

THESIS





This is to certify that the

dissertation entitled

INTERCROPPED TOMATO AND SNAP BEAN: A COMPUTER MODEL

presented by

Ian Bruce McLean

has been accepted towards fulfillment of the requirements for

Ph.D. degree in Horticulture

ell Major profe

Date August 7, 1981

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0-12771



INTERCROPPED TOMATO AND SNAP BEAN:

A COMPUTER MODEL

By

Ian Bruce McLean

A DISSERTATION

Submitted to Michigan State University in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

Department of Horticulture

ABSTRACT

INTERCROPPED TOMATO AND SNAP BEAN: A COMPUTER MODEL

By

Ian Bruce McLean

A dynamic simulation model of intercropped tomato (<u>Lycopersicon</u> <u>esculentum</u> cv. PikRed) and snap bean (<u>Phaseolus vulgaris</u> cv. Bush Blue Lake) is presented. Beans are planted in a matrix of hexagonal rows with a tomato transplanted centrally in each hexagon. Model inputs are real weather data and shadow lengths. Carbon fixation and respiration rates for each species are computed, and photosynthate is partitioned to plant components. Canopy growth and above-ground inter- and intraspecific competition is modeled. Tomato-tomato distance is varied from 0.8 to 1.2 m, and bean-bean distance from 0.05 to 0.15 m. Bean planting date is also varied. By repeated simulations the model predicts the combinations of these three variables which optimize individual and combined species yields. Field validation experiments confirmed the predicted optimum combinations of 0.8 m tomato-tomato and 0.05 m beanbean distances with the earliest bean planting for maximum total yield.

ACKNOWLEDGMENTS

Deep appreciation is felt for my wife, Elly, and children James, Stephanie, Heather and Erica. Their unbounded support and patience have been essential for the successful completion of this degree.

Dr. H. Paul Rasmussen served as my adviser for the M.S. and for all but the last six months of the Ph.D., and has my deep affection and gratitude. Dr. John F. Kelly graciously accompanied me through to completion as committee chairman. The interest and assistance of my committee was also appreciated, especially that of Dr. Brian Croft who contributed vitally to the generation of the dissertation problem.

Bonna Davis provided invaluable assistance in typing the draft and final dissertation. Her kindness and long hours of work were critical for its timely completion.

Financial support from Title XII funds and the People of the State of Michigan has enabled me to attend Michigan State University. I am deeply appreciative of this honor, and will strive to return some of this goodness to the communities in which I will live.

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INTRODUCTION

Multiple cropping is practiced by millions of smallholders¹ throughout tropical and subtropical Africa, Asia and Latin America. These farmers have been largely neglected by agricultural researchers aiming at increased food production. Concern has been primarily with the minority capable of incorporating segments of Western technology and achieving rapid gains dependent upon large inputs (49, 60).

Growing recognition of the widespread practice of multiple cropping throughout the tropics has led to increased research into its principles (124, 125). This dissertation is an extension of that process.

Intercropping research has focused on two main areas: first, the relative yields and competitive strengths of component species grown as intercrops and as monocultures, and second, the environmental changes occurring within the intercropped planting (46).

Classical plant competition research methods do not readily lend themselves to investigation of individual inputs into an ecosystem. A simulation model may be especially useful in testing effects of variables such as solar radiation and light utilization efficiency. Numerous simulations may be quickly and economically made while holding all but one variable constant.

¹More than 90% of all tropical farms are of less than 5 ha in area (49). Diverse traditional farming systems exist on these farms. Smallholder refers to a member of this large group of traditional farmers on small land holdings.

A simulation model of intercropped tomato (<u>Lycopersicon</u> <u>esculentum</u>) and snap bean (<u>Phaseolus vulgaris</u>) is the basis for this investigation into the effects of environmental inputs and plant spacings. This is a unique approach to the study of intercropping. Plant models for crops in monoculture have been published (9,30, 41, 53 93), but there is no published model of systematically intercropped agronomic or horticultural crops. It is intended that this model of two intercropped vegetables will provide new insight into this complex ecosystem.

The initial conceptualization of the model was performed in 1979 by a student group working on a class project for Systems Science 843 at Michigan State University (26). The model was proposed by this author. Crop growth simulation by this model failed after several days and no results were obtained. The model which forms the basis of this dissertation is conceptually derived from this first attempt by the group. The valuable assistance rendered by that initial modeling effort is gratefully acknowledged.

GENERAL LITERATURE REVIEW

A. MULTIPLE CROPPING

1. Definitions

Multiple cropping refers to the growing of mixed crops simultaneously, sole crops in sequence, or mixed and sole crops sequentially, on a unit land area per farming year² (6).

Two major groupings of multiple cropping patterns exist (6):

a. <u>Sequential cropping</u>. Two or more sole crops grow sequentially on the same field per year. No intercrop competition occurs, and the farmer manages one crop at a time on that field. Double, triple, quadruple and ratoon cropping are practiced.

b. <u>Intercropping</u>. Two or more crops grow simultaneously on the same field during all or part of their growth period. Intercrop competition occurs during all or part of crop growth, and the farmer manages more than one crop at a time in that field. Mixed, row, strip and relay intercropping is practiced.

2. Distribution and Characteristics

Multiple cropping is an important part of traditional farming systems throughout tropical and sub-tropical Africa, Asia and Latin

²The farming year is 12 months unless aridity restricts cropping to 24 month cycles.

America. Millions of smallholders use complex cropping patterns developed through empirical experimentation (49, 60).

The high cropping intensity achieved by multiple cropping is dependent upon, or associated with, several factors (11, 49, 60).

a. Adequate water from precipitation and/or irrigation.

b. A long growing season.

c. Suitable soil conditions.

- d. Small farm size.
- e. High marketing costs.
- f. Spreading of peak labor demands.
- g. Low level of mechanization and high labor inputs.

Several benefits are derived from multiple cropping. Most important is the potential for greater total crop yield due to optimum utilization of growth resources (11, 124). Instances of substantially higher yields from sequential and intercrop patterns have been reported (7, 23, 88, 91, 126).

Associated with the possible yield advantage is "harvest insurance." If one crop fails due to climatic or other causes, the remaining crop(s) may partially compensate by producing at least some yield. Harwood <u>et al.</u>, (49) suggest that the failing crop will already have impaired the yield of any intercrop, and that harvest insurance is an an argument for crop diversification rather than multiple cropping. Nevertheless, it is commonly mentioned in the literature as a benefit (6).

Multiple cropping may allow more effective use of family labor. Peak labor demands may be smoothed out and higher labor productivity obtained (60). Family labor may be a readily available input which multiple cropping most effectively utilizes. Pest control in multiple cropping is especially complex. Weeds may be inhibited by the more competitive community and dense canopy of intercropped species (39, 124). However, insect and disease control is not necessarily enhanced. Instances of better control have been reported (22, 74). But poorer control has also occurred, especially in uninterrupted sequential cropping of rice (74). Integrated pest management in multiple cropping requires a planned diversity of control methods. Crop rotation, crop diversity, resistant genotypes, modified plant spatial arrangements, and judicious pesticide use where economically feasible are some control components (74, 99).

3. Multiple Cropping Examples

Multiple cropping patterns frequently involve a main crop intercropped with, or followed sequentially by, a legume or vegetable. Examples of the former are maize (Zea mays), sorghum (Sorghum spp.) or millet (Panicum miliaceum) intercropped with bean (Phaseolus vulgaris), ground nut (Arachis hypogaea), pigeon pea (Cajanus cajan), cowpea (Vigna unguiculata) or soybean (Glycine max) (2,4,10,23,84,90,100).

Examples of sequential cropping involving a cereal are rice (<u>Oryza sativa</u>) followed by rice and/or sweet potato (<u>Ipomea batata</u>), potato (<u>Solanum tuberosum</u>), maize (<u>Zea mays</u>), tobacco (<u>Nicotiana</u> <u>tabacum</u>), soybean (<u>Glycine max</u>), or vegetables (cucurbits, solonaceous species, cole crops, legumes, etc.) (7).

Wide diversity occurs in the number and types of crops which are combined, including numerous combinations not mentioned above. For example, variation in cultivar characteristics such as plant height and days to maturity may be exploited. Many patterns may even occur within

a village. For example, about 60 different combinations were identified in a single village in India (60). Multiple cropping systems are as diverse as the cultures and geographic areas from which they have arisen.

4. Experimental Designs and Statistical Analysis

Compact experimental designs are required for intercropped plant population studies. The large number of crop spacing combinations quickly make experiments large. Several compact designs are used.

> a. Fan designs in which the plant position grid is formed by the intersection of concentric circles and the equally spaced radii of the circles. Various forms emphasize changing shape or area occupied at each grid point. Methods for statistical analysis of the results are available (14,87). Willey (125) noted that fan harvest areas are particularly small, and that results from the fan may not be typical of comparable situations in conventional row designs. Therefore, he suggested a modified fan to allow row planting. Huxley, <u>et al</u>., (58) suggested methods for interpreting the yield/population curves derived from fan designs.

> b. A 2-way grid, non-systematic design which introduces randomization and permits conventional analysis of variance techniques (73).

5. Interpretation of Yield Data

The analysis of intercropping experiments has been addressed by several authors (85,86,94,125,127). These analyses generally attempt separation of the competitive abilities of the intercropped species.

The overall performance of intercropping patterns commonly has been expressed as Land Equivalent Ratio (LER). LER is defined as "the relative land area under sole crops that is required to produce the yields achieved in intercropping", given the same level of management in both situations (124). For example, an LER = 1.10 indicates that 10% more land under sole crops would be required to produce the intercropped yield.

6. Recent Research Trends

Monoculture associated with advanced mechanization has predominated in 20th century Western agriculture. This has led to the early rejection of multiple cropping by Western-trained agriculturists as primitive and inefficient. It was assumed that as modern, Western agricultural practices were explained to traditional farmers, there would be a natural adoption of these practices and multiple cropping would decline (124). This assumption has succumbed to the continued, widespread practice of multiple cropping in spite of efforts to promote monoculture among subsistence farmers (89).

Increasing recognition of multiple cropping has been reported in several reviews and books during the last decade (7,24,48,60,71,68,69, 70,92,106,124,125). These include descriptions of multiple cropping methodology in various cultures and geographic areas.

Recent research by agronomists has focused on population levels, genotype selection, pest management, nutrient and water uptake, and light interception as they influence yield (3,5,39,75,91,99,110,122,126).

7. Farming Systems Research

Cropping systems are enmeshed in the societies of which they form a part. Recent emphasis on this fact has led to the development of

farming systems research (FSR). FSR seeks to "increase the productivity of the farming system in the context of the entire range of private and societal goals, given the constraints and potentials of the existing farming system" (38). Interdisciplinary FSR is currently a major component of programs at the International Rice Research Institute and the International Crops Research Institute for the Semi-Arid Tropics (66,134). FSR methodology is especially suited to the study of multiple cropping and other traditional farming methods (89,135). Its further incorporation into smallholder research will reduce the incidence of proposed technological packages which are unsuited to the socio-economic milieu of the traditional farm and village (34,89).

B. PLANT COMPETITION

Plant competition is a vital component of agronomy, ecology, horticulture and weed science. It is central to research into intercropping principles.

The classical plant competition definition is that of F. E. Clements in 1929, as cited by Hall (43).

Competition is purely a physical process. With few exceptions, such as the crowding of tuberous plants when grown too closely, an actual struggle between competing plants never occurs. Competition arises from the reaction of one plant upon the physical factors about it and the effect of the modified factors upon its competitors. In the exact sense, two plants do not compete with each other as long as the water content, the nutrient material, the light and the heat are in excess of the needs of both. When the immediate supply of a single necessary factor falls below the combined demands of the plants competition begins. Interference by one plant upon another may include allelopathy. Rice (102) defined allelopathy as

> ...any direct or indirect harmful effect by one plant (including microorganisms) on another through the production of chemical compounds that escape into the environment.

Interference is the sum of competition and allelopathy.

Attention was focused on plant competition research methodology in the 1950s through early 1970s. Several publications reviewed competition principles, research practices and mathematical models (13,28 29,46,47,82,107,128,129). Trenbath (118,119) reviewed plant interactions in mixed communities. A series of papers by Kira and associates dealt with intraspecific competition and density-yield relationships of several crops (54,55,62,63,64,65,133).

1. Plant Competition Research Methodology

Mathematical models of varying complexity are used to quantify plant competition.

a. <u>Yield</u>. Total yield as the plant population is varied is used widely in agriculture to establish optimal planting rates. Associated with this is the quantitative analysis of plant growth and yield components (46,104).

b. <u>Environmental change from increased plant density</u>. Light, water and nutrient level changes due to increased plant density have been studied extensively in agriculture (46). These factors are critical for crop growth and most commonly are affected by population increases.

c. <u>Plant weight</u>. Three measures of plant weight are used (79). First, the coefficient of variation of plant weight

may increase with time at high densities. Second, the frequency distribution of individual weights in a plant population may change from "bell-shaped" to "L-shaped" during growth. Third, the correlation between a plant's weight and the weights of neighboring plants may indicate cooperative or competitive situations.

d. <u>Mixture diallel</u>. The diallel design is used by geneticists and agronomists to compare the relative performance of a number of species or genotypes (86). Adaptations of this design to competition studies are available (45,86,101, 127).

e. <u>Replacement series and derived functions</u>. The replacement series technique originated by de Wit (128) and expanded by de Wit <u>et al.</u>, and Hall (43), (132) is widely used in plant competition research (124). Two or more species are grown together in different proportions and in monoculture. The two species' yields are represented on two Y axes, and their relative population proportions on the intersecting X axis. Lines join yield levels at component portions from 0 to 100% of the total population. Interpretation of the resultant diagram places the interspecific relationship in one of three broad categories: mutual cooperation, mutual inhibition, or compensation. Functions developed by de Wit and associates assist in competition analysis (128). The relative reproductive rate of two or more annuals is the ratio of number of seeds sown to number of seeds harvested. The relative replacement rate is derived by resowing seeds of both species previously harvested from monocultures and mixtures and is closely related to the relative reproductive rate. The relative crowding coefficient measures the activity of a species when crowding another species for space.

f. Lotka-Volterra equations and Land Equivalent Ratio. A theoretical explanation of LER > 1 using the classical Lotka-Volterra equations describing two interacting populations was reported (121). Vandermeer (121) showed that for LER to exceed 1 the mutual interference of the two species must be sufficiently weak. He also showed that LER is mathematically identical to the competitive exclusion principle of theoretical ecology.

2. Future Research Needs

Incorporation of the above principles into multiple cropping research must be expanded. Presently there are few instances of the use

of ecological principles and research methods in the applied multiple cropping literature. Willey (124,125) clearly outlined their potential applications. A fertile research area awaits workers capable of bridging the two fields.

C. THE SYSTEMS APPROACH AND MODELING

The reductionist approach to scientific research reduces phenomena to their basic parts. Independence of the parts is requisite. Reductionism leads to the fragmentation and proliferation of disciplines which remain essentially isolated.

The expansionist approach assumes that all entities and phenomena are parts of greater wholes. Interdependence of objects and events is declared. Holistic, interdisciplinary team research is integral to expansionism (27). The systems approach is formalized expansionism.

1. Definitions

De Michelle (81) defined a system as

...an assemblage of objects united by some form of regular interaction or interdependence. It is an identifiable portion of the real world about which we can construct a boundary. Through this boundary we monitor or control all inputs and outputs.

An ecosystem has living organisms as some of its objects (113). An agro-ecosystem adds stricter control over the ecosystem boundary and its inputs and outputs (78).

A model of some sort is essential to systems study. The model is a "set of hypotheses about the system cast in the form of a set of mathematical equations" (81). Systems simulation is problem solving

using a dynamic model over time (8).

Two types of models are identified (81).

a. <u>Descriptive</u> (<u>from observed responses</u>). Responses are recalled from similar past circumstances. Curves are fitted to experimental data and used predictively. Nothing new is learned about the system.

b. <u>Mechanistic</u> (<u>from fundamental concepts</u>). A set of equations describe hypotheses about events occurring within the system. New insights into system behavior are sought.

Models may initially be descriptive, and become increasingly mechanistic through refinement.

2. Reasons for Agricultural Simulation

Several benefits are derived from the modeling process itself,

and from crop simulation (8,15,81,96).

- a. Insight may be gained into a system whose component interactions are too numerous and complex to be comprehended otherwise.
- b. Interdisciplinary coordination of research efforts may reveal and remedy information lacunae. New knowledge from this research may be stored and used in the model.
- c. New hypotheses may be generated and tested.
- d. New knowledge may be gained from the model since the system is more than its isolated parts.
- e. Agricultural management systems may be optimized.
- f. Agricultural problems may be examined which otherwise are intractable due to time, cost or disruption constraints.

3. Crop Modeling Applications

a. Historical view. Pioneering work in crop modeling in the 1960s was by de Wit at Wageningen, Duncan at the Universities of Kentucky and Florida, and Stapleton at the University of Arizona (81,114) During the last decade plant modeling groups have been active at the Agricultural University at Wageningen (Netherlands), the Glasshouse Crops Research Institute (Littlehampton, England), Mississippi State University, Ohio Agricultural Research and Development Center, Purdue University and University of California (Berkeley). Several books and reviews specifically addressed to crop modeling have been published (8,25,31,77,116,131). Two journals, Agricultural Systems and Agro-Ecosystems, are devoted exclusively to extensive agricultural systems and modeling articles. A number of other journals publish plant models.

b. <u>Examples of plant models</u>. A model-building prerequisite is the establishment of its operational level. The model's goals largely establish its resolution. Plant models exist with levels ranging from enzyme kinetics and gas diffusion, to the whole plant (9,76).

