEN WE GET A NEW ONE
C
```

```
      IF((IDAY.LT.TBSR+SRDAY).OR.(PSIAVG.LT.-1.)) GO TO 120
      SRDAY=IDAY
      SRAVG=0.
      SECOND=SECOND+1
C
C   CHECK ON NEW LEAVES
C
  120 CONTINUE
      DO 140 I=1,NSTEMS
      APTMP(I)=APTMP(I)+ATMP
      IF(LEAF(I).GE.6) GO TO 140
      ATTMP(I)=ATTMP(I)+ATMP
      TBL=9.-ATTMP(I)/(IDAY-LLDAY(I))/5.
      IF(TBL.LT.4) TBL=4
C
C   IF SUFFICIENT TIME HAS PASSED SINCE LAST LEAF FORMED &
C    THERE ARE < 6 LEAVES ON THE STEM, THEN A NEW LEAF IS
C    FORMED
C
      IF(LLDAY(I)+TBL.GE.IDAY) GO TO 140
      LLDAY(I)=IDAY
      LEAF(I)=LEAF(I)+1
      LIDATE(I,LEAF(I))=IDAY
      ATTMP(I)=0.
      ALTMP(I,LEAF(I))=0.
  140 CONTINUE
C
C   IF THE PLANT IS JOINTING OR BEYOND THEN TILLERING IS COMPLETE
C
      IF(IDAY.GE.JOINT(1)) GO TO 300
      IF((IDAY.LT.TILLER).OR.(NSTEMS.GE.10)) GO TO 170
C
C   IF THERE ARE < 10 STEMS, ENOUGH CARBOHYDRATES ARE AVAILABLE
C    & SUFFICIENT TIME HAS ELAPSED SINCE LAST TILLER WAS FORMED
C    THEN ANOTHER TILLER IS FORMED
C
      J=NSTEMS
      DO 160 I=1,J
      TBT=30.-APTMP(I)/(IDAY-LIDATE(NSTEMS,1))
      IF(TBT.LT.5) TBT=5
      IF(NSTEMS.GE.10) GO TO 170
      IF(LEAF(I).LE.2) GO TO 160
      IF(IDAY.LT.LTDAY(I)+TBT) GO TO 160
      IF(NTILL(I).GE.3) GO TO 160
      NTILL(I)=NTILL(I)+1
```

```
      NSTEMS=NSTEMS+1
      LEAF(NSTEMS)=1
      LIDATE(NSTEMS,1)=IDAY
      LEAFW(NSTEMS,1)=0.
      LTDAY(I)=IDAY
      IF(NSTEMS.LE.3) GO TO 160
      IF(PSIAVG.LT.-1.) GO TO 180
      IF(LEAFCN.LT..03) GO TO 180
      IF(CSTRSV.LE..99) GO TO 180
  150 CONTINUE
  170 CONTINUE
C
C    IF PAST FIRST DAY OF SPRING, LEAF OR SOIL H2O POTENTIAL
C     IS < REQUIRED & A STEM HAS < 4 SECONDARY ROOTS, THEN
C     ABORT THE LATEST TILLER
C
      IF(IDAY.LT.SPRING) GO TO 220
      IF((PSIL.GE.-20.).OR.(SECOND/NSTEMS.GE.4)) GO TO 220
  180 LLDAY(NSTEMS)=0
      LEAF(NSTEMS)=0
      NTILL(NSTEMS)=0
      STEMW(NSTEMS)=0
      ATTMP(NSTEMS)=0.
      APTMP(NSTEMS)=0.
C
      DO 210 I=1,6
      ALTMP(NSTEMS,I)=0.
      LIDATE(NSTEMS,I)=0
      LEAFW(NSTEMS,I)=0
  210 CONTINUE
C
C
      NSTEMS=NSTEMS-1
C
C
  220 CONTINUE
C
C    IF NOT DAY OF DIFFERENTIATION RETURN
C
      IF(IDAY.NE.DIFREN) GO TO 600
C
C    DETERMINE THE POTENTIAL NUMBER OF SPIKELETS PER SPIKE
C
      ISPLTS=22
      DUM1=RESC/(RESC+LEAFWT)
```