(1) Plant physiological processes.

Models exist for light interception, photosynthesis, respiration, evapotranspiration and partitioning of carbohydrate (1,21,35, 50,56,76,108,116,120,131). No attempts to simulate plant hormone control have been published.

(2) Organ level.

The growth of several plant organs has been modeled. These include leaves, roots and flowers (18,19,20,37). To date, no model has been published of fruit growth per se.

(3) Whole plant level.

Whole plant models for several species now exist. The first whole plant model was of cotton, and models of this species have continued to be developed (41,114) Models of other economic species include alfalfa, apple, maize, ryegrass, soybean, sugar beet, tomato, and a management model for asparagus (9,30,32,53,57,71,80,93,109,117).

Modeling has been utilized heavily in pest management research and plant models have been required for plant-herbivore models. An example is the cotton-herbivore interaction (123).

MATERIALS AND METHODS

A. SPECIES SELECTION

1. Criteria

Vegetables form an integral part of intercropping systems in the tropics (92). However, the bulk of intercropping research has been with agronomic crops. Two vegetables were selected for this study to increase knowledge about vegetable intercropping.

The first criterion for species selection was wide adaptation throughout temperate to tropical zones. Availability of a comprehensive literature was required for both species. The two canopies were to combine readily into a cropping pattern. Tomato (Lycopersicon esculentum) was selected to be intercropped with either pea (Pisum sativum), snap bean (Phaseolus vulgaris), or cabbage (Brassica oleracea var. capitata).

2. Preliminary Field Experiment

Preliminary experiments were carried out at the Michigan State University Horticulture Research Center in 1978 and 1979 to assist intercrop species selection. On May 2, 1978, cabbage plants (cv. Market Victor) were transplanted .46 m apart, and peas (cv. Lincoln) direct-seeded .05 m apart, in 1.5 m rows which were 7.6 m long. Bush snap beans (cv. Bush Blue Lake) were direct-seeded .05 m apart in similar rows on May 29. On the same day, low lying determinate hybrid tomato plants (cv. PikRed) were transplanted .76 m apart in rows

exactly centered between the cabbage, bean and pea rows. A tomato row was also planted without any intercrop. Monocultures of each intercropped species were also grown at the end of the plot in .76 m rows at the same density within the row as above. The treatments were replicated four times. Prior to planting, 64 kg/ha of 5-20-20 fertilizer was added to the Capac loam soil, and the field was sprayed with Treflan. The tomatoes were side-dressed on July 19 with 9 kg/ha of N. The experiment was repeated on essentially the same dates in 1979.

Harvest was performed by hand, and the cabbage, bean and pea plants were removed from the field after harvest. The results of this preliminary experiment are presented in Appendix A.

The three intercropped species affected the tomato yields differently, due partly to their different planting dates and growth stages at planting (transplant or seed). These differences influenced their relative competitive effect on the tomato plants. The beans had the least deleterious effect on tomato yields in 1978. The 1979 results were less conclusive due to a latent infestation of quackgrass (<u>Agropyron repens</u>). Due to these results and the excellent literature available for <u>Phaseolus vulgaris</u>, this species was selected to be intercropped with tomato. Bean cv. 'Bush Blue Lake' was especially suitable due to its short harvest period.

B. INTERCROP PLANTING DESIGN

Hexagonal bean rows with single tomato plants located centrally in the hexagon form the planting design (Figure 1). Each hexagon side with its adjacent tomato plants may be considered a segment of a straight row.

Figure 1. Hexagonal planting design with bean rows placed between equidistant tomato plants.



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Hexagon symmetry allows simplification of the model. All tomato plants are equidistant and effectively separated by the dense bean canopy. They are assumed to be identical and non-competing with each other. This assumption is maintained after bean plant removal following bean harvest. The tomato plants are sufficiently separated to have little competitive effect. All tomato plants in the field are, therefore, represented by one plant in the model.

All bean plants are similarly located with respect to the tomato plants. The bean plant at position <u>a</u> in Figure 2 is approximately 15% further from the tomato plants than that at position <u>b</u>. Also, it is adjacent to three tomato plants rather than two. However, it is assumed that bean plants located at position <u>b</u> are representative of all bean plants in the field.

The hexagons form convenient experimental units and pack perfectly in a matrix. The tomato plant yield is entirely allocated to its enclosing hexagon. The associated bean yield is divided equally between the two hexagons whose boundary it forms.

The model allows for a range of tomato-tomato distances. This distance automatically sets the hexagon width, circumference and area. The bean-bean distance within the row may also be adjusted. These two parameters (tomato-tomato and bean-bean distances) define the component and total plant populations.

Hexagonal planting patterns were used previously in plant competition research (47,63,81). Single plants located at hexagon corners were surrounded by various mixtures of their own and other species. Hexagonal planting patterns are recommended in the biodynamic/French intensive organic farming technique (59).

Figure 2. System diagram of MULTICROP



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C. MODEL CONDITIONS

1. System Boundary³

The system is located in the field with the upper boundary 2 m above the crop. The lower boundary is .3 m below the soil surface.

2. Driving Variables

The model driving variables are exogenous weather inputs. Solar radiation data in langleys was recorded hourly by a pyranometer and strip chart recorder located approximately 2 miles from the Horticulture Research Center. These data were accumulated and punched onto computer cards by the Agricultural Engineering Department. A permanent magnetic tape file of solar radiation data was created for the period May 20 to September 30 in 1968-1970, and is accessed by the model. No solar radiation data exist for Lansing for the 1980 summer due to failure of the above instrument. The simulations are, therefore, run using the above years' data. The weather of 1970 is most similar to that of 1980.

Temperature (°F), windspeed (knots) and relative humidity data were recorded at Lansing airport and obtained from the National Weather Service via the Michigan Department of Agriculture Weather Service. A program was written to read these tapes and create a permanent file accessed by the model. These data are for 3 hour blocks.

Rain (inch) data were obtained from Local Climatological Data, U.S. Department of Commerce, for Lansing, Michigan. A permanent file of these data is read by the model at 0100 hr daily and the full

³For a glossary of modeling terms see Appendix B.

precipitation for that day is assumed to have been received.

Shadow lengths specific for 42° latitude, month, day and hour were obtained from the U.S. Forest Service (44) and are read into an array in the main program.

3. Initial Plant Description in the Model

At simulation commencement the tomato plants are represented as transplants planted 21 days previously with canopies .2 m in diameter. The bean plant canopies are .1 m in diameter after 7-10 days growth following seeding in the field. The tomato plant growing season commences on June 23 and terminates on September 11 after 81 days. The bean plant season is 52 days long and may commence on or after day 1 of the tomato plant season.

4. Variables for Testing

The primary aim of the model is to predict optimum planting distances and relative planting dates for the two species to ensure maximum yield. The model satisfactorily allows hexagon widths as low as .5 m and bean-bean distances of .02 m. No upper limits are defined, so isolated plants of both species may be modeled.

In the model the tomato commencement date is fixed. The bean commencement date may be retarded as late as July 22. In this way the competitive effect of the bean canopy on the tomato plant may be varied.

The model may be driven with any weather data which is in the required form. Weather data from three quite different years were selected to test the model's response to its exogenous driving variables. Summaries from National Weather Service data for these three

years are presented in Appendix C.

D. MODEL DESCRIPTION

1. Overview

The model consists of state, rate and driving variables, and constants. Driving variables supply exogenous data which are used to compute rates of carbohydrate production, loss and translocation, etc. State variables are updated by the rate variables and their values are retained for the iteration. This process is repeated on a 1 hr timestep throughout the growing season, resulting in 1944 iterations per simulation. A conceptual diagram of the model, named MULTICROP, appears in Figure 2.

The model structure consists of a main program with 7 subroutines. The main program controls the simulation. Each subroutine is a submodel which performs a segment of the simulation.

The model language is FORTRAN 4 adapted for use on the Cyber 750 computer at Michigan State University. Program execution time is approximately 2.2 seconds per 81 day simulation. The program was written by the author and is intended for interactive operation. A complete listing of the program appears in Appendix D.

2. Main Program (Program DRIVER)

The main program is in 3 sections (Figure 3).

a. Information is passed between DRIVER and the subroutines in COMMON. Storage arrays for variable values to be printed following the simulation are established. Data for shadow lengths are read into an array. Initial values for beanbean and tomato-tomato distances, bean commencement and



Figure 3. System diagram of PROGRAM DRIVER

harvest dates, and the print type are set. The operator is asked for any changes to these initial values.

Four print types are available. The operator may request printing of variable values stored daily at 1200 and 2400 hr, daily at 2400 hr only, final variable values only, or final yield values only.

b. The simulation is controlled by a single DO loop.
Counters for day and hour are advanced and subroutines are
called. The correct sequencing of operations within and
between subroutines is paramount.

c. Upon completion of the simulation the program exits the DO loop and prints as previously defined. The operator is asked to specify printing at the terminal or disposal to a printer. Following printing, the program requests instruction for futher simulations, or termination.

3. Weather Data (Subroutine WEATHER)

This subroutine reads 3 weather files which are attached prior to program execution (Figure 4). Data are read daily and stored for use throughout each of the following 24 hr. No unit conversions are made. The subroutine is called only at 0100 hr.

4. Evapotranspiration and Soil Water (Subroutine WATER)

All weather inputs are adjusted to their correct units in this subroutine. Those not used here are accessed elsewhere through COMMON (Figure 5).

The evapotranspiration, soil water and leaf water potential



Figure 4. System diagram of Subroutine WEATHER

Figure 5. System diagram of Subroutine WATER



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sections of this subroutine are adapted from subroutine WATER in SOYMOD/OARDC (82). This model is a dynamic simulation of soybean (<u>Glycine max</u>) growth, development and seed yield. Modifications have been made to adapt the logic to the requirements and variable of MULTICROP. However, the section remains essentially the same as subroutine WATER in SOYMOD/OARDC.

The evapotranspiration rate is computed using a modified Penman equation after Monteith (85) (Figure 6). Atmospheric diffusion resistance is assumed to be a function of wind velocity above the canopy (130).

ATMDRES = 8.28 / WINDSPD

where:

WINDSPD = wind speed m s^{-1}

The canopy diffusion resistance utilizes stomatal diffusion resistance and leaf area index (LAI). Stomatal diffusion resistance is assumed to be the same for both crops. It is computed by a function derived from bean (<u>Phaseolus vulgaris</u>) data (105), and is solely dependent upon temperature. Canopy diffusion resistance is then computed from stomatal diffusion resistance divided by the total leaf area per unit ground area (2 LAI) (12). The LAI used is for tomato both prior to and after bean growth. During bean growth the LAI used is for bean because of the relative spatial dominance of the bean canopy.

The evapotranspiration function assumes a closed canopy and no soil surface evaporation. This is a shortcoming of this subroutine, particularly early in the season and in the absence of the bean canopy. ((DELTA x 1.5 x PAR) + (290. x (VAPSAT - ATMDRES) x 10^{-6} EVAPOTN = --

(DELTA + GAMMA x (1. + CANDRES / ATMDRES)) x 585.

where:

= photosynthetically active radiation incident at the top of the canopy erg $\,\rm cm^{-2}~s^{-1}$ bar VAPSAT = saturated vapor pressure at current temperature ATMDRES = atmospheric diffusion resistance s cm⁻¹ _1 CANDRES = canopy diffusion resistance s cm = (.0712 - .0004596 x TEMP) x VAPSAT EVAPOTN = evapotranspiration rate m hr^{-1} VAPTEMP = actual vapor pressure bar = temperature C = constant mbar DELTA GAMMA TEMP PAR

Figure 6. Evapotranspiration function after Monteith (85).

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Following computation of evapotranspiration, the soil water content is updated. Inputs are rain and irrigation, and the output is evapotranspiration. No irrigation is involved in the simulation but the capacity to use it is there. The model does not allow for surface runoff or losses to the water table.

The soil volume modeled is a cone directly under a bean or tomato plant selected according to the same criteria as was LAI. The cone depth is set at .3 m which was the maximum effective depth of the root systems on the Capac loam. A heavy clay layer prevented deeper root penetration (Figure 7) (112). The cone radius was assumed to be the tomato radius, or the bean radius in the direction perpendicular to the row.

Soil water potential is computed from soil water content and bulk density.

SWPOT = $42.61 \times e^{(-15.27 \times SWC/SOILBD)}$

where:

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SOILBD = soil bulk density g cm<sup>-3</sup>
SWC = volumetric soil water content
SWPOT = soil water potential bar
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This function is for Wooster silt loam and is derived from data by Brady <u>et al</u>. (16). It is an approximation for the Capac loam. Leaf water potential is computed from soil water potential.

LFWPOTL = $2.61 \times e^{(.161 \times \text{SWPOT})}$

where:

LFWPOTL = leaf water potential bar

This function is for soybean (<u>Glycine max</u>) and is an approximation for the two crops modeled here.



Figure 7. Soil profile of the somewhat poorly drained Capac loam.

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The final step in WATER is to store variables for printing. The 1200 hr and 2400 hr values are placed into arrays through COMMON and are later printed as a block. All following subroutines act identically.

5. Photosynthesis and Respiration (Subroutine PHOTO)

This subroutine computes bean and tomato plant net photosynthetic rates in full sun and 60% shade. Photosynthate produced in grams of glucose for each species is the subroutine output (Figure 8).

Dark respiration rates for the canopies of both species are calculated according to the method of Acock <u>et al.</u>, (1) (Figure 9). The function is used identically for both species. Different respiration rates arise because of their different LAI. The equation integrates respiration over the entire leaf area of the canopy. A deficiency of this model is that the rate is unaffected by diurnal light changes. However, the average light flux density at the top of the canopy over the most recent 7 days indicates recent photosynthetic history and is used to modify respiration rate.

Stem, root and fruit respiration is assumed to be 1/3 of leaf respiration. Acock <u>et al.</u>, found this to be a fair approximation (1).

The total plant respiration is adjusted for temperature with $Q_{10} = 2$, and optimum temperature set at 25 C (53).

Photosynthetic rates for both species are calculated according to the same Acock, <u>et al</u>. model (1). The canopy photosynthetic rate function is shown in Figure 10. The function is the same for both species.



Figure 8. System diagram of Subroutine PHOTO

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Tomato leaf respiration rate integrated over the whole canopy (after Acock et al., 1978). Figure 9.

$$TPARTI = ((1, - TTRANS) \times TUTILIZ \times ENERCY) + (TA \times AVENRCY \times CO_2)$$

$$TPART2 = TB \times TUTILIZ \times ENERCY \times AVENRCY \times TEXCOEF$$

$$TPART3 = (TA \times CO_2)/(TB \times TEXCOEF)$$

$$TPART4 = EXP(-TEXCOEF \times TLAI)$$

$$TPART4 = EXP(-TEXCOEF \times TLAI)$$

$$TPNRATE = \left[TPART3 \times 1n \left[TPART2 = TPART1 \right] \times RATIOE \times RATIOM - (TRESP \times RATIOM) - (TAM \times RATIOM) - (TRESP \times RATIOM) - (TAM \times TRESOF + TRESOF + RATIOM) - (TAM \times TRESOF + TRE$$

Figure 10. Tomato photosynthetic rate integrated over the whole canopy (after Acock et al., 1978)

= tomato total dark respiration rate per unit ground area mg CO₂ m⁻² s⁻¹ = tomato leaf transmission confination

TUTILIZ = tomato leaf light utilization efficiency mg CO_2 J⁻¹

= tomato leaf transmission coefficient

TTRANS TRESP

The photosynthetic rate function integrates single leaf responses over the entire canopy. Light attenuation through the canopy, and changes in leaf conductance to CO₂ transfer and dark respiration rate with depth in the canopy, are included (the latter in the leaf respiration function).

Photorespiration is not separately identified in the rate but is inherent in the light utilization coefficient. Dark respiration is subtracted from the gross rate. The photosynthetic rate therefore becomes negative when the solar radiation level is low or zero.

The use of the same respiration and photosynthesis functions for both species is reasonable due to their similar maximum net photosynthetic rates. Differences in species yield, canopy size, growth rates, etc., arise in the model from different carbohydrate partitioning strategies.

Three functions modify the photosynthetic rate. Functions describing the effect of temperature and leaf water potential are used to scale photosynthetic rate. The temperature function is derived from data of Kuiper (67).

RATIOT = .858 + .139 TEMP - .0026 (TEMP)²

where:

RATIOT = adjustment to photosynthetic rate due
 to temperature differences from the
 optimum

The value of RATIOT ranges between 1. and 0., with the optimum value of 1. at 26.5 C.

The leaf water potential function is derived from data of Brix (17).

RATIOP =
$$3.75 - 3.3 \log (LFWPOTL)$$

where:

The value of RATIOP ranges from 1. to 0., with the optimum value of 1. when LFWPOTL is less than 6.9 bar. When LFWPOTL reaches 14.5, RATIOP is .001.

Photosynthetic rate is scaled down by the lesser of these two ratios before respiration is subtracted. The same ratio is used for both species.

The third function is a maturity factor used only on tomato photosynthesis. This function scales down tomato photosynthetic rate after 50 simulation days (Figure 11).

 $RATIOM = 4.30 - 1.94 \log (DAY)$

where:

DAY = simulation days

This function is an approximation derived from field observations of the gross deterioration of the canopy. This was seen as senescence of the lower leaves, and fungal pathogen damage.

A second photosynthetic rate (STPNRATE) is computed using a solar radiation (ENERGY) value for 60% shade. The function is exactly the same as that described above. ENERGY is reduced to .4 times the input value from subroutine WEATHER. STPNRATE is used in photosynthate computations described below.

The above-ground interspecific and intraspecific competition is modeled by applying shading to the two species canopies. Donald (28), stated that light may be the only factor for which there is



Figure 11. Tomato photosynthetic rate maturity function.

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competition in crop situations with sufficient fertilization and water for rigorous growth. Both of those conditions are assumed here. Also, light is unique among crop growth inputs in that there is no reservoir of energy to draw upon during times of fluctuating or inadequate supply. This is different from water, whose bulk acts as a capacitor in smoothing out sporadic precipitation inputs.

The shading section of this subroutine computes bean canopy height from a regression on bean radius. This function was fitted to data collected by the author.

BNHIGHT =
$$.0337 + .572 \times BNRADB^2$$

where:

BNHIGHT = bean canopy height m BNRADB = bean canopy radius in the direction perpendicular to the row m

Bean shadow length is then the product of BNHIGHT and the shade data.

Tomato shading by the bean canopy is assumed to explain most of the interspecific competition (Figure 12). Although the bean and tomato canopies were observed to be of similar heights in the field in 1980, most of the tomato canopy was between zero and .15 m from the soil surface. Only occasional branches exceeded this height. By contrast, the bean canopy was dense over its full height, and formed an effective light screen. The model assumes that the low-lying, relatively open tomato canopy has no impact on light reaching the bean canopy. However, shading of the bean canopy by its counterpart on the opposite side of the hexagon is modeled. It is the bean-to-tomato and bean-to-bean shading which models the light competition.

The shading effect on tomato photosynthate production is computed by partitioning the tomato ground area. The photosynthetic rate



Figure 12. Shading of the tomato canopy by the dense bean canopy shown in a transverse section of a hexagon.

unit is mg CO_2 m⁻² sec⁻¹. Ground area is, therefore, vital to total canopy photosynthate production. The model computes the fraction of the tomato ground area in shade. Early and late in the day this is 1. For several hours around solar noon it may be .1 to zero. As the bean canopy increases in height this shading effect becomes increasingly severe. Diminishing hexagon widths have the same effect. The relative fractions of tomato ground area in full sun and in shade are then used with full sun and shaded photosynthetic rates to compute total tomato plant photosynthate produced in that time step.

The bean shading effect is also computed by partitioning the bean ground area. However, due to the rather uniform vertical distribution of the bean canopy, the fraction shaded is computed differently (Figure 13). Bean shadow height \underline{S} on its counterpart canopy across the hexagon is divided by total canopy height. The relative vertical fractions of full sun and shade are multiplied by bean ground area and used similarly as above in computing total canopy photosynthate. Due to the greater distance between the bean rows (i.e., hexagon sides) than between bean and tomato canopies, there is less of a shading impact on photosynthate production in bean.

Photosynthate produced in the 1 hr timestep is computed by multiplying full sun and shaded photosynthetic rates by the above fractions and summing the products. The subroutine output is g glucose per tomato and bean plant. The conversion from CO_2 to glucose uses the ratio of carbon content in CO_2 to that in glucose (111).

6. Carbohydrate Partitioning (Subroutines BNPART and TOMPART)

The logic in these two subroutines is identical. The difference between them lies in their equations.



Figure 13. The fraction of shadow height S over canopy height C is used to partition bean ground area.

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These subroutines partition the photosynthate produced in each timestep to state variables representing leaf, stem, root and fruit dry weight. (Figure 14).

Two carbohydrate pools are represented. Soluble carbohydrate is considered a short-term pool (CPOOL) available for immediate translocation. Sucrose is its major constituent. Insoluble carbohydrate is a long-term pool (CSTORE) available for slow release. Starch is its major constituent.

The carbohydrate input from subroutine PHOTO may be positive (e.g., full sun) or negative (e.g., night hours). If it is positive then 25% is retained in CSTORE and 75% is added to CPOOL. If CPOOL is greater than 10% of CSTORE then 67% of CPOOL is translocated or available for structural growth in the leaf. This means that up to 50% of new carbohydrate is available for translocation in that timestep. If CPOOL is less than 10% of CSTORE (e.g., at night) then CPOOL is made up to 10% by transfer of dry matter out of CSTORE. The full amount transferred is then translocated.

This allocation ratio is based on work with several species. Ho (51) found in tomato that the rate of carbon export in leaves with high carbon fixation rates was 60-66% of the rate of carbon fixation. This export rate was less at lower carbon fixation rates. Hofstra, et al., (52) found the amount translocated after 1 hr to be 38% in tomato, 50% in sunflower, 53% in sorghum and 32% in castor bean. Pearson (95) found the rate in broad bean to be 35%. From these data a translocation rate of 50% of new photosynthate was assumed for both species.

Figure 14. System diagram of Subroutine BNPART and TOMPART



The partitioning of carbohydrate to plant components is a major problem in plant modeling. Two general approaches have been taken. First, functions have been fitted to dry weight data accumulated over the growing season. This descriptive approach reveals nothing about the mechanism of partitioning and is somewhat season-specific. An example is the perennial ryegrass model of Sheehy, <u>et al</u>., (109). This approach is also used in MULTICROP. Regression equations of dry weight data are used in this subroutine to partition both bean and tomato photosynthate.

The second approach is to attempt descriptions of carbohydrate flow rates between plant parts. Holt, <u>et al.</u>, (53) used this approach in an alfalfa model, but scaled the maximum rates back with "maturity factors" which are again descriptive. A more complex model devoted entirely to dry matter distribution in sugar beet uses a primarily mechanistic approach, with partitioning rates controlled by the internal water supply and internal photosynthate supply (35). The most complex attempt to describe partitioning mechanistically is that of Thornley (117).

The descriptive approach was used in this model due to its relative simplicity and reasonable accuracy. Further expansion and refinement of the model would benefit from inclusion of a mechanistic partitioning section.

The component demand functions for carbohydrate used in partitioning are regressions fitted to field data (Figure 15). An exception is that for roots. The root : shoot ratio is an extremely complicated relationship to which an entire model has been devoted (18).

Figure 15. Equations used to partition carbohydrate between plant parts.

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Bean demand functions:
leaf demand = 10<sup>(-.407 + .0425 DAY)</sup>
stem demand = 10<sup>(-.84 + .0466 DAY)</sup>
fruit demand = 156.3 - 8.73 DAY + .122 DAY<sup>2</sup>
if DAY<37, fruit demand = 0.
root demand
if DAY<20, root demand = .16 (stem + leaf + fruit demands)
21<DAY<48, root demand = .11 (stem + leaf + fruit demands)
DAY>49 root demand = .08 (stem + leaf + demands)
```

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Tomato demand functions
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leaf demand = .882 + .308 DAY + .0269 DAY<sup>2</sup>
stem demand = 1.17 + .274 DAY + .0161 DAY<sup>2</sup>
fruit demand = 47.3 - 5.10 DAY + .138 DAY<sup>2</sup>
if DAY<19, fruit demand = 0.
root demand
if DAY<20, root demand = .16 (stem + leaf + fruit demands)
21<DAY<48, root demand = .11 (stem + leaf + fruit demands)
DAY>40, root demand = .08 (stem + leaf + fruit demands)
```

where:

DAY = days after commencement of the simulation

A simple method based on the data of Richards, <u>et al.</u>, (103) and Gulmon, <u>et al.</u>, (40) is used in this model. Root:shoot ratios ranging from .16 in young plants to .08 in older plants are used. No attempt to modify these ratios in response to environmental factors is made in the model.

The component demands are balanced so that their total is 1. The carbohydrate available is allocated according to this balance, and reduced by 25% before being added to the component cumulative dry weights. Data by Penning de Vries, <u>et al.</u>, (97) indicate a conversion efficiency of 75% in producing plant structure from glucose, assuming an adequate supply of NH₃ and minerals. This value is also used elsewhere (53).

The outputs of these subroutines are cumulative values of leaf, stem, root and fruit dry weight for bean and tomato plants.

7. Bean and Tomato Canopy Growth (Subroutine CANOPY)

This model converts leaf dry matter to leaf area and simulates bean and tomato canopy growth. Four different modes of bean canopy exapansion are modeled (Figure 16).

Leaf dry matter is converted to leaf area by a regression of ground area on leaf dry weight. Both functions are derived from growth data collected in 1980.

> BLFAREA = .0241 BDRYLF -.0062 TLFAREA = .0243 TDRYLF -.0143

where:

BDRYLF = bean leaf dry weight g BLFAREA = bean leaf area m^2 TDRYLF = tomato leaf dry weight g TLFAREA = tomato leaf area m^2

Figure 16. System design of Subroutine CANOPY



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Bean and tomato canopy ground areas are also functions of their respective leaf dry weights. The functions are regressions derived from 1980 field data.

> BGRAREA = $10.(-1.79 + .779 \log BDRYLF)$ TGRAREA = $10.(-1.62 + .685 \log TDRYLF)$

where:

BGRAREA = bean canopy ground area m^2 TGRAREA = tomato canopy ground area m^2

Tomato canopy ground area is assumed to be circular. Its radius is limited by either an absolute limit when no bean canopy is contacted, or a maximum tomato-bean overlap of .1 m. Tomato LAI is computed from leaf and ground areas.

Bean canopy ground area changes shape during the season. Its maximum radius in the direction perpendicular to the row is a function of hexagon size, derived from 1980 field data.

 $MBNRADB = .327 + .632 \log TTDIST$

where:

MBNRADB = maximum bean radius perpendicular to the bean row m TTDIST = tomato-tomato distance (hexagon width) m Bean canopy growth simulation is in 4 modes (Figure 17).

a. Mode 1.

Initial bean canopy growth is assumed to be circular. The canopy radii parallel to the row (BNRADA) and perpendicular to the row (BNRADB) are equal. The radius is derived from the ground area. No bean-bean overlap occurs.

b. Mode 2

Early overlap of neighboring bean canopies occurs in





Mode 2. Circular canopy expansion continues until a maximum overlap of .05 m occurs. The duration of the simulation in Modes 1 and 2 is highly dependent upon bean-bean distance.

The overlap of neighboring bean canopies adds to LAI of the single plant modeled. The model simulates this by computing the overlap area which is approximated as an ellipse (Figure 18). Dry leaf weight of the overlap area contributed by the neighboring plant is computed and added to the dry leaf weight of the modeled plant. Leaf distribution in the canopy is not evenly spread over the plant ground area. The LAI at the canopy edge is less than in its center. Therefore, the LAI of the neighboring plant added in the overlap is reduced by two-thirds.

This method of increasing LAI due to the overlap is also followed in Modes 3 and 4.

c. Mode 3.

Upon expansion of BNRADA to its defined limit, the canopy changes shape to an ellipse. Further advance in BGRAREA is in the BNRADB direction.

d. Mode 4.

Elliptical growth continues until the maximum tomatobean overlap is just exceeded. In Mode 4, BGRAREA expansion has terminated and BDRYLF is added to the ground area occupied.

Outputs of this subroutine are LAI and ground area.



Figure 18. Bean canopy overlap with approximating ellipses.
8. Bean and Tomato Yield (Subroutine YIELD)

Bean and tomato fruit yields are computed in this subroutine. Plant populations are computed and various yield descriptions given (Figure 19).

Fresh fruit is computed from fruit dry weight using regression functions derived from 1980 field data.

TFRFRT = (50.5 + 18.9 TDRYFR) /1000. BFRFRT = .014 BDRYFR

where:

BDRYFR = bean fruit dry weight g BFRFRT = bean fruit fresh weight kg TDRYFR = tomato fruit dry weight g TFRFRT = tomato fruit fresh weight kg

Hexagon area, circumference and number per hectare are computed. This allows computation of bean and tomato populations.

Yield for each species and their sum is computed per hexagon, m^{-2} and hectare. These are the subroutine outputs.

9. Simulation Termination

Upon completion of the required number of iterations, the program prints variable values as initially requested. The operator is asked if further simulations are intended. If not, the program immediately terminates. A positive response causes a return to an early point in DRIVER and initialization of variable values. The operator may then run the program again.

E. DATA COLLECTION FOR THE MODEL

1. Plant Growth Curves

Growth curves were required for both species to partition carbohydrates in the model. Plants were grown as non-competing



Figure 19. System diagram of Subroutine YIELD

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individuals and harvested at regular intervals throughout the 1980 season.

Tomato transplants (cv. PikRed) were started in VSP Peat Lite Mix in cell packs on April 28, 1980. After hardening-off, they were transplanted into the field on May 25. The Capac loam soil was fertilized with 170 kg P_2O_5 , 170 kg K_2O and 113 kg N per hectare, and sprayed with .85 kg per hectare Treflan 1 week prior to planting. A 250 ml portion of 12:48:8 starter solution and .078% Chlordane was poured in each hole before putting in the transplant. The plants were not staked. Cultivation following transplanting was by hoe.

A hexagonal planting design was used, which placed the plants lmfrom each neighbor (Figure 20). Interplant competition was virtually absent at this distance. A total of 100 plants were planted.

Bean seeds (cv. Bush Blue Lake) were planted in the field on June 5. The field conditions were as above with the exception of the starter solution and Chlordane. Three seeds were planted in each of 100 positions in a .8 m hexagonal grid (Figure 20). The germinated seedlings were thinned to 1 plant per position.

Entire plants of both species were harvested at 4 day intervals throughout the growing season, commencing June 23. Five randomly selected plants of each species were measured for height and canopy diameter in 2 directions, at each harvest date. The plants were cut off at ground level, placed immediately in individually sealed plastic bags, and transported to a 2 C refrigerator.

Leaf area was measured in a Lycor leaf area meter for each bean plant for the first 4 weeks. Leaves were removed from the petioles and their areas were measured. The plant parts were then dried and



Figure 20. Planting design for bean and tomato growth curve data.

weighed. After 4 weeks the plants were large and this operation became prohibitively time-consuming.

Tomato leaf area was measured similarly. After 2 weeks the number of plants measured was reduced to 1 due to the canopy size.

All harvested plants were oven-dried at 70 C in a forced-air oven. Space in this oven was unavailable during the latter half of the season. During this time plants were stored at -5 C and dried as above when space became available.

With the exception of those plants dissected for leaf area measurement, the plants were dried intact and separated into leaf, stem and fruit components prior to weighing. Curves were fitted to the data and plots made on the MINITAB interactive statistical analysis system (98).

2. Fruit Fresh Weight : Dry Weight Ratios

Three 1.5 kg fresh samples of bean fruits were dried to obtain a fruit fresh weight : dry weight ratio. These samples contained a range of fruit sizes typical of those found in harvests from the validation experiments described later.

Three samples each of 10 tomato fruit were dried to obtain their fresh weight : dry weight ratio. Each sample was composed of a different fruit ripeness stage ranging from mature-green to firm-ripe.

3. Soil Water Content

Gravimetric soil water measurements were taken on June 24 (one day after model commencement) and July 16. A .1 m diameter hand auger was used to take soil samples from each .1 m layer to a depth of 1.5 m. The samples were taken from 5 different positions across the field on each date.

Samples were removed from the auger and immediately enclosed in a sealed plastic bag. Their gravimetric water content was determined by oven drying approximately 250 g samples at 70 C.

4. Preliminary Hexagon Trial

A preliminary experiment was performed during the summer of 1979 to determine suitable hexagon sizes and bean spacings for the model.

Three plots were planted with tomato plants placed hexagonally and encircled by hexagonal bean rows (Figure 21). Each harvested tomato plant and its associated bean hexagon was completely surrounded by guard hexagons. Each of the three plots was identical except for the hexagon width, which was .8, 1., or 1.2 m per plot. Within each plot, the harvested hexagons were planted with beans .05, .1, or .15 m apart within the row. Three hexagons were randomly allocated to each bean planting distance, giving a total of 9 harvested hexagons per plot.

Soil type and field preparation were as above. The beans were hand-harvested twice, and the plants were removed from the field after the second harvest. The tomatoes were hand-harvested 5 times.

These planting distances were found to be suitable for the simulation. Reasons for this are discussed in the Results and Discussion section. The hexagon dimensions and bean populations were retained for use in the 1980 validation experiment.

F. FIELD VALIDATION

Two field validation experiments were performed in 1980. Bean and tomato plants were grown in hexagons with various plant POPulations and bean planting dates.



Figure 21. Plot design for preliminary spacing experiments.

hyp ind fac Sir who pla Th Ni of he: Ъe ha g:: si di ac Ea çэ ¥. . t: 1. Spacing Experiment

A replicated spacing experiment was conducted to test the hypothesis that hexagon size and bean population had no effect on individual species yields. The design was a split plot in a 3 x 3 factorial randomized block design.

The main plots were hexagon widths of .8, 1. and 1.2 m. Since hexagons of differing widths cannot combine into a single matrix, whole plots were assigned to each main plot level (Figure 22). Split plots were 3 bean-bean planting distances at .05, .10 and .15 m. Three subsamples of each subplot were planted (Figure 22).