```
      DUM2=10.*DUM1+.5
      IF(DUM2.GT.1.) DUM2=1.
      ISPLTS=ISPLTS*DUM2+.5
      DUM2=15.*LEAFCN+.5
      IF(DUM2.GT.1.) DUM2=1.
      ISPLTS=ISPLTS*DUM2+.5
      GO TO 600
C
C   IF JOINTING IS COMPLETED THEN RETURN
C
  300 CONTINUE
      IF(IDAY.GT.JOINT(1)+15) GO TO 600
      IF(STEMND.GE.10) GO TO 340
C
C   DETERMINE THE NUMBER OF STEMS ALLOWED TO BEGIN JOINTING
C    TODAY
C
      DUM1=(WSTRSD*DAYTYM+WSTRSN*NYTTYM)/24.
      DUM1=DUM1*.4+CSTRSV*.35+NSTRES*.25
      STEMJ=0.
      IF(DUM1.GE..3) STEMJ=1
      IF(DUM1.GE..75) STEMJ=2
      IF(DUM1.GE..99) STEMJ=3
C
C   MARK THE FIRST & LAST STEMS TO BEGIN JOINTING TODAY
C
      IF(STEMJ.LE.0) GO TO 340
      STEMND=STEMBG+STEMJ-1
      IF(STEMND.GT.10) STEMND=10
C
C   ELONGATE THE FIRST JOINT FOR EACH STEM BEGINNING JOINTING
C
      DO 330 I=STEMBG,STEMND
      IF(LEAF(I).GE.6) GO TO 320
      STEMND=STEMBG-2+I
      GO TO 340
  320 NODE(I)=1
      JOINT(I)=IDAY
  330 CONTINUE
C
C   STEM DOES NOT JOINT BEFORE IT HAS SIX LEAVES
C
  340 L=STEMBG-1
      IF(STEMBG.LE.STEMND) STEMBG=STEMND+1
      IF(L.LE.0) GO TO 600
```

```
      IF(L.GT.10) L=10
      IF(PSIL.LT.-10.) GO TO 600
      DNODE=2
C
C   FOR STEMS PREVIOUSLY BEGAN JOINTING THEN DETERMINE IF
C     ADDITIONAL NODES ARE TO BE ADDED TODAY
C
      DO 380 I=1,L
      NODE(I)=NODE(I)+DNODE
      IF(NODE(I).GT.7) NODE(I)=7
  380 CONTINUE
      GO TO 600
C
C   DETERMINE DAY OF ANTHESIS & IF NOT WITHIN THE PERIOD
C     THEN RETURN
C
  400 CONTINUE
      IF(ACCDEG.LT.1300.) GO TO 600
      IF(ANTHES(1).LT.IDAY) GO TO 440
      ANTHES(1)=IDAY
      DFAC=.25
      DO 420 I=1,NSTMH
      IDIFF=JOINT(I)-JOINT(1)
      ANTHES(I)=ANTHES(1)+IDIFF
      TDES(I)=0.
      FLORET(I)=SPIKE(I)*4
  420 CONTINUE
C
C
C
  440 CONTINUE
      DO 460 I=1,NSTMH
      IF((IDAY.LT.ANTHES(I)).OR.(IDAY.GT.ANTHES(I)+3)) GO TO 460
C
C   DETERMINE FRACTION OF FLORETS DESSICATED DUE TO LOW LEAF WATER
C     POTENTIAL & WIND
C
      DES=(-.04)*PSIL-.6
      IF(DES.LT.0.) DES=0.
      IF(DES.GT.1.) DES=1.
      TDES(I)=DES*DFAC+TDES(I)
      IF(IDAY.NE.ANTHES(I)+3) GO TO 460
C
C   ELIMINATE THE DESSICATED FLORETS FROM THE ARRAY
C