All main plots were of an identical design (Figure 23). Nine hexagons with bean and tomato for harvesting formed the center of each plot. At one end were 17 tomato plants without encircling bean hexagons. Three of these were harvested. At the opposite end were bean hexagons without tomato. Each harvested hexagon of this group had a different bean spacing.

A difficulty with the hexagonal design is the large number of guard hexagons required. This was minimized by bisecting the hexagon side which linked neighboring hexagons with different bean planting distances (Figure 24). Any error introduced was uniformly applied across the plot and assumed to be negligible.

Field preparation and planting details were as stated above. Hand cultivation and harvesting were practiced. This and all other experiments received 3 overhead irrigations. A total of .065 m of water was applied.

Beans were harvested and weighed on August 5 and 12. All the bean plants in the harvested hexagons and the guard rows were

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Figure 23. Individual main plot design for spacing experiment.



Figure 24: Segment of spacing experiment plot showing interlocking of hexagons planted to different bean-bean distances in the row.

----- = beans planted .05 m apart

----- = beans planted .10 m apart

= beans planted .15 m apart



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removed from the field during the second harvest. Care was taken during the harvests to minimize spatial dislocation of the two canopies. Heights and widths of the two species' canopies were measured prior to the first harvest.

Tomatoes were harvested at the 'breaker' stage on September 4. A second harvest on September 10 removed all remaining fruit regardless of size and ripeness. Reported yields are totals of all fruit from both harvests.

Analysis of variance and Duncan's multiple range test were performed on the yield data (115).

2. Planting Date Experiment

A replicated planting date experiment was conducted to test the hypothesis that varying the bean planting date would have no effect on individual species yield. The design was a split-split plot in a 3 x 3 x 3 factorial randomized block design (Figures 25,26).

The main plots were hexagon widths of .8, 1. and 1.2 m. Split plots were bean-bean planting distances of .05, .1 and .15 in. The split-split plots were 3 planting dates. All the tomato transplants were set on May 25. The first bean planting was on June 5, with the others following on July 9 and August 8. Harvests of the first beans planted were on August 5 and 12. The second planting was harvested on September 5 and 11. Bean plants in the third planting date section were frozen and no yield data were collected.

Statistical analysis was performed as for the spacing experiment.



Figure 25. Schematic representation for planting date experiment.

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Figure 26. Individual main plot design for planting date experiment.

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G. MODEL SIMULATIONS

Simulations were performed to ascertain the model's response to planting distances of both species. Tomato planting distance (hexagon size) was held constant at .8 m while bean-bean distance was varied between .05 and .15 m. The tomato distance was then increased to 1. and 1.2 m and the process was repeated.

This series of simulations was repeated with the bean planting date moved later into the season. Simulations were run with planting distances in all combinations of .8, 1. and 1.2 m between tomato plants and .05, .10 and .15 m between bean plants.

The third series of simulations was to repeat the first series with weather data from two other years. A total of 3 years' weather data were used.

Finally, tomato-tomato distance was increased to 5 m and beanbean distance to 2 m. This simulation was equivalent to isolated tomato and bean plants.

RESULTS AND DISCUSSION

A. DATA COLLECTION

1. Plant Growth Curves

The bean and tomato growth curve data appear with their fitted curves in Figures 27-32. The data show increasing leaf and stem dry weight up to the final harvest. This is because the plants were still vegetatively expanding.

The tomato samples were more variable than were the bean samples. This resulted in lower R^2 values for all the tomato parts. No outstanding reason for the greater tomato variability was apparent.

The logarithmic bean leaf and stem growth functions reflected the short bean growing season. The longer growing tomato was adequately described by a quadratic equation. The fitted curves were incorporated into subroutines BNPART and TOMPART.

Functions relating leaf area to leaf dry weight were derived from the leaf area and leaf dry weight data. Similar functions were derived for predicting canopy ground area from leaf dry weight. These functions appear in subroutine CANOPY.

2. Fruit Fresh Weight : Dry Weight Ratios

Bean and tomato fruit fresh and dry weights, and their ratios, appear in Table 1. Due to the larger number of tomato data points, a function could be fitted to them rather than a simple ratio. The



Figure 27: Bean leaf dry weights with fitted curve.



Fitted curve: Y = 10 (-.840 + .0466X) with: $R^2 = .96$, adjusted for 79 d.f.

Figure 28: Bean stem dry weights with fitted curve.





Figure 29: Bean fruit dry weights with fitted curve.



 $Y = .882 + .308X = .0269X^2$ with: $R^2 = .87$, adjusted for 55 d.f.

Figure 30: Tomato leaf dry weights with fitted curve.



 $Y = 1.17 = .274X + .0161X^2$ with: $R^2 = .85$, adjusted for 55 d.f.

Figure 31: Tomato stem dry weight with fitted curve.



 $Y = 47.3 - 5.10X + .138X^2$ with: $R^2 = .89$, adjusted for 43 d.f.

Figure 32: Tomato fruit dry weight with fitted curve.

Table 1. Bean and Tomato Fruit Fresh Weight: Dry Weight Ratios

Bean	Sample	Fresh Weight (kg)	Dry Weight (g)	Ratio
	1	1.22	87.55	.0139
	2	1.79	123.75	.0145
	3	1.76	129.50	.0136
Tomato	Fruit Color	Ave. Fruit Fresh Weight (kg)	Ave. Fruit Dry Weight (g)	Ratio
	Mature Green	.1667	7.69	.0216
	1/2 Red	.2162	7.74	.0279
	Firm Ripe	.2753	11.42	.0241

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functions used in the model appear in Materials and Methods on page 16.

3. Soil Water Content

The gravimetric soil water content remained quite high by July 16, 1980. A diminution was apparent (Figure 33), but the upper .3 m retained 10-12% water. The WATER subroutine is not functioning correctly in the present version of the model. It fails to increment soil moisture accurately. It appeared that soil moisture deficits had little impact on the validation experiment. This model deficiency probably did not significantly affect the simulated yields.

4. Preliminary Hexagon Trial

Field space limitations prevented replication of this experiment. No statistical analysis of the data was performed. However, the experiment provided valuable information regarding the plant spacings selected (Table 2).

Bean yield per plant more than doubled as bean-bean distance changed from .05 to .15 m. A slight response was observed with increased hexagon size and a constant bean-bean distance.

Tomato yield was less consistent. Yields in all the .8 m hexagons and .05 m bean rows were smaller than those from the other spacings, which were indistinguishable.

Visual observations confirmed that canopy density, and therefore, plant competition, varied noticeably across the plots. From these data and observations it was decided to retain the 9 spacing combinations used in the trial.





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		.05	.10	.15	
Tomato	.8	.047	.084	.114	.082
distance (m)	1.0	.047	.092	.125	.088
	1.2	.054	.117	.159	.110
		•049	.098	.133	

Table 2. Bean and Tomato Yield per Plant (kg)

Bean distance (m)

Bean yield per plant (kg)

Bean distance (m)

		.05	.10	.15	
Tomato	.8	1.09	2.77	1.81	1.89
(m)	1.0	2.63	2.95	3.63	3.07
	1.2	2.00	3.36	3.49	2.95
		1.91	3.03	2.98	

Tomato yield per plant (kg)

B. SIMULATION RESULTS

Component and total populations varied widely across the 9 possible spacing combinations (Table 3). Total population per hectare at .8 m tomato-tomato and .05 m bean-bean distances was 4.5 times that at 1.2 m and .15 m respectively. The component and total population variation profoundly influenced yield per unit area.

1. Spacing Simulation

Component and total fruit yields appear in Tables 4-12. Simulation results from 9 planting distance combinations, and 4 bean starting dates, appear in Tables 4-7 (weather data from 1970) and Tables 9-12 (weather data from 1968). Results from a single series of 9 simulations with only the earliest bean starting date, and 1969 weather data, appear in Table 8. Results from 3 simulations with 5. m tomatotomato distance and 2. m bean-bean distance using 1968-1970 weather data are in Table 13.

The following discussion centers primarily on Tables 4-7, with 1970 weather data. The same trends are apparent in the 1968 results (Tables 9-12).

a. Bean Fruit Yield.

When tomato-tomato distance was held constant, bean yield per plant doubled as bean planting distance increased from .05 m to .15 m. This ratio was constant over the 4 bean starting dates.

When bean-bean distance was held constant, bean yield per plant increased approximately 50% as tomato-tomato distance increased from .8 m to 1.2 m. Maximum bean

Table 3. Component and Total Populations at Each Planting Distance Combination

BEAN POPULATIONS

		Per Hex	agon			Per Hectare			
(m)		Bean di	istance (m)	(m)	Be	an distan	ce (m)	
nce (.05	.10	.15	l l		.05	.10	.15
listaı	.8	55	28	18	listar	.8	500072	250036	166691
to	1.0	69	35	23	tod	1.0	400058	200029	133353
Toma	1.5	83	42	28	Toma	1.5	333381	166691	111127

	TOMATO POPULATIONS				Т	TOTAL POPULATIONS				
		<u>Per</u> <u>Hect</u>	are			Per Hectare				
(m)		Bean dis	tance (m))	(m)	E	Bean distan	ce (m)		
ince		.05	.10	.15	nce		.05	.10	.15	
dista	.8	18043	18043	18043	dista	.8	518115	268079	184733	
ato	1.0	11547	11547	11547	ato	1.0	411605	211576	144900	
Tom	1.5	8019	8019	8019	Tom	1.5	341400	174710	119146	

Table 4. Component and Total Yields Simulated from 1970 Weather Data with Bean Planting Date = 1, Bean Harvest Date = 52.

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(u	Bean	distance	(m)	
ce (.05	.10	.15
stan	.8	.044	.066	.088
lomato di	1.0	.055	.082	.109
	1.2	.064	.097	.128

BEAN YIELD/UNIT AREA (kg m⁻²)

Bean distance (m)

е Е		.05	.10	.15
tanc	.8	2.213	1.655	1.471
dis	1.0	2.196	1.649	1.456
Tomato	1.2	2.127	1.612	1.419

TOMATO FRUIT WEIGHT (kg)

BEAN FRUIT WEIGHT (kg)

E Bean distance (m)

ຍ . ປວ . 10 .	12
.8 1.878 2.001 2.	064
I.0 1.968 2.084 2.	156
te 1.2 2.069 2.188 2.	283

TOMATO YIELD/UNIT AREA (kg m⁻²)

E Bean distance (m)

) e o		.05	.10	.15
stan	.8	3.388	3.610	3.724
ib o:	1.0	2.273	2.407	2.490
lomat	1.2	1.659	1.755	1.831
. .				

COMBINED YIELD/UNIT AREA (kg m^{-2})

 \hat{E} Bean distance (m)

ice (.05	.10	.15
stan.	.8	5.601	5.265	5.194
ib o	1.0	4.469	4.056	3.746
lomat	1.2	3.786	3.366	3.250



Table 5. Component and Total Yields Simulated from 1970Weather Data with BEANPLANT = 10, HARVEST = 62

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COMBINED YIELD/UNIT AREA (kg m⁻²)

Ē	Bean	distance	(m)	
ce (i		.05	.10	.15
stan	.8	5.165	4.785	4.699
d d d	1.0	4.280	3.898	3.818
Tomat	1.2	3.655	3.278	3.190

r

BEAN FRUIT WEIGHT (kg)			BEAN YIELD/UNIT AREA (kg m ⁻²)					
	Bean d:	Bean distance (m)			Bean distance (m)			
e (B		.05	.10	.15	е 1	.05	.10	.15
tanc	.8	.037	.056	.074	s. tranc	1.858	1.392	1.234
dis	1.0	.046	.069	.092	τ τ 1.0	1.841	1.383	1.222
Tomato	1.2	.053	.080	.107	Loamto	1.783	1.333	1.191

Table 6. Component and Total Yields Simulated from 1970 Weather Data with BEANPLANT = 20, HARVEST = 72

TOMATO FRUIT WEIGHT (kg)

Tomato distance (m)

TOMATO YIELD/UNIT AREA (kg m⁻²)

Bean distance (m)

Bean distance (m)					
	.05	.10	.15		
.8	1.518	1.577	1.669		
1.0	1.829	1.908	1.980		
1.2	2.126	2.256	2.315		

		.05	.10	.15
stanc	.8	2.738	2.846	3.011
dis	1.0	2.112	2.204	2.286
omatc	1.2	1.705	1.809	1.856
				

COMBINED YIELD/UNIT AREA (kg m⁻²)

Bean distance (m)

ance		.05	.10	.15
listé	.8	4.596	4.237	4.246
to	1.0	3.952	3.587	3.508
Tomá	1.2	3.488	3.142	3.047

.
BE	AN FRUI	IT WEIGHT	(kg)	BEAN YIEL	BEAN YIELD/UNIT AREA (kg m ⁻²)			
~	Bean o	distance (n	n)		Bean d	istance	(m)	
e (n)		.05	.10	.15	(m)	.05	.10	
distance	.8	.028	.042	.055	8. auce	1.391	1.045	
	1.0	.034	.052	.069	dist 1.0	1.374	1.035	
lomato	1.2	.040	.060	.080	1.2 gg	1.333	1.005	
-								

	Bean distance (m)									
(m)		.05	.10	.15						
ance	.8	1.391	1.045	.922						
dist	1.0	1.374	1.035	.916						
Tomato	1.2	1.333	1.005	.885						

TOMATO FRUIT WEIGHT (kg)

Bean distance (m) Tomato distance (m) .10 .15 .05 .8 2.007 1.460 1.863 1.0 1.706 1.974 2.171 1.2 2.228 2.115 2.365

TOMATO YIELD/UNIT AREA (kg m⁻²)

Bean distance (m)

e (m		.05	.10	.15
tanc	.8	2.635	3.361	3.621
dis	1.0	1.970	2.279	2.507
omato	1.2	1.696	1.787	1.896
Ĕ		•		

COMBINED YIELD/UNIT AREA (kg m^{-2})

Bean distance (m) Tomato distance (m) .05 .10 .15 4.205 4.406 4.543 .8 1.0 3.345 3.314 3.423 1.2 3.030 2.791 2.781

Table 7. Component and Total Yields Simulated from 1970 Weather Data with BEANPLANT = 30, HARVEST = 82

BEAN FRUIT WEIGHT (kg)					BE	BEAN YIELD/UNIT AREA (kg m ⁻²)				
	Bean distance (m)				Bean distance (m)					
e (2		.05	.10	.15	e (n		.05	.10	.1	
tanc	.8	.042	.062	.084	tanc	.8	2.093	1.562	1.3	
dis	1.0	.052	.078	.104	dis	1.0	2.075	1.552	1.3	
Tomato	1.2	.061	.091	.121	Tomato	1.2	2.021	1.520	1.3	
то	MATO FR	RUIT WEIGH	T (kg)		TO	MATO YI	ELD/UNIT	AREA (kg	; m ⁻²)	
2	Bean d	listance (m)		2	Bean o	listance	(m)		
е (п		.05	.10	.15	е (п		.05	.10	.1	
distanc	.8	2.091	2.228	2.303	tanc	.8	3.773	4.021	4.1	
	1.0	2.177	2.305	2.393	dis	1.0	2.514	2.661	2.7	
Toma to	1.2	2.270	2.404	2.512	Tomato	1.2	1.820	1.928	2.0	

Table 8. Component and Total Yields Simulated from 1969 Weather Data with BEANPLANT = 1, HARVEST = 52

e,		.05	.10	.15
canc	.8	2.093	1.562	1.395
STD 0	1.0	2.075	1.552	1.381
	1.2	2.021	1.520	1.342

	.05	.10	.15
.8	3.773	4.021	4.154
1.0	2.514	2.661	2.763
1.2	1.820	1.928	2.014

COMBINED YIELD/UNIT AREA (kg m^{-2})

(Bean distance (m)							
е (п		.05	.10	.15				
tanc	.8	5.866	5.583	5.549				
dis	1.0	4.589	4.213	4.145				
Tomato	1.2	3.841	3.448	3.356				

•

Table 9. Component and Total Yields Simulated from 1968 Weather Data with BEANPLANT = 1, HARVEST = 52

BEAN FRUIT WEIGHT (kg)					BEAN YIELD/UNIT AREA (kg m ⁻²)					
(u	Bean distance (m)				Bean o	listance ((m)			
ce (n		.05	.10	.15	e (m		.05	.10	.15	
stanc	.8	.032	.047	.063	tanc	.8	1.585	1.187	1.046	
itb c	1.0	.039	.058	.079	dis	1.0	1.560	1.170	1.053	
Tomato	1.2	.046	.069	.092	omato	1.2	1.526	1.146	1.018	
TOMATO FRUIT WEIGHT (kg)					TOMATO YIELD/UNIT AREA (kg m ⁻²)					
u	Bean distance (m)			(e	Bean o	listance	(m)			
) eo		.05	.10	.15	е (<mark>п</mark>		.05	.10	.15	
stan	.8	2.227	2.381	2.469	tanc	.8	4.017	4.296	4.455	
tbo	1.0	2.327	2.480	2.573	dis	1.0	2.687	2.864	2.971	
ŭ			0 507	2 606	ato	1.2	1.960	2.074	2,162	
Toma	1.2	2.444	2.387	2.090	Tomá	1.2	1	20074		

COMBINED YIELD/UNIT AREA (kg m^{-2})

	Bean distance (m)						
е (ш		.05	.10	.15			
tanc	.8	5.603	5.483	5.502			
dist	1.0	4.247	4.034	4.024			
Tomato	1.2	3.486	3.221	3.180			

BEAN FRUIT WEIGHT (kg) Bean distance (m) (II) .05 .10 .15 Tomato distance .8 .059 .079 .039 1 1.0 .098 .049 .073 1.2 .057 .086 .114 Ē

BEAN YIELD/UNIT AREA (kg m^{-2})

Bean	distance	(m)	
	.05	.10	.15
.8	1.955	1.468	1.310
1.0	1.942	1.460	1.302
1.2	1.892	1.427	1.270
	.8 .8 1.0 1.2	Bean distance .05 .8 1.955 1.0 1.942 1.2 1.892	Bean distance (m) .05 .10 .8 1.955 1.468 1.0 1.942 1.460 1.2 1.892 1.427

TOMATO FRUIT WEIGHT (kg)

Bean distance (m) Tomato distance (m) .05 .10 .15 1.199 1.216 .8 1.144 1.0 1.284 1.362 1.402 1.2 1.369 1.481 1.554

TOMATO YIELD/UNIT AREA (kg m^{-2})

_ Bean distance (m)

ce (m		.05	.10	.15
stan	.8	2.064	2.164	2.194
o di	1.0	1.483	1.573	1.619
omat	1.2	1.098	1.188	1.246
E-		•		

COMBINED YIELD/UNIT AREA (kg m^{-2})

œ	Bean distance (m)							
i) a ji		.05	.10	.15				
stan	.8	4.019	3.632	3.504				
o dis	1.0	3.424	3.033	2.921				
Comate	1.2	2.990	2.615	2.516				
Ĥ.								

BE.	BEAN FRUIT WEIGHT (kg)				BEAN YIELD/UNIT AREA (kg m ⁻²)	
2	Bean distance (m)			Bean distance (m)		
e (n		.05	.10	.15	ຼື .05 .10	
tanc	.8	.023	.034	.045	.8 1.142 .855	
dis	1.0	.028	.042	.057	ម៉ី 1.0 1.136 .849	
Tomato	1.2	.033	.050	.066	1.2 1.105 .828	
TO	MATO FR	UIT WEIGH	ſ (kg)		TOMATO YIELD/UNIT AREA (kg m ⁻	
(H)	Bean d	istance (1	n)		Bean distance (m)	
e		.05	.10	.15	.05 .10	

1.126

1.389

1.627

1.217

1.422

1.681

n distance (m) .05 .10 .15 .855 .757 1.142 1.136 .849 .755 .828 .733 1.105

YIELD/UNIT AREA (kg m⁻²)

се <u>(</u> п		.05	.10	.15
stanc	.8	1.956	2.031	2.195
c d1:	1.0	1.516	1.604	1.642
omati	1.2	1.219	1.304	1.348
F-1		-		

COMBINED YIELD/UNIT AREA (kg m⁻²)

Bean distance (m)

JCe		.05	.10	.15
lstai	•8	3.098	2.886	2.952
Ц С	1.0	2.652	2.452	2.396
[oma1	1.2	2.324	2.132	2.081

Table 11. Component and Total Yields Simulated from 1968 Weather Data with BEANPLANT = 20, HARVEST = 72

Tomato distance (m .8

1.0

1.2

1.084

1.313

1.521

Table 12. Component and Total Yields Simulated from 1968 Weather Data with BEANPLANT = 30, HARVEST = 82

BEAN YIELD/UNIT AREA (kg m^{-2}) BEAN FRUIT WEIGHT (kg) Bean distance (m) Bean distance (m) Ē (II .05 .10 .15 **Fomato distance** .05 .10 Tomato distance .8 .015 .022 .030 .8 .743 .553 1.0 .018 .028 .037 1.0 .733 .550 1.2 .021 .032 .043 1.2 .712 .537 TOMATO YIELD/UNIT AREA (kg m⁻²) TOMATO FRUIT WEIGHT (kg) Bean distance (m) Bean distance (m) E Ē .15 Tomato distance .05 .10 .8

1.721 1.276 1.611 1.440 1,806 1.929 1.680 1.853 2.074

1.0

1.2

.15

.492

.488

.475

<u> </u>		05	10	16
JCe		.05	.10	•13
lstar	.8	2.303	2.908	3.106
tb o:	1.0	1.663	2.085	2.228
[omat	1.2	1.307	1.486	1.663
L 7				

COMBINED YIELD/UNIT AREA (kg m⁻²)

Bean distance (m) (H .05 .10 .15 **Fomato distance** 3.046 3.461 3.598 .8 1.0 2.396 2.635 2.716 2.059 2.023 2.138 1.2

Table 13. Bean and Tomato Fruit Yields over 3 Different Years' Weather Data. Planting Distances Were 5 m Tomato-Tomato and 2 m Bean-Bean

Year	Bean Yield Per Plant (kg)	Tomato Yield Per Plant (kg)
1968	.578	2.803
1969	.675	2.984
1970	.723	3.742

yield per plant was at 1.2 m and .15 m tomato and bean spacings.

Bean yield per hexagon is confounded with the rapidly increasing bean population as hexagon width changes from .8 m to 1.2 m. Yields per hexagon are not reported here. Rather, yields per m^2 are reported because this relationship simultaneously accounts for changes in both population and area. Yield per hexagon deals only with population changes.

Maximum bean yield per m^2 occurred at .8 m and .05 m tomato and bean planting distances. This was exactly opposite to the individual plant optimal spacing. Individual plant yield maxima peaked where intra- and interspecific competition was at a minimum. Yield per unit area peaked where the competition was at a maximum.

b. Tomato Fruit Yield.

Maximum individual plant yield occurred with the most distant plant spacings. The relative yield increase when moving from .8 m and .15 m to 1.2 m and .15 m tomato and bean spacings was less than the relative bean yield increase over the same changes in planting distance. Maximum tomato yield per m² was at .8 m and .15 m tomato and bean distances. The bean canopy was not as tall with the .15 m spacing as with the .05 m spacing. Diminished shading from the .15 m spacing canopy allowed greater yield. 2. Model Response to Weather Changes

The model responded to differences in weather data. Yields generated using weather data from 1969 and 1968 appear in Tables 8 and 9-12, respectively. A comparison using the earliest bean commencement date is obtained by comparing Tables 4, 5 and 9.

The two species responded differently to the weather changes. Bean yields in descending order were from 1970, 1969 to 1968. Tomato yields in descending order were from 1968, 1969 to 1970, which was the opposite direction to the bean. The tomato pattern was not the same when the plants were simulated as free-standing individuals (Table 13). In this case, the tomato yields paralleled the bean yields in descending order over 1970, 1969 to 1968. This reversal is largely due to the dominance of the bean canopy in the model caused by the bean shading effects. When the bean grew relatively better, tomato growth was diminished.

C. VALIDATION RESULTS AND SIMULATION COMPARISON

1. Spacing Experiment.

Bean yields per plant differed significantly (1% level) as a result of changes in either bean-bean or tomato-tomato distances. Bean yield per unit area differed significantly (1% level) only in response to change in bean-bean spacing (Table 14). The mean separations of yield per unit area revealed no difference due to changes in tomatotomato distance. However, there was a trend toward increased yield with .8 m hexagons (Table 15).

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Table 14. Analysis of Variance (ANOVA) of the Spacing Experiment Bean Yields

ANOVA OF BEAN YIELD (WEIGHT PER PLANT)

Source of variation	<u>df</u>	<u>Mean square</u>	F
Replication	2	.00015	.579
Tomato spacing	2	.00717	27.145**
Error a	4	.00026	
Bean spacing	2	.0244	81.078**
Tomato spacing x Bean spacing	4	.00008	.262
Error b	12	.00030	

ANOVA OF BEAN YIELD (WEIGHT PER UNIT AREA)

Source of variation	<u>df</u>	<u>Mean</u> square	F
Replication	2	.062	.540
Tomato spacing	2	.261	2.284
Error a	4	.114	
Bean spacing	2	.709	17.873**
Tomato spacing x Bean spacing	4	.079	1.991
Error b	12	.040	

•

Table 15.Spacing Experiment Bean Fruit Yields with AveragesSeparated by the Duncan's Multiple Range Test

WEIGHT PER PLANT (kg)

Bean distance (cm)

		5	10	15	
Tomato	80	.042	.074	.099	.072c
	100	.057	.091	.12	.089ъ
(Cm)	120	.069	.11	.13	.103a
		.056c	.092Ъ	.116a	•

WEIGHT PER UNIT AREA (kg m⁻²)

Bean distance (cm)

.

		5	10	15	_
Tomato	80	1.68	1.64	1.51	1.61a
(cm)	100	1.86	1.52	1.34	1.57a
	120	1.58	1.41	1.29	1.43a
		1.71a	1.52ъ	1.38c	-

Tomato yields per plant differed significantly (1% level) as a result of changes in either bean-bean or tomato-tomato distances. Tomato yields per unit area differed significantly (5% level) only in response to changes in bean-bean spacing (Table 16). The mean separations confirmed the lack of difference in yield per unit area over different tomato-tomato distances (Table 17).

Comparisons of the simulation and validation yields appear in Tables 18-20.

Simulated bean yields per plant from 1970 weather data closely paralleled validation yields at each spacing combination. A Chi² test to assess the goodness of fit of the two data sets was significant at the 1% level.

The goodness of fit of simulation and validation bean yields per unit area was not significant. This was contributed to by errors in bean populations in the field. Cold, wet weather during bean germination, followed by warm, dry weather and soil surface crusting, led to uneven germination across the plots. Some plots did not reach their specified population levels. The validation did support the prediction of maximum bean yield at the .05 m bean-bean distance (Table 15).

Simulation tomato yields per plant followed the same direction as the validation, but were not significant (Table 19). Tomato yields per plant doubled from minimum to maximum levels in the field, but increased only 18% in the simulation. However, the range of simulated yields was similar to the validation results.

Simulation and validation yields per unit area for tomato showed similar trends, but again were not significant (Table 19). As bean-bean distance increased, tomato yields also increased. However,

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Table 16. Analysis of Variance (ANOVA) of the Spacing Experiment Tomato Yields

ANOVA OF TOMATO YIELD (WEIGHT PER PLANT)

Source of Variation	<u>df</u>	<u>Mean square</u>	<u>F</u>
Replication	2	1.030	1.296
Tomato spacing	2	21.797	27.425**
Error a	4	.795	
Bean spacing	2	2.651	8.163**
Tomato x Bean spacing	4	.410	1.262
Error b	12	.325	

ANOVA OF TOMATO YIELD (WEIGHT PER UNIT AREA)

Source of Variation	df	<u>Mean square</u>	F
Replication	2	.823	.828
Tomato spacing	2	2.482	2.497
Error a	4	.994	
Bean spacing	2	3.407	5.533*
Tomato x Bean spacing	4	. 348	.566
Error b	12	.616	

Table 17.Spacing Experiment Tomato Fruit Yields with AveragesSeparated by the Duncan's Multiple Range Test

WEIGHT PER PLANT (kg)

Bean distance (cm)

		5	10	15	_
Tomato	80	1.55	1.90	1.82	1.76Ъ
(cm)	100	1.79	2.27	2.62	2.23Ъ
	120	3.05	3.89	3.53	3.49a
		2.12b	2.69a	2.66a	

WEIGHT PER UNIT AREA (kg m^{-2})

.

Bean distance (cm)

		5	10	15	_
Tomato	80	2.80	3.43	3.28	3.17a
(cm)	100	2.07	2.62	3.02	2.57a
	120	2.45	3.12	2.83	2.80a
		2.44b	3.06a	3.04a	-

SIMULATION (1970 weather) Fruit weight/plant (kg) Bean distance (m) E .05 .10 .15 Tomato distance .8 .044 .066 .088 1.0 .055 .082 .109 1.2 .064 .097 .128

VALIDATION (1980)

Fruit weight/plant (kg)

Bean distance (m) 9

<u>п</u> ө		.05	.10	.15
tanc	.8	.042	.074	.099
dis	1.0	.057	.091	.12
Tomato	1.2	.069	.11	.13

Fruit weight/unit area (kg m⁻²)

Fruit weight/unit area (kg m^{-2})

Bean distance (m) Tomato distance (m) .05 .10 .15 .8 2.213 1.655 1.471 1.0 2.196 1.649 1.456 1.2 2.127 1.612 1.419

Bean distance (m)

	Bean distance (m)				
ce (.05	.10	.15	
stan	.8	1.68	1.64	1.51	
b di	1.0	1.86	1.52	1.34	
omati	1.2	1.58	1.41	1.29	
Ĕ					

Tomato distance (m) Tomato distance (m) B Tomato distance (m) P To

SIJ	MULATI	ON (1970	weather)		VA	LIDATI	ON (1980)		
Fr	uit we	ight/plan	t (kg)		Fr	uit we	ight/plan	t (kg)	
(u	Bean	distance	(m)		(u	Bean o	listance	(m)	
ce (n		.05	.10	.15	ce (I		.05	.10	.15
stanc	.8	1.878	2.001	2.064	stanc	.8	1.55	1.90	1.82
th c	1.0	1.968	2.084	2.156	o dis	1.0	1.79	2.27	2.62
Tomato	1.2	2.069	2.188	2.283	Tomato	1.2	3.05	3.89	3.53
Fr	uit we	ight/unit	area (kg	; m ⁻²)	Fr	uit we:	ight/unit	area (k	g m ⁻²)
(u	Bean	distance	(m)		(m	Bean o	listance	(m)	
ce (i		.05	.10	.15	ce (i		.05	.10	.15
stan	.8	3.388	3.610	3.724	stanc	.8	2.80	3.43	3.28
di	1.0	2.273	2.407	2.490	dis	1.0	2.07	2.62	3.02

Ĵ.	Bean distance (m)					
ce (i		.05	.10	.15		
stan	.8	3.388	3.610	3.724		
di.	1.0	2.273	2.407	2.490		
Tomate	1.2	1.659	1.755	1.831		

ce (n		.05	.10	.15
stan	.8	2.80	3.43	3.28
dis	1.0	2.07	2.62	3.02
Tomate	1.2	2.45	3.12	2.83

variability in the field reduced the clarity of this comparison as it did with the bean. In this case only one plant was involved in each hexagon, so the specified population was always met. The variability was, therefore, entirely in plant growth.

Total yields of both species per unit area appear in Table 20. The simulation predicted a maximum total yield at .8 m and .05 m tomato and bean distances. This was due to the overriding influence of the bean yields. The validation results were too random to be useful. However, given the results for each species previously presented, it seems reasonable to expect that maximum yields in this system would come from .8 m and .05 m tomato and bean distances, out of the spacing combinations tested.

2. Planting Date Experiment

Bean yields per plant and per unit area differed significantly (1% level) as a result of changes in either bean-bean distance or planting date (Tables 21, 22). Tomato-tomato distance was significant in neither case, as in the spacing experiment (Table 14). The early bean planting produced significantly higher yields than did the later planting (Tables 23, 24).

Tomato yields per plant and per unit area differed significantly (5% level) as a result of changes in planting date. Yields per unit area also differed significantly (1% level) as a result of changes in tomatotomato distance. Tomato x bean distances and planting date x bean distance interactions were both significant at the 1% level in the yields per plant and per unit area (Table 25).

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VALIDATION (1980)

Fruit Weight/Unit Area (kg m⁻²)

Fruit Weight/Unit Area (kg m⁻²)

(m	Bea	Bean distance (m)				
) eo		.05	.10	.15		
stan	.8	5.165	4.785	4.699		
o di	1.0	4.280	3.898	3.818		
omato	1.2	3.655	3.278	3.190		
Ē						

Bean distance (m)

ce (n		.05	.10	.15
stan	.8	4.48	5.07	4.79
o di	1.0	3.93	4.14	4.36
omat	1.2	4.03	4.53	4.12
-		•		

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Table 21. Analysis of Variance (ANOVA) of the Planting Date Experiment Bean Yields per Plant.

ANOVA OF BEAN YIELD (WEIGHT PER PLANT)

Source of Variation	<u>df</u>	<u>Mean Square</u>	F
Replication	2	.00056	.348
Tomato	2	.00349	2.188
Error a	4	.00159	
Bean	2	.01807	38.184**
Tomato x Bean	4	.00049	1.033
Error b	12	.00047	
Planting	1	.02160	35.453**
Planting x Tomato	2	.00060	.985
Planting x Bean	2	.00136	2.225
Planting x Tomato x Bean	4	.00021	.337
Error c	18	.00061	

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Table 22.Analysis of Variance (ANOVA) of the PlantingDate Experiment Bean Yields per Unit Area

ANOVA OF BEAN YIELD (WEIGHT PER UNIT AREA)

Source of Variation	df	Mean Square	F
Replication	2	.028	.101
Tomato	2	.042	.151
Error a	4	.278	
Bean	2	1.361	13.858**
Tomato x Bean	4	.111	1.131
Error b	12	.098	
Planting	1	1.245	13.299**
Planting x Tomato	2	.206	2.198
Planting x Bean	2	.158	1.691
Planting x Tomato x Bean	4	.106	1.135
Error c	18	.094	

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Table 23. Planting Date Experiment Bean Fruit Yields per Plant with Averages Separated by the Duncan's Multiple Range Test.