      FLORET(I)=FLORET(I)-TDES(I)*FLORET(I)+.5001
      IF(FLORET(I).GT.60) FLORET(I)=60
      IF(FLORET(I).LT.10) FLORET(I)=10
  460 CONTINUE
  600 CONTINUE
      RETURN
      END
```

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      SUBROUTINE RUTGRO(KALL)
C*******************************************************************
C   THIS SUBROUTINE CALCULATES THE GROWTH (IN TERMS OF DRY        *
C MATTER) OF ROOTS IN EACH CELL FOR THE DAY.  FIRST, THE POTENTIAL*
C GROWTH (PDWRT) FOR THE EXISTING SOIL WATER POTENTIAL (PSIS)     *
C AND TEMPERATURE (TSOILD & TSOILN) IS CALCULATED FOR EACH        *
C SOIL CELL, BASED ON THE WEIGHT OF ROOTS CAPABLE OF GROWTH       *
C IN EACH CELL (RTWTCG).  THEN THE ACTUAL GROWTH IS               *
C DETERMINED, BASED ON THE CARBOHYDRATE SUPPLY FOR ROOT GROWTH    *
C AND THE POTENTIAL GROWTH FOR THE CELL.  THE ACTUAL GROWTH       *
C OCCURING FOR A GIVEN CELL MAY OCCUR WITHIN THE CELL OR IN       *
C THE CELLS TO THE RIGHT OR LEFT & BELOW.                         *
C   GROWTH IN THE 4 AVAILABLE CELLS IS BASED ON RELATIVE          *
C WATER POTENTIALS OF THE FOUR, WITH A HEAVIER WEIGHTING          *
C GIVEN TO DOWNWARD GROWTH.                                       *
C    THIS SUBROUTINE DRAWS HEAVILY ON THE IDEAS AND THEORIES OF   *
C  DR. M. G. HUCK, USDA-ARS, AUBURN, ALA.  THIS IS ESPECIALLY     *
C  AS REGARDS SLOUGHING.  C. F. 'A MODEL FOR SIMULATING ROOT      *
C  GROWTH AND WATER UPTAKE ', M. G. HUCK, F. W. T. PENNING DE     *
C  VRIES, AND M. G. KEIZER.  IN PRESS.                            *
C*******************************************************************
      REAL INT,LATUDE,LEAFWT,NF,NV,NYTTYM,LAI,NSTRES,MH2O
      DIMENSION DWRT(20,6)
      INTEGER DAYNUM
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /LOST  / WTSLFD
      COMMON /MATR  / KRL(20), LR
      COMMON /POP   / PN,PSTAND,PTSN,PTSRED,RESCF,PPLANT,RESP,SPN
      COMMON /PS    / PSIS(20,6)
      COMMON /ROOTIM/ RTIMPD(20,6),SNAME(3),TSTBD(9,20),INRT,MRT
     .    ,TSTIMP(9,20),GH2OC(9),FACR
      COMMON /RUTWT / RCH2O, ROOTS, ROOTSV(20,6), RTWT(20,6,3)
      COMMON /SIZES / ROWSP,LAI,POPFAC,XLEAFL,AREA
      COMMON /SOILID/ DIFF0(5),THETA0(5),BETA(5),SDEPTH(5),THETAS(5),
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)
      COMMON /SOLAR / INT, RI, RN, PNFAC
      COMMON /SPD   / SPDWL,SPDSTM,SPDWRT,SPDGLM,SPDGRN
      COMMON /STRESS/ CSTRSV, CSTRSF, NF, NSTRES, NV, WSTRSD, WSTRSN,
     . STRSD,STRSN,FACL
      COMMON /TEMP  / DTAVG(7), TAVG, TDAY, TMAX, TMIN, TNYT
      COMMON /TSDN  / TSOILD(20), TSOILN(20), TSOLAV(2)
      COMMON /WEIGHT/ LEAFWT,PLANTW,ROOTWT,STEMWT,GLUMWT,GRANWT,VEGWT
      COMMON /WETS  / MH2O,PSIAVG,PSIMAX,RAIN,PSIL
C
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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 POWRT 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 )
C  GROWTH INSIDE CELL
      RTWT(L,K,1) = RTWT(L,K,1) + DWRT(L,K)*(1./PSIS(L,K)**3)/SRWP
C  GROWTH TO THE LEFT