WEIGHT PER PLANT (kg)

(u		Bean distance (m)			
ce (I	_	.05	.10	.15	Date
stanc	.8	.077	.13	.13	1
die	1.0	.070	.12	.16	.119a
mato	1.2	.087	.12	.18	
Ĕ					•

(m		Bean	distance	(m)		
ce (.05	.10	.15	_	Date
stan	.8	.043	.053	.080	.086a	2
di.	1.0	.063	.073	.11	.099a	.0796
mato	1.2	.067	.093	.13	.113a	
Ţ	-	.068c	.098ъ	.132a		

Table 24. Planting Date Experiment Bean Fruit Yields per Unit Area with Averages Separated by the Duncan's Multiple Range Test.

	Bean di	istance	(m)	
e (m	.05	.10	.15	Date
tanc 8.	2.47	2.09	1.28	1
sip 1.0	2.04	1.70	1.65	<u>1.80</u> a
1.2	1.86	1.57	1.51	
Tol				

WEIGHT PER UNIT AREA (kg m^{-2})

2	Bean di	stance	(m)		
е) е	.05	.10	.15		Date
tanc 8	1.73	1.22	1.30	1.68a	2
sib 1.0	1.79	1.33	1.48	1.67a	<u>1.49</u> b
1.2	1.85	1.39	1.36	1.59a	
Toi	1.96a	1.55b	1.43b		

Table 25. Analysis of Variance (ANOVA) of the Planting Date Experiment Tomato Yields.

Bean	Ħ	bean-bean distance	
Plant	×	bean planting date	
Tomato	-	tomato-tomato distan	ce

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ANOVA OF IOPAID HELD (WEIGHT FER FLANT		ANOVA	OF	TOMATO	YIELD	(WEIGHT	PER	PLANT)
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Source of Variation	df	<u>Mean square</u>	F
Replication	2	1.872	.899
Tomato	2	1.982	.951
Error a	4	2.083	
Bean	2	.326	.961
Tomato x Bean	4	3.550	10.452**
Error b	12	. 340	
Planting	2	3.119	3.508*
Planting x Tomato	4	.433	.487
Planting x Bean	4	3.741	4.208**
Planting x Tomato x Bean	8	.406	.457
Error c	36		

ANOVA OF TOMATO YIELD (WEIGHT PER UNIT AREA)

Source of Variation	df	<u>Mean square</u>	F
Replication	2	2.576	1.211
Tomato	2	40.960	19.256**
Error a	4	2.127	
Bean	2	.602	1.408
Tomato x Bean	4	3.370	7.888**
Error b	12	.427	
Planting	2	6.188	4.299*
Planting x Tomato	4	2.050	1.424
Planting x Bean	4	6.175	4.290**
Planting x Tomato x Bean	8	.983	.683
Error c	36		

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Table 26. Tomato Fruit Yields per Plant in the Planting Date Experiment, with Averages Separated by the Duncan's Multiple Range Test*

Plant Dat	e 🚊 Bean di	E Bean distance (m)				
1	nce	.05	.10	.15		
	sta 8	1.54aAY	1.31aAY	1.76aAy		
	문 1.0	1.70aAY	1.43aAX	1.18aAX		
	1.2 g	1.70aAXY	1.01aAY	2.31aAX		
	Hean ¹	1.65	1.25	1.75		
Plant Dat	e ^E Bean di	stance (m)				
2	nce	.05	.10	.15		
	8. ta	1.56aAY	2.35aAX	2.78aAX		
	j 1.0	1.59aAY	2.03aAX	1.09aBX		
	<u>ទ្</u> ជ 1.2	.94aAY	2.44aAX	3.15aAX		
	e Mean ¹	1.36	2.27	2.34		
Plant Dat	e 🔒 Bean di	stance (m)				
3	e U	.05	.10	.15		
	s.	3.45aAX	2.61aAX	1.92aAXY		
	st 1.0	3.44aAX	1.51aAX	.59bBX		
	ت 1.5	2.21aAX	1.49aAXY	2.75aAX		
	Hean ¹	3.03	1.87	1.75		

MEAN YIELD AT CONSTANT TOMATO AND BEAN DISTANCE ACROSS PLANTING DATE

e(m)	Bean di	stance (m)		
anc		.05	.10	.15
lst	.8	2.18	2.09	2.15
þ	1.0	2.24	1.66	.95
Tomato	1.2	1.62	1.65	2.74

*A, B, C = bean distance

a, b, c = tomato distance

X, Y = planting date

 L_{Mean} yield at constant bean spacing within planting date.

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Table 27.	Tomato Fruit Yields per Unit Area in the Planting Date					
	Experiment, with Averages Separated by the Duncan's					
	Multiple Range Test*					

Plant date	EBean dis	tance(m)		
1	nce	.05	.10	.15
	8. gt	2.78aAY	2.37aAY	3.17aAY
	ı.0	1.97aAY	1.65aAX	1.36aAX
	<u> 약</u> 1.2	1.47aAXY	.81aAX	1.86aAX
	Mean ¹	2.07	1.61	2.13
Plant date	Bean dis	tance(m)		
2	8. gu	2.81bAY	4.25abAX	5.01aAX
	s 1.0	1.83aABY	2.35aBX	1.25aBX
	7 1.2	.75aBY	1.96aBX	2.53aBX
	wean ¹	1.80	2.85	2.93
Plant date	EBean dis	tance(m)		
3	E) a	.05	.10	.15
	.8	6.19aAX	4.70abAX	3.47bAY
	0.1 ^{ct}	5.82aAX	1.74bBX	.68bBX
	节 1.2	2.21aBX	1.20aBX	2.21 a ABX
	mean ¹	4.74	2.55	2.12

MEAN YIELD AT CONSTANT TOMATO AND BEAN DISTANCE ACROSS PLANTING DATE

Ē	Bean di	stance(m)		
ce(.05	.10	.15
tan	.8	3.93	3.77	3.88
1st	1.0	3.21	1.91	1.10
Tomato d	1.2	1.48	1.32	2.20

*A, B, C = bean distance

a, b, c = tomato distance

X, Y = planting date

 ${}^{1}\!\!\!\!$ Mean yield at constant bean spacing within planting date.



Figure 34. Tomato yields per plant in the planting date experiment. Data are means of yields at constant tomato and bean distances across planting dates. Refer Table 26.



Figure 35. Tomato yields per plant in the planting date experiment. Data are means of yields at constant bean spacing within planting date. Refer Table 26.

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Figure 36. Tomato yields per unit area in the planting date experiment. Data are means of yields at constant tomato and bean distances across planting dates. Refer Table 27.



Figure 37. Tomato yields per unit area in the planting date experiment. Data are means of yields at constant bean spacing within planting date. Refer Table 27.

Tomato yields per plant and per unit area are shown in Tables 26 and 27. Means across planting dates with tomato and bean distances held constant, and across tomato distance with planting date and bean distance held constant, are also shown. These means assist interpretation of the interactions, and are presented graphically in Figures 34-37.

The tomato x bean planting distances interaction from the tomato yield per plant ANOVA is depicted graphically in Figure 34. Yields were constant with .8 m tomato-tomato distance as bean-bean distance increased. However, with 1. and 1.2 m tomato-tomato distance the yields decreased and increased respectively as bean-bean distance increased. Similar results occurred in yield per unit area (Figure 36).

The bean planting date x bean-bean distance interaction from the tomato yield per unit area is depicted graphically in Figure 35. Yield per plant increased with the third planting date when bean-bean distance was held constant at .05 m (Figure 35). No such increase occurred with the two larger bean-bean distances. Similar trends occurred with this interaction in tomato yield per unit area (Figure 37).

The reasons for these interactions are not clear. No tomato x bean distance interaction occurred in the spacing experiment. Its presence in the planting date experiment may have been an aberration unique to that season. Further field experiments would be required to establish its importance.

A partial explanation of the tomato yield increase in the .05 m bean-bean distance hexagons in planting date 3 is possible. The beans were killed by frost damage in this final planting. Also, the intense bean competition did not occur until late in the season, and was

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diminished by tomato shading of the bean canopy. The reduction in bean competition may have had a relatively greater effect with the .05 m bean-bean than with the lower competition from the wider bean spacings.

A comparison of simulation and validation bean yields across 2 planting dates appears in Table 28. Yield reductions in weight per plant as planting date was retarded were 37% and 33% in the simulation and validation yields respectively. The yield reductions in weight per unit area as planting date was retarded were 37% and 17% in simulation and validation yields respectively. Comparisons of simulation and validation yields for tomato are not made here because of the interactions.

These results reconfirm that the canopy shading section of the model has captured a significant part of the real system. Without that section, neither the changes in planting distances nor bean planting dates would have caused the simulation yield changes reported.

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Table 28. Comparison of Average Yield for All Plant Spacing Combinations at each of 2 Bean Planting Dates. Simulated Yields Were for 1970 Weather Data, and BEANPLANT = 1 or 30

		Average Yi Planting C	eld for All ombinations	
Planting Date	Weight/P	lant (kg)	Weight/Unit	Area (kg m ⁻²)
	Simulation	Validation	Simulation	Validation
1	.081	.119	1.76	1.80
30	.051	.080	1.10	1.49

SUMMARY AND CONCLUSIONS

The optimum plant spacings, of those combinations tested, for maximizing bean and total yields were .05 m bean-bean and .8 m tomatotomato distances. Maximum tomato yields were at .15 m bean-bean and .8 m tomato-tomato distances. These maximum yields occurred with the earliest bean planting date.

It has not been shown whether closer spacings would produce greater yields. However, it is expected that the above spacings are close to the ideal for maximum yields.

The model performs well in its present form. Simulation and validation bean yields were significant at the 1% level. Although all other results were not significant, the simulation results were of the same order of magnitude and moved in similar directions to the validation yields.

Further work with the model is required for increased accuracy. The soil water subroutine is not functioning correctly and needs reworking. No attempt has been made to model root competition for water and nutrients. This area is vital to overall competition.

Tomato shading of the beans should be incorporated into the photosynthesis subroutine. This is especially important for later bean plantings which are shaded by a relatively large tomato plant.

Presently the model uses the bean plant nearest to the tomato. A more representative bean plant would be the plant located equidistant

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between the nearest and furthest bean plants.

Potential tests and uses of the model include modification of some existing constants, rates, spacings, etc. Photosynthetic rates could be reduced by a known amount, and yields observed to determine if the yield reduction was equivalent. Different canopy shapes and types could be incorporated, such as caged tomatoes or pole beans. The planting design could be converted to rows, or even to a monoculture.

The program has numerous comments throughout to enable another person to quickly comprehend it. It is hoped that others will take this current version and improve and modify it for new purposes. APPENDICES

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APPENDIX A



Figure 38. Plot design for one replicate of preliminary intercropping experiment.

Where:

b = bean row c = cabbage row n = no intercrop between tomato rows p = pea row t = tomato guard row t' = tomato harvested row

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Table 29. Tomato Yields for 1978 and 1979 from the Preliminary Intercropping Experiment

Intercropped	Year	Yield	Percent of
species		(tons/acre)	control
control	1978 1979	33.2 24.8	
cabbage	1978	18.6	56
	1979	13.4	54
pea	1978	20.7	62
	1979	19.3	78
bean	1978	27.2	82
	1979	17.2	69

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TOMATO YIELD

Table 30. Cabbage, Pea and Bean Yields for 1978 and 1979 from the Preliminary Intercropping Experiment

CABBAGE YIELDS

Situation	Yi (tons	eld /acre)	Perce cont	nt of rol
	1978	1979	1978	1979
intercropped	11.1	9.5	116	133
control	9.6	7.1		

PEA YIELDS

Situation	Yi (tons	eld /acre)	Percer cont	nt of rol
	1978	1979	1978	1979
intercropped	2.6	2.3	124	164
control	2.1	1.4		

BEAN YIELDS

Situation	Yi (tons	eld /acre)	Perce	nt of rol
	1978	1979	1978	1979
intercropped	3.7	4.4	73	85
control	5.1	5.2		

APPENDIX B

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APPENDIX B

Glossary of modeling terms.

- state variables elements describing the components of the system; levels or amounts of material. Examples are leaf dry weight, photosynthate produced in one hour, and leaf area index.
- rate variables rates of transfer of material between state variables per unit time.
- driving variables forces external to but acting upon the system. Examples are solar radiation, temperature, rainfall and relative humidity.
- output variables states or rates produced by the model and which are the objectives of the system.
- system boundary the boundary between the system and its environment.

exogenous - outside the system boundary.

Flowcharting Symbols (36,72)

Beginning or end of an algorithm Arithmetic calculation or state variable



Any input or output operation

Beginning of series of operations to be performed repetitively; a DO loop



Comparison or decision making



Jump (used to direct to another flowchart segment)

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Rate variable

APPENDIX C

Climatic data for 1968, 1969, 1970 and 1980 compiled from Local Climatological Data, National Climatic Center, and from data provided by the Agricultural Weather Service, Michigan State University.

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Annua1	May-Sept.
Average Temperature (F) 1968	20.1	21.2	36.7	48.9	53.2	66.5	70.2	69.5	62.7	51.3	37.5	25.5	46.9	64.4
1969	21.8	25.4	30.4	47.2	56.5	61.9	71.1	72.8	64.2	50.0	36.2	25.8	47.0	65.3
1970	16.4	23.6	29.1	46.5	58.6	65.5	70.2	68.2	61.5	51.8	39.1	25.8	46.3	64.8
1980	22.2	19.6	29.9	45.0	58.5	63.5	72.5	71.8	61.8	45.2	36.7	23.7	45.9	65.6
Precipitation														
(11) 1968	1.46	1.56	1.49	2.96	4.16	7.94	3.03	2.98	2.73	1.56	3.26	2.62	35.75	20.8
1969	1.91	0.22	1.06	4.02	4.47	4.03	4.89	0.17	1.67	2.74	2.32	0.53	28.03	15.2
1970	0.91	0.66	2.20	3.13	2.89	3.02	3.37	2.36	4.61	3.77	2.85	2.48	32.25	16.3
1980	0.70	0.99	1.94	2.41	1.84	3.20	3.56	4.76	3.22	2.02	06.0	3.06	28.6	16.6
MDO 50 Monthly Degree Days														
1968	0.	0.	30.	89.	174.	509.	620.	647.	430.	166.	11.	0.	2676.	2380.
1969	0.	0.	5.	88.	272.	410.	654.	.669	390.	138.	0.	0.	2626.	2395.
1970	0.	0.	0.	127.	351.	517.	696.	651.	438.	154.	4.	0.	2938.	2653.
1980	0.	0.	0.	42.	306.	466.	718.	704.	391.	65.	0.	0.	2650.	2543.

APPENDIX D

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*18F	C 0 1	(-001F0 1)	
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,			
r		DEFINITION OF CONSTANTS AND VARIABLES	
r			
ATMDRES	=	ATMOSPHERIC DIFFUSION RESISTANCE S CM++-1	
AVENRGY	=	AVERAGE LIGHT FLUX DENSITY INCIDENT AT TOP OF CANOPY	
r		DURING PREVIOUS WEEK W M**-2	
BA	=	CONSTANT	
r 88	=	CCNSTANT	
BBDIST	=	BEAN-BEAN PLANTING DISTANCE P	
BBMOVLP	=	MAXIMUM ALLOWABLE OVERLAP OF BEAN-BEAN CANOPIES M	
BBOVLP	=	OVERLAP OF THE BEAN-BEAN CANOPIES M	
ВСНОДМЭ	Ξ	BEAN CARBOHYDRATE DEMAND FOR LONGTERM STORAGE G	
BCPOOL	Ξ	BEAN SHORTTERM CARBOHYDRATE STORAGE G	
BCSTORE	=	BEAN LONGTERM CARBOHYDRATE STORAGE G	
BCUMPHD	=	BEAN CUMULATIVE PHOTOSYNTHESIS PER DAY MG CO2	
BORYFR	=	BEAN FRUIT DRY WEIGHT G	
BURYLF	=	BEAN CANCPY LEAF DRY WEIGHT G	
BORYRT	=	BEAN ROOT DRY WEIGHT G	
BURYST	=	BEAN STEM URY WEIGHT G	
BEXCUEF	=	BEAN CANOPY EXTINCTION COEFFICIENT	
BERDMU	=	BEAN FRUIT DEMAND FUNCTION FOR PARTITIONING	
000007	_	CARBUNTURAIL G	
SFRFRI SFRFRI	=	BEAN FRESH FRUIT WEIGHT KG	
BERINLR	-	AREA UNDER THE REAL CANODY MALO	
DIAT	-	ARLA UNUER INE DEAN LANUPT M##2 DEAN LEAE ADEA THDEM	
OLAL OLAL	-	DEAN CENODY LEAS ADEA MAAD	
DIEDMO	-	DEAN FRAE DEMAND EINCTION FOR RAPTITIONING	
CLFUMU	-	CADRONYDRATE C	
	-	DEAN IEAE DRY MATTED INCREACE C	
RIEDECD	-	REAN LEAF DARK RECOTRATION RATE DER HNITT CROHAD ADEA	
- DEINESP	-	MC CO2 N++=2 C++=1	
BNELAG	=	FLAG TO DECLARE THAT REAN-REAN OVERLAD HAS REACHED THE	
	-	MAYIMUM ALLOWARIE DISTANCE	
BNHTGHT	=	HEIGHT OF THE BEAN CANOPY M	
ANPLANT	=	REAN PLANTING DATE IN MODEL DAYS	
BNRADA	-	BEAN CANCER RADIUS IN THE DIRECTION OF THE ROL N	
BNRADR	=	BEAN RADIUS IN THE DIRECTION PERPENDICULAR TO THE POU	M
BNSHADE	=	HORIZONTAL LENGTH OF THE BEAN CANOPY SHADOW M	• •
BOVARFA	=	SUM OF OVERLAP GROUND AREA ON POTH SIDES OF REAN	
	-	CANOPY M++2	
BOVERCT	=	BEAN-BEAN OVERLAP AREA AS & FRACTION OF REAN GROUND AREA	
BPHSATE	=	BEAN NET PHOTOSYNTHATE EXPRESSED AS GLUCOSE G	
BPNRATE	=	BEAN NET PHOTOSYNTHESIS RATE PER UNIT GROUND AREA	
		MG CO2 M**=2 S±±=1	
BPOPHEC	=	BEAN POPULATION PER HECTARE	
BPOPHEX	Ξ	BEAN POPULATION PER HEXAGON	
BRESP	=	BEAN TOTAL DARK RESPIRATION RATE PER UNIT GROUND AREA	
	-	MG CO2 M±==2 S±==1	
BRFRDMD	Ξ	BEAN RELATIVE FRUIT DEMAND FOR PARTITIONING OF	
		CARBOHYDRATE	
BRLFDMD	=	BEAN RELATIVE LEAF DEMAND FOR PARTITIONING OF	
		CAREOHYDRATE	
REPTONO	=	BEAN RELATIVE ROOT DEMAND FOR PARTITIONING OF	

```
CARBOHYDRATE
                                                                         +710
+ BRIDMO
         = BEAN ROOT DEMAND FUNCTION FOR PARTITIONING
                                                                         +720
            CARBOHYDRATE G .
                                                                         +730
* BRTINCR = BEAN ROOT DRY MATTER INCREASE
                                             G
                                                                         +740
 BSTDMD = BEAN STEM DEMAND FUNCTION FOR PARTITIONING
                                                                         *750
            CARBOHYDRATE G
                                                                         *760
٠
 BSTINCR = BEAN STEM DRY MATTER INCREASE
                                                                         *771
                                             G
 BSTRESP = BEAN STRUCTURE DARK RESPIRATION RATE PER UNIT GROUND
٠
                                                                         +780
            AREA (ROOT. STEM AND FRUIT)
                                                 MG CO2 M**-2 S**-1
                                                                         +750
* BSUMDMD = BEAN SUM OF THE COMPONENT PARTITIONING DEMANDS FOR
                                                                         + 800
            CARBOHYDRATE G
                                                                         *810
 BTRANS = BEAN LEAF TRANSMISSION COEFFICIENT
*
                                                                         *820
BTRLCTE = BEAN CARBOHYDRATE REMOVED FROM SHORTTERM STORAGE FOR
                                                                         +830
            TRANSLOCATION TO THE VARIOUS COMPONENTS G
                                                                         #840
* BUTILIZ = BEAN LEAF LIGHT UTILIZATION EFFICIENCY
                                                      MG CO2 J++-1
                                                                         *850
+ BX
         = CONSTANT
                                                                         *860
# RY
          = CCNSTANT
                                                                         *870
* BYLDHEC = BEAN YIELD PER HECTARE
                                     KG HECTARE**-1
                                                                         +880
* BYLDHEX = BEAN YIELD PER HEXAGON KG HEXAGON**-1
                                                                         +890
* BYLDM2 = BEAN YIELD PER UNIT AREA
                                       KG <u>M**-2</u>
                                                                         +900
 CANDRES = CANOPY DIFFUSION RESISTANCE S CM++-1
                                                                         +910
* COUNTER = CCUNT OF NUMBER OF ITERATIONS DURING A PARTICULAR DAY
                                                                         +920
* CO2
         = CO2 CONCENTRATION MG CO2 M**-3
                                                                         +930
• CUMENDY = CUMULATIVE ENERGY OVER THE DAY W M**-2
                                                                         +940
* CUMEVAP = CUMULATIVE EVAPOTRANSPIRATION
* CUMIRGN = CUMULATIVE IRRIGATION M
                                             M
                                                                         *950
                                                                         *960
* CUMRAIN = CUMULATIVE PRECIPITATION
                                                                         +970
                                        M
          = DAYS AFTER COMMENCEMENT OF THE SIMULATION (FIRST DAY
+ DAY
                                                                         *980
            IS DEFINED AS DAY 1)
                                  DAY
                                                                         +990
 DELTA
          = CHANGE OF SATURATION VAPOR PRESSURE WITH TEMPERATURE
                                                                     MB
٠
                                                                         +1000
 DSHC
         = CHANGE IN SOIL MOISTURE IN A GIVEN VOLUME OF SOIL
                                                                         +1010
                                                            M HR ++-1
                                                                         +1020
          = CHANGE IN SOIL VOLUME OCCUPIED BY THE ROOT SYSTEM M**3
٠
 DVOL
                                                                         +1030
 EBDRYLF = EFFECTIVE BEAN LEAF DRY WEIGHT DUE TO BEAN-BEAN
٠
                                                                         +1040
            OVERLAP
                     G
                                                                         +1050
• ECOUNT = COUNT OF EVENT WHEN ENERGY EXCEEDS .01 . SET TO ZERO
                                                                         +1060
            EACH DAY WHEN COUNTER = U. USED TO COMPUTE S1 IN PHOTO.
                                                                         +1070
         = LIGHT FLUX DENSITY INCIDENT AT TOP OF CANOPY W M**-2
* ENERGY
                                                                         +1080
* ENSTORE = STORED VALUE OF ENERGY FOR THAT ITERATION W M**-2
                                                                         +1090

    EVAPOTN = ACTUAL EVAPOTRANSPIRATION RATE M HR++-1

                                                                         +1100
* GAMMA
         = CONSTANT MB
                                                                         +1110
* HARVEST = BEAN HARVEST DATE IN MODEL DAYS
                                                                         +1120
* HBBDIST = HALF THE BEAN-BEAN PLANTING DISTANCE
                                                    Μ
                                                                         +1130
* HEXAREA = HEXAGON AREA M**2
                                                                         +1140
+ HEXCIRC = HEXAGON CIRCUMFERENCE
                                    1 M
                                                                         +1150
* HEXPHEC = NUMBER OF HEXAGONS PER HECTARE
                                                                         +1160
* HTTDIST = HALF THE TOMATO-TOMATO PLANTING DISTANCE
                                                                         +1170
          = TOTAL NUMBER OF ITERATIONS IN THE RUN
* T
                                                                         +1180
* IBNDAY = NUMBER OF BEAN DAYS AFTER BNPLANT
                                                                         +1190
         = VARIANT OF DAY USED IN THE WEATHER SUBROUTINE
* IDAY
                                                                         *1200
 IHR = SAME AS COUNTER.
IMONTH = VARIANT OF MONTH USED IN THE WEATHER SUBROUTINE
 IHR
*
                                                                         +1210
                                                                         +1220
٠
 IRRIGTN = IRRIGATION
                        M
                                                                         +1230
٠
 JDAY
         = VARIANT OF DAY USED IN THE WEATHER SUBROUTINE
                                                                         +1240
 JMCNTH = VARIANT OF MONTH USED IN THE WEATHER SUBROUTINE
                                                                         +1250
 KOUNTER = SPECIAL VERSION OF COUNTER WHICH RUNS FROM 1 TO 8 AND IS
                                                                         +1260
٠
            USED IN CALLING SHADE
                                                                         +1270
 LEVPOTE = LEAF WATER POTENTIAL
                                   BAR
                                                                         +1280
 MBNRADB = MAXIMUM ALLOWABLE BEAN CANOPY RADIUS PERPENDICULAR TO
                                                                         +1290
            THE ROW
                     M
                                                                         +1300
          = TYPE OF BEAN GROWTH
* MODE
                                                                         +1310
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+ MONTH
         = MONTH OF THE YEAR
                                                                        +1320
          = PHOTOSYNTHETICALLY ACTIVE RADIATION INCIDENT AT TOP OF
 PAR
                                                                        *1330
            CANOPY ERG CM++-2 S++-1
                                                                         +1340
* POOLCHK = MINIMUM CARBOHYDRATE LEVEL ALLOWED IN SHORTTERM STORAGE G *1350
 RAIN
          = PRECIPITATION M
                                                                         +1360
★ RATIQE = LESSER VALUE OF RATICP AND RATIOT, USED TO SCALE DOWN
                                                                        +1370
            PHOTOSYNTHETIC RATE
                                                                        +1380
* RATIOM = ADJUSTMENT TO TOMATO PHOTOSYNTHETIC RATE DUE TO AGE OF
                                                                        +1390
            THE CANOPY
                                                                        +1400
* RATIOP = ADJUSTMENT TO PHOTOSYNTHETIC RATE DUE TO LEAF WATER
                                                                         +1410
            POTENTIAL DIFFERENCES FROM THE OPTIMUM
                                                                        +1420
* RATIOT = ADJUSTMENT TO PHOTOSYNTHETIC RATE DUE TO TEMPERATURE
                                                                         +1430
            DIFFERENCES FROM THE OPTIMUM
                                                                        +1440
* RELHUM = RELATIVE HUMIDITY
                                                                         +1450
* RHMSAVE = STORED VALUE OF RELHUM TO ALLOW FOR MISSING VALUES IN
                                                                        +1460
            THE WEATHER DATA
                                                                        +1470
* RTDEPTH = ROOT SYSTEM DEPTH
                                м
                                                                        *1480
* S
          = AVERAGE ENERGY RECEIVED DURING A 3 HOUR PERIOD FOR ONE
                                                                        +1490
٠
            OF THE PREVIOUS 7 DAYS
                                                                         *1500
* SHADE
          = RATIC OF AN OBJECT"S SHADOW LENGTH TO THE HEIGHT OF
                                                                        +1510
٠
            THE OBJECT
                                                                         +1520
* SOILBD = SOIL BULK DENSITY
                               G CM++-3
                                                                         +1530
* STPNRTE = SHADED TOMATO NET PHOTOSYNTHESIS RATE PER UNIT GROUND
                                                                        +1540
            ARFA
                    MG CO2 M**-2 S**-1
                                                                        +1550
* SWC
          = VOLUMETRIC SOIL WATER CONTENT
                                                                         *1560
* SWPOT
         = SCIL WATER POTENTIAL
                                   BAR
                                                                        +1570
SYLDHEC = SUM OF THE YIELDS OF THE TWO SPECIES PER HECTARE
                                                                ΚG
                                                                        +1580
* SYLDHEX = SUM OF THE YIELDS OF THE TWO SPECIES PER HEXAGON
                                                                        11590
                                                                KG
* SYLDM2 = SUM OF THE YIELDS OF THE TWO SPECIES PER UNIT AREA
                                                                 KG
                                                                        *1600
* TA
          = CONSTANT
                                                                         +1610
         = CONSTANT
* TB
                                                                         +1620
* TBMOVLP = MAXIMUM ALLOWABLE OVERLAP OF TOMATO-BEAN CANOPIES
                                                                         +1630
* TBOVLP = OVERLAP OF THE TOHATO-BEAN CANCPIES