      RTWT(L,KL1,1)=RTWT(L,KL1,1)+DWRT(L,K)*(LC/PSIS(L,KL1)**3)/SRWP
C  GROWTH TO THE RIGHT
      RTWT(L,KR1,1)=RTWT(L,KR1,1)+DWRT(L,K)*(IRC/PSIS(L,KR1)**3)/SRWP
C  GROWTH DOWNWARD
      RTWT(LD1,K,1)=RTWT(LD1,K,1)+DWRT(L,K)*(LDC/PSIS(LD1,K)**3)/SRWP
C
      IF(K.NE.KR.OR.KR.GE.6) GO TO 11
C  INCREMENT KOLUMN COUNTER FOR THIS LAYER
      KRL(L) = KRL(L) + 1
 11   CONTINUE
      IF(L.NE.LR.OR.LR.GE.NL) GO TO 9
C  INCREMENT LAYER COUNTER
      IF(K.EQ.1) LRT = LR + 1
      KRL(L+1) = KRL(L+1) + 1
      GO TO 9
 10   CONTINUE
C  GROWTH INSIDE CELL ONLY
      RTWT(L,K,1) = RTWT(L,K,1) + DWRT(L,K)
C
 9    CONTINUE
 8    CONTINUE
      LR =LRT
C
      ROOTS = 0.
      PSITOT = 0.
      PSINUM = 0.
      DO 23 LAYER  = 1, LR
      KR = KRL(LAYER)
      DO 23 KOLUMN = 1, KR
C SLOUGH ROOTS IN ALL BOX CARS IN ALL CELLS.
      WTBSLF = RTWT(LAYER,KOLUMN,2)
      RTWT(LAYER,KOLUMN,2) = WTBSLF*(1. - SLF)
      WTSLFD = WTSLFD + (WTBSLF-RTWT(LAYER,KOLUMN,2))
      ROOTSV(LAYER,KOLUMN) = RTWT(LAYER,KOLUMN,1) + RTWT(LAYER,KOLUMN,2)
     .   + RTWT(LAYER,KOLUMN,3)
      ROOTS = ROOTS + ROOTSV(LAYER,KOLUMN)
 23   CONTINUE
      ROOTWT = ROOTS * POPFAC * 2. / ROWSP * 100.
C  ROOTWT IS DOUBLED TO ACCOUNT FOR FULL PROFILE.
      DO 25 LAYER = 2, LR
      KR = KRL(LAYER)
      DO 26 KOLUMN = 1, KR
      IF(PSIS(LAYER,KOLUMN).LT.-15.) GO TO 26
      PSITOT = PSITOT + PSIS(LAYER,KOLUMN)
      PSINUM = PSINUM + 1
 26   CONTINUE
 25   CONTINUE
      IF(IFIX(PSINUM).LE.0) GO TO 27
      PSIAVG = PSITOT / PSINUM
      DROOT = ROOTWT - RUTWT
      RETURN
   27 PSIAVG = -15.
      WRITE(6,28)
   28 FORMAT(/' ',42(1H*)/' *  PLANT IS DEAD DUE ',
     .'TO MOISTURE STRESS  *'/' ',42(1H*))
      RETURN
      END
```

```
      SUBROUTINE RIMPED
C     ******************************************************************
C      THIS SUBROUTINE CALCULATES ROOT IMPEDENCE BASED UPON THE BULK      *
C     DENSITY AND WATER CONTENT. THIS IS BASED UPON DATA FROM ARTICLES BY *
C     R.B.CAMPBELL,D.C.REICOSKY,AND C.W.DOTY J.OF SOIL AND WATER CONS.   *
C     29:220-224,1974 AND                                                 *
C     H.M.TAYLOR AND H.R.GARDNER. SOIL SCI.96:153-156,1963.               *
C      A LINEAR TABLE LOOK-UP PROCEDURE IS USED. ASSUME ALL CURVES ARE    *
C     READ AT THE SAME BD.                                                *
C                                                                         *
C     ******************************************************************
      COMMON /GEOM  / D, G, NK, NL, RTP1, RTP2, SLF, THRLN, W
      COMMON /H2ONO3/ VH2OC(20,6), VNO3C(20,6)
      COMMON /SOILID/ DIFFO(5),THETAO(5),BETA(5),SDEPTH(5),THETAS(5),
     .                THETAR(5),AIRDR(5),ETA(5),FLXMAX(5),BD(5)
      COMMON /ROOTIM/ RTIMPD(20,6),SNAME(3),TSTBD(9,20),INRT,MRT
     .     ,TSTIMP(9,20),GH2OC(9),FACR
      J = 1
C
      NKH = NK/2
      DO 99 LAYER = 1,NL
   24 IF(LAYER*D.LE.SDEPTH(J))GO TO 25
      J=J+1
      IF(J.LT.5)GO TO 24
C
   25 JJ = 1
   26 IF(BD(J)-TSTBD(1,JJ))30,30,27
   27 JJ = JJ+1
      IF(JJ.LE.INRT)GO TO 26
      JJ = JJ-1
C
   30 DO 98 KOLUMN = 1,NKH
      TEST1=VH2OC(LAYER,KOLUMN)/BD(J)
      IK = 1
   32 IF(TEST1-GH2OC(IK))35,40,33
   33 IK = IK+1
      IF(IK.LE.MRT)GO TO 32
      IK = IK-1
C     SOIL CELL H20 LESS THAN TEST H20
   35 IF(IK.EQ.1)GO TO 40
C     CALCULATE SOIL STRENGTH
C      FOR VALUES OF BD LESS THAN TABLE VALUES
      IF(JJ.GT.1)GO TO 39
      RTIMPD(LAYER,KOLUMN)=TSTIMP(IK-1,JJ)-(TSTIMP(IK-1,JJ)-TSTIMP(IK,JJ
     .))*((TEST1-GH2OC(IK-1))/(GH2OC(IK)-GH2OC(IK-1)))

      GO TO 98
C      FOR VALUES OF BD AND H2O BETWEEN TABLE VALUES
   39 TEMP1=TSTIMP(IK,JJ-1)-(TSTIMP(IK,JJ-1)-TSTIMP(IK,JJ))*((TSTBD(IK,
     .JJ-1)-BD(J))/(TSTBD(IK,JJ-1)-TSTBD(IK,JJ)))
      TEMP2=TSTIMP(IK-1,JJ-1)-(TSTIMP(IK-1,JJ-1)-TSTIMP(IK-1,JJ))*((TSTB
     .D(IK-1,JJ-1)-BD(J))/(TSTBD(IK-1,JJ-1)-TSTBD(IK-1,JJ)))
C
      RTIMPD(LAYER,KOLUMN)=TEMP2+(TEMP1-TEMP2)*((TEST1-GH2OC(IK-1))/(GH2
     .OC(IK)-GH2OC(IK-1)))
      GO TO 98
C      FOR VALUES OF H2O LESS THAN OR EQUAL TO TABLE H2O
   40 RTIMPD(LAYER,KOLUMN)=TSTIMP(IK,JJ-1)-(TSTIMP(IK,JJ-1)-TSTIMP(IK,JJ
     .))*((TSTBD(IK,JJ-1)-BD(J))/(TSTBD(IK,JJ-1)-TSTBD(IK,JJ)))
C
   98 CONTINUE
   99 CONTINUE
C
      NKH = NKH+1
      DO 109 KOLUMN=NKH,NK
      NKK=NK+1-KOLUMN
      DO 108 LAYER = 1,NL
  108 RTIMPD(LAYER,KOLUMN)=RTIMPD(LAYER,NKK)
  109 CONTINUE
C
      RETURN
      END
```

```
      SUBROUTINE OUT(ARRAY,TTL1,TTL2,RANGE,UNITS,TOTAL,UNITST)
C   ************************************************************
C   *                                                          *
C   *   THIS SUBROUTINE PLOTS THE SOIL SLAB AND THE DENSITIES  *
C   *   OF THE ARRAY ELEMENTS IN EACH CELL.                    *
C   *                                                          *
C   ************************************************************
      INTEGER DAYNUM
      DIMENSION ARRAY(20,6), RANGE(11)
      DIMENSION TTL1(10), TTL2(10), UNITS(6), UNITST(4)
C
      COMMON /LIGHT / DAYLNG,DAYNUM,LATUDE,DAYTYM,NYTTYM,IDAY,IPRNT
      COMMON /PLOTS / NPN, NPP, NPR, NPW
      COMMON /LOCOUT/ KA(12),KHAR(20,6)
C
      DO 1 K=1, 6
      DO 1 L=1, 20
      ARAYLK = ARRAY(L,K)
      DO 2 I=1, 11
      RANGE1 = RANGE(I)
      IF(ARAYLK.LE.RANGE1) GO TO 1
  2   CONTINUE
      I = 12
  1   KHAR(L,K) = KA(I)
      RANGE1 = RANGE(1)
      WRITE(6,100) TTL1,DAYNUM,TTL2,UNITS,KA(1),RANGE1,RANGE1,KA(2),
     . RANGE(2)
 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)
      DO 14 L=1, 17, 2
      L1=L+1
 14   WRITE(6,102)L,(KHAR(L,K),K=1,6),L1,(KHAR(L+1,K),K=1,6),
     . RANGE((L+3)/2),KA((L+3)/2+1),RANGE((L+3)/2+1)
 102  FORMAT(1X,I2,3X,6A2 / 1X,I2,3X,6A2,7X,F8.4,' < ',
     .  A1,' <= ',F8.4)
      L19=19
      L20=20
      WRITE(6,104) L19,(KHAR(19,K),K=1,6),L20,(KHAR(20,K),K=1,6),
     . RANGE(11),KA(12),TOTAL,UNITST
 104  FORMAT(1X,I2,3X,6A2 / 1X,I2,3X,6A2,7X,F8.4,' < ', A1 //
     . 6X,'TOTAL = ',F11.4,1X,4A4)
      RETURN
      END
```

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	LATUDE	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.

```
C    CALL NITROGEN BUDGET SUB TO GET NSTRES, THE SUPPLY DEMAND RATIO FOR
C     NITROGEN (ANALOGOUS TO CSTRES)
C
      CALL NITRO
      LEAFWT=0.
      STEMWT=0.
      GLUMWT=0.
      GRANWT=0.
      XTRAC=0.
C
C    DISTRIBUTE DRY MATTER TO PLANT PARTS. CHANGE IN WEIGHT OF STEM =
C     POTENTIAL CHANGE IN WEIGHT * SUPPLY DEMAND RATIOS FOR CARBOHYDRATE
C     AND NITROGEN
C
      DO 400 I=1,NSTEMS
      IF(LEAF(I).LE.0) GO TO 340
      K=LEAF(I)
      DO 320 J=1,K
      IF(POWL(I,J).LE.0.) GO TO 300
C
C    ACCUMULATE LEAF AREA AND LEAF WT
C
      AREA=AREA+POWL(I,J)/WTF*CSTRSV*NV
      LEAFW(I,J)=LEAFW(I,J)+POWL(I,J)*CSTRSV*NV
      XTRAC=XTRAC+POWL(I,J)*CSTRSV*(1.-NV)
  300 LEAFWT=LEAFWT+LEAFW(I,J)
  320 CONTINUE
C
C    ACCUMULATE STEM WT
C
  340 STEMW(I)=STEMW(I)+PDSTEM(I)*RFWST*CSTRSV*NV
      XTRAC=XTRAC+PDSTEM(I)*RFWST*CSTRSV*(1.-NV)
      STEMWT=STEMWT+STEMW(I)
C
C    ACCUMULATE WEIGHT IN THE GLUMES
C
      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)
C
C    ACCUMULATE WEIGHT IN THE GRAIN
C
      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)
```

```
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.
 NORFOLK 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	-.4	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	7.4	-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	-13.0	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	273.8	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 ##############

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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
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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.

DACNT - 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.

DUMMYO - 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)
GRANCN - AVERAGE NITROGEN CONCENTRATION IN GRAIN
GRANN - TOTAL GRAIN NITROGEN (GRAMS)
GRANR1 - GRAIN NITROGEN REQUIREMENT FOR GROWTH (GRAMS)
GRANW - (I) TOTAL WEIGHT OF ALL GRAIN ON STEM I (GRAMS)
GRANWT - 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 - NUMPER 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.
VPO   - 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

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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              #######
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              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
SPOWL       SPOSTM      SPOGLM      SPOGRN      SPOWRT      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                      LEGEND
   1 2 3 4 5 6                          <=       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
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VOLUMETRIC WATER CONTENT OF SOIL                                      JULIAN DAY 263
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   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
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ROOTS IN EACH CELL, TOTAL                                             JULIAN DAY 263
    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   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
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PSIS FOR EACH LAYER AND COLUMN                                        JULIAN DAY 263
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   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
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```
         ROOTS IN EACH CELL, TOTAL                                 JULIAN DAY 288
             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 0 0
    2    8 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                       LEGEND
         1 2 3 4 5 6                              <= -15.0000
                                 -15.0000 < 0 <= -10.0000
    1    2 2 2 2 2 2
    2    6 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      SPDWPT      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   0.150E-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        STRSD        STRSN        WSTRSD         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                      LEGEND
1 2 3 4 5 6                            <=    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                     LEGEND
1 2 3 4 5 6                            <=    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                         LEGEND
1 2 3 4 5 6                            <=    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                          JULIAN DAY  75
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   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       PPLANT      RESP
0.378E-01   0.962E+02   0.100E+01   0.507E+00   0.178E+00   0.554E-01   0.000E+00
LEAFWT      STEMWT      GLUMWT      GRANWT      ROOTWT      SPN
0.179E+01   0.798E-02   0.000E+00   0.000E+00   0.147E+01   0.303E+01
SPOWL       SPOSTM      SPOGLM      SPOGRN      SPOWRT      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                      JULIAN DAY 120
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   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	0.860E+00	0.198E+00	0.639E-01	0.291E-01
LEAFWT	STEMWT	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	STEMN	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                   LEGEND
     1 2 3 4 5 6                        <=     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                  LEGEND
     1 2 3 4 5 6                        <=     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                                          JULIAN DAY 149
          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 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                                     JULIAN DAY 149
      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    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
     SPOWL       SPOSTM      SPOGLM      SPOGRN      SPOWRT      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                    LEGEND
     1 2 3 4 5 6                          <=    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                   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   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                       LEGEND
     1 2 3 4 5 6                          <=    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 <=     0.03
15   2 2 2 1 0 0
16   2 2 1 1 0 0              0.0300 < 8 <=     0.03
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 WEI
```

```
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              LEGEND
    1 2 3 4 5 6                   <=     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             LEGEND
    1 2 3 4 5 6                   <=     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                                JULIAN DAY 212
        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 =      0.6646   GM. DRY WEIGHT

    PSIS FOR EACH LAYER AND COLUMN                           JULIAN DAY 212
    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  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
```

CITATIONS

Baker, D. N., and R. B. Musgrave. 1964. Photosynthesis Under Field Conditions V. Further plant chamber studies of the effects of light on corn (Zea mays, L.). Crop Sci. 4:127-131.

Baker, D. N., J. D. Hesketh, and W. G. Duncan. 1972. The simulation of growth and yield in cotton: I. Gross photosynthesis, respiration and growth. Crop Sci. 12:431-435.

Baker, D. N., J. D. Hesketh, and R. E. C. Weaver. 1978a. Crop architecture in relation to yield. In Crop Physiology. ed. U. S. Gupta. Mohan Primlani, Oxford & IBH Co.

Baker, D. N., J. Parsons, C. J. Phene, J. R. Lambert, and J. M. McKinion. 1978b. SPAR data on the influence of environmental factors photosynthesis, respiration and growth rates in winter wheat. (unpublished).

Baker, D. N., J. A. Landivar, F. D. Whisler, V. R. Reddy. 1979b. Plant responses to environmental conditions and modeling plant development. Proc. Weather and Agriculture Symposium, Kansas City, MO. 1979. ed. Wayne Decker. pp. 69-109.

Baker, D. N., J. R. Lambert, and J. M. McKinion. 1982. GOSSYM. Clemson Agr. Exp. Sta. Bul. in press.

Boyer, J. S. 1970. Leaf enlargement and metabolic rates in corn, soybean, and sunflower at various leaf water potentials. Plant Physiol. 46:233-235.

Canvin, D. T. 1970. Summary: Losses in transformation in relation to the use of photosynthates for growth and maintenance of photosynthetic system. In Prediction and Measurement of Photosynthetic Productivity. J. Malek ed. Centre for Agricultural Publishing and Documentation, Wageningen. pp. 259-261.

Chollet, R., and W. L. Ogren. 1975. Regulation of photorespiration in C_3 and C_4 species. Bot. Rev. 41:137-179.

Duncan, W. G., R. S. Loomis, W. A. Williams, and R. Hanau. 1967. A model for simulating photosynthesis in plant communities. Hilgardia, J. Agric. Sci. 38:181-205.

Fisher, R. A. 1921. Ann. Applied Biol. 7;367-372. Cross reference Watson, D. J., 1952. The physiological basis of variation in yield. Adv. Agron. 4:101-45.

Friend, D. J. C., V. A. Nelson, and J. E. Fisher. 1962. Leaf growth in Marquis wheat, as regulated by temperature, light intensity, and daylength. Can. J. Bot. 40:1299-1311.

Fye, R. E., V. R. Reddy, and D. N. Baker. 1981. The validation of GOSSYM: Arizona conditions. In preparation.

Gregory, F. G. 1917. Physiological conditions in cucumber houses. Third Ann. Rep., Experiment and Research Station, Cheshunt, 19-28.

Holt, D. A., R. J. Bula, G. E. Miles, M. M. Schreiber, and R. M. Peart (1975) Environmental physiology, modeling and simulation of alfalfa growth. I. Conceptual development of SIMED. Purdue Agr. Exp. Sta. Res. Bul. 907.

Klepper, E. 1980. personal communication

Lambert, J. R., and D. N. Baker. 1981. RHIZOS: A Simulator of Row Crop Rhizospheres. South Carolina Agr. Exp. Sta. Bul. in process.

Lawlor, D. W. 1976. Water stress induced changes in photosynthesis, photorespiration, respiration and CO_2 compensation concentration of wheat. Photosynthetica 10:378-387.

Marani, A., D. N. Baker. 1981. Development of a predictive dynamic simulation model of growth and yield in Acala cotton. Science Report to U. S.- Israel Binational Foundation. April 30, 1981. 177 pp.

McKinion, J. M. 1980. Dynamic simulation: A positive feedback mechanism for experimental research in the biological sciences. Agr. Systems 5:239-250.

McWhorter, J. C., and B. P. Brooks. 1965. Climatological and solar radiation relationships. Bull. 715, Miss. Agr. Exp. Sta.

Monsi, M. and T. Saeki. 1953. Uber den lichtfaktor in den pflanzengesellschaften und seine bedeutung fur die stoffproduktion. Jap. J. Bot. 14:22-52.

Monteith, J. L. 1965. Light and crop production. Field Crop Abstracts. 18:213 - 219.

Moss, D. N., R. B. Musgrave, and E. R. Lemon. 1961. Photosynthesis Under Field Conditions III. Some effects of light carbon dioxide, temperature, and soil moisture on photosynthesis, respiration and transpiration of corn. Crop Sci. 1:83-87.

Murata, Y. 1961. Studies on the photosynthesis of rice plants and its culture significance. Bul. of the National Inst. of Agr. Sic. Series D. No. 9:1-170.

Nichiporovich, A. A. 1954. Photosynthesis and the theory of obtaining high crop yields. 15th Timiryazev Lecture 1-57.

Phene, C. J., D. N. Baker, J. R. Lambert, J. E. Parsons, J. M. McKinion. 1978. SPAR- A soil-plant-atmosphere-research system. Trans. ASAE. 21:24-30.

Ritchie, J. T. 1972. A model for predicting evapotranspiration from a row crop with incomplete cover. Water Resources Research 8:1204-1213.

Ross, J. 1969. Mathematical models of photosynthesis in a plant stand. In: Prediction and Measurement of Photosynthetic Productivity. Proc. IBP/PP Technical Meeting, Trebon, 29-45.

Sofield, I., L. T. Evans, and I. F. Wardlaw. 1974. The effects of temperature and light on grain filling in wheat. In Mechanisms of Ragulation of Plant Growth. R. L. Bielski, A. R. Ferguson, M. M. Cresswell eds. Bul 12, The Roy. Soc New Zeal., Wellington. 1974. pp. 909-915.

Smika, D. E., A. L. Black, D. N. Baker, W. O. Willis, and A. Bauer. 1978. Modelling the growth and grain yield of wheat. Abstract. in Proc. Workshop On Crop Simulation. Sponsored by Biological Systems Simulation Group. April 4 - 6, 1978. Clemson University.

Tooming, Kh. 1967. An approximate method of determining the attenuation and reflection of PHAR. In Nichiporovich (ed.)Photosynthesis of Productive Systems. Israel Program of Scientific Transl. Jerusalem.

Watson, D. J. 1947. Comparative physiological studies on the growth of field crops. I. Variation in net assimilation rate and leaf area between species and varieties, and within and between years. Ann. Bot. N. S. 22:37-54.

Whisler, F. D., J. R. Lambert, C. J. Phene, Parsons, J. E., and D. N. Baker. 1977. Cotton root growth, and water uptake with impedance limitations. Agron. Abs. 69:95.

Whisler, F. D., J. R. Lambert, and J. A. Landivar. 1981. Predicting tillage effects in cotton growth and yield. In "Predicting the Effect of Tillage on Soil-Plant Relationships." American Soc. of Agron. Special Pub. No. _ ed. Van Dorn and Unger. in press.

de Wit, C. T. 1965. Photosynthesis of leaf canopies. Agricultural Research Report 663. Inst. for Biol. and Chem. Resch. on Field Crops and Herbage. Wageningen.

YM-U2-04281: Winter Wheat: A Model for the Simulation of Growth
JSC-18229 and Yield in Winter Wheat

Distribution

Level 2*	
Project Managers*	
D. Baker	(25)
A. Black	(5)
A. Bauer	(5)
W. Willis	(5)
D. Smika	(5)
J. L. Rogers	
F. Barrett	
SH3/Documentation	(2)
CASPAN	(5)

*Abstract only