                                                     М
                                                                        +1640
TCHODMD = TOMATO CARBOHYDRATE DEMAND FOR LONGTERM STORAGE
                                                               G
                                                                        +1650
* TCPOOL = TOMATO SHORTTERM CARBOHYDRATE STORACE G
                                                                        +1660
* TCSTORE = TOMATO LONGTERM CAREOHYDRATE STORAGE
                                                    G
                                                                         +1670
* TCUMPHD = TOMATO CUMULATIVE PHOTOSYNTHESIS PER DAY
                                                      MG CO2
                                                                        *1680
          = CONVERSION OF DAY TO REAL FOR RATION CALCULATION
 TDAY
                                                                        +1690
         = TOMATO CANOPY DIAMETER
# TDIAM
                                    M
                                                                        +1700
* TDRYFR = TOMATO FRUIT DRY WEIGHT
                                      G
                                                                        +1710
• TDRYLF = TOMATO CANOPY LEAF DRY WEIGHT
                                            G
                                                                        +1720

    TDRYRT = TOMATO ROOT DRY WEIGHT
    TDRYST = TOMATO STEM DRY WEIGHT

                                                                        +1730
                                   G
                                                                        *1740
                                     G
* TEMP
         = DRY BULB TEMPERATURE C
                                                                        +1750
* TEXCOEF = TOMATO CANOPY EXTINCTION COEFFICIENT
                                                                        +1760
* TFROMD = TOMATO FRUIT DEMAND FUNCTION FCR PARTITIONING
                                                                        +1770
            CARBOHYDRATE
                         ·G
                                                                        +1780
* TFRINCR = TOMATO FRUIT DRY MATTER INCREASE
                                                                        +1790
                                               G
* TFRFRT = TOMATO FRESH FRUIT WEIGHT KG
                                                                        +1800
* TGRAREA = AREA UNDER THE TOMATO CANOPY M**2
                                                                        +1810
 TGRSHDE = GROUND AREA OF THE TOMATO CANOPY SHADED BY THE
٠
                                                                        +1820
            BEAN CANOPY M**2
                                                                        *1830
         = TOMATO LEAF AREA INDEX
* TLAT
                                                                        +1840
* TLFAREA = TOMATO CANOPY LEAF AREA
                                     M++2
                                                                         +1850
 TLFDMD = TOMATO LEAF DEMAND FUNCTION FOR PARTITIONING
                                                                        +1860
            CARBOHYDRATE
                          G
                                                                         +1870
* TLFINCR = TOMATO LEAF DRY MATTER INCREASE
                                               G
                                                                        +1880
* TLFRESP = TOMATO LEAF DARK RESPIRATION RATE PER UNIT GROUND AREA
                                                                        *1890
                                                  MG CO2 M++-2 S++-1
                                                                        +1900
* TMPSAVE = STORED VALUE OF TEMP TO ALLOW FOR MISSING VALUES IN THE
                                                                        +1910
            WEATHER DATA
                                                                         +1920
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* TOTLPOP = TOTAL PLANT POPULATION PER HECTARE *1930 * TPHSATE = TCMATO NET PHOTOSYNTHATE EXPRESSED AS GLUCOSE G +1940 • TPNRATE = TOMATO NET PHOTOSYNTHESIS RATE PER UNIT GROUND AREA +1950 MG CO2 M**-2 S**-1 +1960 * TPOPLIN = TOMATO POPULATION PER HECTARE +1970 + TRAD = TOMATO CANOPY RADIUS M +1980 = TOMATO TOTAL DARK RESPIRATION RATE PER UNIT GROUND AREA * TRESP *1990 MG CO2 M**-2 S**-1 +2000 +2010 * TRFRDMD = TOMATO RELATIVE FRUIT DEMAND FOR PARTITIONING OF CARBOHYDRATE +2020 ★ TRLFDMD = TOMATO RELATIVE LEAF DEMAND FOR PARTITIONING OF +2030 CAREOHYDRATE ±2040 * TRRTDMD = TOMATO RELATIVE ROOT DEMAND FOR PARTITIONING OF +2050 CARBOHYDRATE +2060 * TRSTDMD = TOMATO RELATIVE STEM DEMAND FOR PARTITIONING OF +2070 CARBOHYDRATE +2080 * TRTDMD = TOMATO ROOT DEMAND FUNCTION FOR PARTITIONING +2090 CARBOHYDRATE G +2100 * TRTINCR = TOMATO ROOT DRY MATTER INCREASE G +2110 * TSHADE = HORIZONTAL ENCROACHMENT DISTANCE OF THE BEAN SHADOW \$2120 ONTO THE TOMATO GROUND AREA M. +2130 * TSTDMD = TOMATO STEM DEMAND FUNCTION FOR PARTITIONING +2140 CARBOHYDRATE +2150 ÷ G +2160 * TSTINCR = TOMATO STEM DRY MATTER INCREASE G * TSTRESP = TOMATO STRUCTURE DARK RESPIRATION RATE PER UNIT GROUND *2170 AREA (ROOT, STEM AND FRUIT) MG CO2 M**-2 S**-1 +2180 * TSUMDMD = TOMATO SUM OF THE COMPONENT PARTITIONING DEMANDS FOR +2190 CARBOHYDRATE G +2200 * TTDIST = TOMATO-TOMATO PLANTING DISTANCE M
* TTRANS = TOMATO LEAF TRANSMISSION COEFFICIENT +2210 +2220 * TTRLCTE = TOMATO CARBOHYDRATE REMOVED FROM SHORTTERM STORAGE FOR +2230 TRANSLOCATION TO THE VARIOUS COMPONENTS G +2240 * TUTILIZ = TOMATO LEAF LIGHT UTILIZATION EFFICIENCY MG CO2 J**-1 *2250 * TX = CONSTANT \$2260 * T-Y = CONSTANT +2270 * TYLDHEC = TOMATO YIELD PER HECTARE KG HECTARE**-1 +2280 * TYLDHEX = TOMATO YIELD PER HEXAGON KG HEXAGON**-1 +2290 * TYLDM2 = TOMATO YIELD PER UNIT AREA KG M**-2 * VAPSAT = SATURATED VAPOR PRESSURE AT CURRENT TEMPERATURE +2300 BAR +2310 * VAPTEMP = VAPCR PRESSURE AT CURRENT TEMPERATURE BAR +2320 * VOLS1 = SOIL VOLUME OCCUPIED BY ROOT SYSTEM M**3 +2330 = NEW VALUE OF VOLS1 * VOLS2 +2340 + WINDCON = CONSTANT +2350 * WINDSPD = WIND SPEED M S**-1 *2360 * WNDSAVE = STORED VALUE OF WINDSPD TO ALLOW FOR MISSING VALUES IN +2370 THE WEATHER DATA +2380 +2390 2410 2420 * ESTABLISH REAL AND INTEGER VARIABLES 2430 2440 INTEGER COUNTER.DAY.PRINTYP.XCOUNTR.XDAY.XI.XMONTH.XDATE.XJMONTH. 2450 +XJDATE,XIMONTH,XIDATE,DATE,BNPLANT,HARVEST,XBNPLAN,XHARVES 2460 REAL MBNRADB.LFWPOTL 2470 2480 2490 * ESTABLISH ALL COMMON BLOCKS. "MAIN" IS THE PRIMARY COMMON BLOCK FOR 2500 * TRANSFER OF VARIABLE VALUES BETWEEN SUBROUTINES. ALL OTHER COMMON 2510 * BLOCKS ARE USED FOR STORING VARIABLE VALUES FOR PRINTING. 2520 2530

		C	:0	MP	0	N	/	M A	I	N/	1	86	D	15	T	• E	3 D	R١	ΥF	R -	• B	C	RY	1L)	F,	B	CI	RY	R	Τ,	6	D.B	Y	s T	•	3 G	R	A F	١E	A	B	LA	I	,			2	540
		+ E	3 N	RA	D	A 🔸	8	NR	A S	DE	3.	BF	P H	s /	T	Ė,	, C	01	UN	TI	ER	.,	ΕN	IE	R G	ŞΥ	C	24)	• H	T	TC	I	S T	•	R A	I	N ,	,								2	550
		+ F	۱E	LH	U	4 (2	4)	•	TC) R	YF	R	• 1	D	ß١	٢L	F	, T	DI	RY	'R	τ,	T	DR	۲Y	S	T e	T	EM	P	(2	24	>,	T	GR	A	RE	A	• 1	TL	A1	•				2	560
		+1	P	HS	Α.	ΓE	•	TR	t A	D,	, T	TC)1:	S 1		W]	1	0:	SP	0	(2	4),	I	, S	SН	A (DE	. C	10	1	• 8)	, I	H	۲,	D	Α١	•	LF	Ξ¥	PC) T	L	,		2	570
		++	1B	BC	1	ST	•	MC) N	Tł	1.	DA	T	E	I	:"() N	Tł	1.	I	DA	T	E,	J	M C) N	TI	H,	J	D.A	T	ε.	Ê	NP	11	ΛN	Т	• †	1 A	R١	/E	S 1					2	580
+										_																										•											2	590
		C	:0	MM	101	4	/	H A	T	ER	27	XC		NC)R	E (1	81))	•	XC	U	ME	Υ.	A (1	8(0)	•	XC	:01	MI	R	G (18	30)	• >	(C	UN	1R	AI	. (18	30) (2	600
		+ X		EL	. T.	A (1	55	;)	•)	K D	Si			. 8	01	2	XI		0		1	80)	• X	(E	<u>v</u> /	A P	0	Τ(1	08		• X		- И	P	01		18	50) 1)				2	610
		+) 	(R	10	E	- 1	() /	18	50	? •	X	S	IC	()	. 8	01	,	Χ:	SW	P	01	C	18	10),	X	Ŷ	OL	S	1(1	80)	• X		A P	S	AI		18	30) (•				2	620
		+)	(V	AP	11	L M	C.	16	50	2																																					2	630
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		• x	(B			TF	è	1 P	10	5.	ŝ	RR		SE	•	1 6	20	ъ.	. Y	Ê		R	GY		18	20	3	. Y	ŝ	1 (1	า เ ค.ก	2	. X	101	26	1	A .	11		21	30	1	81	1		2	670
		+)	s	4 (1	R 0	ì	۰x	s	56	1	80	5	• >	ŝ	6	1	81	n)		xs	: 7	(1	8	n t) .	x	s T	P	NR	Ŧ	(1	8	n 2	•)	κT	ĉ		1P	нí	(1	80	1.	•		•	2	680
		+)	(T	GR	s	ΗD	Ċ	18	30) .	x	TL	F	R S	SP	(1	8	٥) .	X	ΤP	н	ST	E	()	8	0).	x	TΡ	N	RI	Έ	(1	. 81	0)	č	x 1	r R	ES	SP	()	8	01			2	690
		+)	T	SH	A	DE	C	18	0)	, X	RA	I	N	1	8 ())	•	XR	EI	ĹН	U	M (1	6 0))	•)	ΧT	EI	MP	•	18	0),	X	i I	Ň	DS	SP	()	31	0)	•		•		2	700
		+)	(1	(1	8	0)	•	X۲	10	NI	ГH	(1	8	0 3	•	XC) A (ŤI	Ε(1	8 0)	• X	(J	м (N	ŤI	H (1	80)	• X	J	DÀ	T	E (1	80))	•							2	710
		+)	(1	MO	N	ΤH	(18	3 0) (X	IC	A (T E		18	3 0)	• X	8	NP	۲Ľ	AN	10	18	30) (• X	H.	A R	٧	ES	6	18	0)											2	720
*																																															2	730
		C	:0	MM	0	V	1	TC) M	P A	\ R	T/	X	PC	0	L (CH	C	18	0),	X	TC	;H	00	DM	C	18	0),																	2	740
		+)	(T	CP	0	٥L	(18	30) (X	TC	S	T C	R	(1	18	C.) •	X	TD	R	ΥF	R	(1	18	0) •	X	TD	R	YR	T	(1	. 81))	٠	X 1	r D	R	۲L	F (1	8 ())	•	2	75C
		+)	(T	DR	Y	ST	().	3 8	30)	X	TF	R	DH	10	(1	18	0),	X.	TF	R	IN	: C	(1	18	0),	X	TL	F	DY	D	(1	. 8 () }	۹	XI	I L	F	IN	C	1	8 ())	9	2	760
		+)	(T	PH	S	A T	C	18	0) (• X	TR		RC	M	0	18	0) ,	X	TR	Ľ	FC	H:	(1	8	0)),	X	ĩ R		TC	M	(1	.80	"	٠	X 1	r R	S	TD	M	1	80))	٠	2	770
		+) 	(/ T	ו א ד ח		110 2 T	(/	18	50	11	×	18	C I	I r	IC	C	18	Ű.) •	X	IS	1	UM	D	0	18	0),	X	IS	1	11	IC	C 1	. 81	3	•	XI	S	U	טף	M	1	8 ())	٠	2	780
		+)	(I	IN			٠.	1 5	50	,																																					2	190
-		6	:0	MY	0	u	/	81	P	Δ 6	2 7	1	P	n r	11	C I		1.3	n n	3	. x	R	CH	10	0.8		1	e 0	•	- Y	R	٢ç	0	••		1 8	n	۰.									2	800 81 N
		+ `	(8	C S	: T	n R	ć	18	10	5	ÌX	R	18	YF	R	(1	I P	ก่) .) .	Ŷ		R	YR	λ.Τ	11		n').	x	• • 8 0	R	Y	:т	(1	A I	1 1		Ý	, an	R١	~	FC	1	80	1 3		2	820
		+)	(B	FR		40	Ċ	18	30	,	x	BF	R	ĪŅ	iĊ	ċ	18	0		x	BL	F	אס	20	i i	18	0	, .	x	BL	F	IN	ic	(1	8			XE	βP	H S	SA	T	1	80	5		2	830
		+)	B	RF	R	DM	C	1 3	0)	X	BR		FC	M	(1	8	0),	X	BR	R	TO)M	(1	8	0),	X	BR	S	TC	M	(1	. 80))	;	XE	3 R	Τt	DM	DO	1	80))	•	2	840
		+)	(B	R T	I	NC	(1 8	30)	X	BS	ST I	D١	D	()	18	0) 🖕	XI	8 S	T	IN	1C	(1	8	0 3),	X	BS	U	МС	M	(1	80))	•	XE	3 T	RL	_ C	T (1	8 ())		2	850
*																																															2	860
		C	;0	MM	10	Ŋ	1	C A	N	0 F	۲	/1	M	0 0)E	(1	8 1	0) ,	XI	BN	R	AD) A ((1	8	0 3),	X	BN	IR	AC	6	(1	.81))	•	XE	3 G	R /	AR	A (1	8 ())	•	2	870
		+ >	(E	60	R	۲L	C	18	30) (, X	61	.F	A F	ł A	()	8 1	0),	XI	BL	. A	1(1	80))	•)	ΧB	8	0 V	Ľ	P (1	80) (•											2	880
		+)	(B	0 1	' A	RA	C .	18	30) (X	ec) V (FF	C	(1	8	0) •	X	BN	IF	LA	G	(1	8 1	0 3),	X	TR	A	DC	1	80))	, X	τ	GF	R N	R /	A (18	30)			2	890
		+ X	(T	LF	A	R A	(18	30) (, X	TL	. A :	[1	8())	•	ΧT	B	o v	Ľ	Ρ(1	80))																					2	900
*			• •	M 14					-		· /	~		~ ~		Ŧ /			••	,	~ •		• •		~ /		~ .	• •		~ ~		~~			•						~		. ,	•			2	910
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		+ (•	• 3	•	5 .	1	• 5	•	• 1	•	•7		2.	2	•	•	•	• 0	•	0.	٠	5.	.5	•]	•	5	• •	4	••	7	• 2	•	2•	7.	• •	0	• 1	•								3	030
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		+ 0		• 5		5.	1			. 4	• •	.7		2 -	2			• 1	0	•		-	5-	5	• 1		5		4	• •	7	• 2		2 •	7.		0	• •	,								3	090
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		+ 0	•	, 5	i !	5	1	• 5	•	• 4	۱,	• 8	3.	2 .	5	• 9	۶.	•	0.	•	0.		5.	5	• 1		5		4	• •	8	, 2	•	5,	9	• •	0	• •	,								3	120
		+ 0	•	• 5	• !	5•	1	• 5	5 •	• 4	••	• 8	3 • 2	2 •	5	• 9	•	,	0 •	•	0 .		5.	5	• 1	L .	5	• •	4	• •	8	, 2	•	5,	9.	• •	0	• /	1								3	130
		0) A (T A	. ((S	H.	A C)E	()	1,	N)		N =	:1	• 8	3)		M =	2	1.	3	0)	1																							3	140

+0.,5.5,1.5,.4,.8,2.5,9.,0.,0.,5.5,1.5,.4,.8,2.5,9.,0., 3150 +0.+5.5,1.5,.4,.8,2.5,9.+0.+0.+5.5,1.5,.4,.8,2.5,9.+0.+ 3160 +0.,5.5,1.5,.4,.8,2.5,9.,0.,0.,5.5,1.5,.4,.8,2.5,9.,0., 3170 +0.,5.5,1.5,.4,.8,2.5,9.,0.,0.,5.5,1.5,.4,.8,2.5,9.,0., 3180 +0.,5.5,1.5,.4,.8,2.5,9.,0.,0.,5.5,1.5,.4,.8,2.5,9.,0./ 3190 DATA((SHADE(M,N),N=1.8),M=31,40)/ 3200 +0.,9.,1.7..5,.9,2.2,0.,0.,9.,1.7,.5,.9,2.2,0.,0., 3210 +0.,9.,1.7,.5,.9,2.2,0.,0.,0.,9.,1.7,.5,.9,2.2,0.,0., 3220 +0.,9.,1.7,.5,.9,2.2,0.,0.,0.,9.,1.7,.5,.9,2.2,0.,0., 3230 +0.,9.,1.7,.5,.9,2.2,0.,0.,9.,1.7,.5,.9,2.2,0.,0., 3240 +0.,9.,1.7,.5,.9,2.2,0.,0.,0.,9.,1.7,.5,.9,2.2,0.,0./ 3250 DATA((SHADE(M+N)+N=1+8)+M=41+50)/ 3260 +0.,9.,1.7,.5,.9,2.2,0.,0.,0.,9.,1.7,.5,.9,2.2,0.,0., 3270 +0...9..1.7..5..9.2.2.0..0..9..1.7..5..9.2.2.0..0.. 3280 +0.,9.,1.7,.5,.9,2.2,0.,0.,0.,0.,2.,.6,1.,2.,0.,0., 3290 +0.,0.,2.,.6,1.,2.,0.,0.,0.,0.,2.,.6,1.,2.,0.,0., 3300 +0.,0.,2.,.6,1.,2.,0.,0.,0.,0.,2.,.6,1.,2.,0.,0./ 3310 DATA((SHADE(M.N),N=1.8),M=51.60)/ 3320 +0.+0.+2.+.6+1.+2.+0.+0.+0.+0.+2.+.6+1.+2.+0.+0.+ 3330 +0..0..2...6.1..2..0..0..0..0..2...6.1...2..0..0.. 3340 +0.,0.,2.,.6,1.,2.,0.,0.,0.,0.,0.,2.,.6,1.,2.,0.,0., 3350 +0.,0.,2.,.6,1.,2.,0.,0.,0.,0.,2.,.6,1.,2.,0.,0., 3360 +0.,0.,2.,.6,1.,2.,0.,0.,0.,0.,2.,.6,1.,2.,0.,0./ 3370 DATA((SHADE(M+N),N=1+8),M=61,70)/ 3380 +0.,0.,2.,.8,1.1,3.5,0.,0.,0.,0.,2.,.8,1.1,3.5,0.,0., 3390 +0.,0.,2.,.8,1.1,3.5,0.,0.,0.,0.,2.,.8,1.1,3.5,0.,0., 3400 +0..0..2...8.1.1.3.5.0..0..0..2...8.1.1.3.5.0..0.. 3410 +0.,0.,2.,.8,1.1,3.5,0.,0.,0.,0.,2.,.8,1.1,3.5,0.,0., 3420 +0-+0-+2-+-8+1-1+3-5+0-+0-+0-+2-+-8+1-1+3-5+0-+0-/ 3430 DATA((SHADE(M,N),N=1,8),M=71,80)/ 3440 +0.,0.,2.,.e,1.1,3.5,0.,0.,C.,0.,2.,.8,1.1,3.5,0.,0., 3450 +0.,0.,2.,.8,1.1,3.5,0.,0.,0.,0.,2.,.8,1.1,3.5,0.,0., 3460 +0.,0.,2.,.8,1.1,3.5,0.,0.,0.,0.,2.,1.,1.2,5.,0.,0., 3470 +0.,0.,2.,1.,1.2,5.,0.,0.,0.,0.,2.,1.,1.2,5.,0.,0., 3480 +0.,0.,2.,1.,1.2,5.,0.,0.,0.,0.,2.,1.,1.2,5.,0.,0./ 3490 DATA((SHACE(M+N)+N=1+8)+M=81+90)/ 3500 +0.,0.,2.,1.,1.2,5.,0.,0.,0.,0.,2.,1.,1.2,5.,0.,0., 3510 +0.,0.,2.,1.,1.2,5.,0.,0.,0.,0.,2.,1.,1.2,5.,0.,0., 3520 +0.,0.,2.,1.,1.2,5.,0.,0.,0.,2.,1.,1.2,5.,0.,0., 3530 +0.,0.,2.,1.,1.2,5.,0.,0.,0.,0.,2.,1.,1.2,5.,0.,0., 3540 +0.,0.,2.,1.,1.2,5.,0.,0.,0.,0.,2.,1.,1.,2,5.,0.,0./ 3550 DATA((SHADE(M,N),N=1,8),M=91,101)/ 3560 +0.,0.,3.,1.5,2.,8.,0.,0.,0.,3.,1.5,2.,8.,0.,0., 3570 +0.,0.,3.,1.5,2.,8.,0.,0.,0.,0.,3.,1.5,2.,8.,0.,0., 3580 +0.,0.,3.,1.5,2.,8.,0.,0.,0.,0.,3.,1.5,2.,8.,0.,0., 3590 +0.+0.+3.+1.5+2.+8.+0.+0.+0.+0.+3.+1.5+2.+8.+0.+0.+ 3600 +0.+0.+3.+1.5+2.+8.+0.+0.+0.+0.+3.+1.5+2.+8.+0.+0.+ 3610 +0..0..3..1.5.2..8..0..0./ 3620 3630 CALL DISCON(6LOUTPUT) 3640 **REWIND 61** 3650 CALL CONNEC(6LOUTPUT) 3660 3670 3680 3690 * RETURN TO THIS POINT IF A FURTHER RUN IS REQUIRED 3700 3710 1000 CONTINUE 3720 **REWIND 10** 3730 REWIND 20 3740 REWIND 30 3750

٠

```
3760
* INITIALIZE ALL NECESSARY VARIABLES AND CONSTANTS.
                                                                          3770
                                                                          3780
     BBDIST=.05
                                                                          3790
     BNPLANT=1
                                                                          3800
     COUNTER=0
                                                                          3810
     HARVEST=52
                                                                          3820
     PRINTYP=1
                                                                          3830
     TTDIST=.8
                                                                          3840
     MBNRADB=•327 + •632*ALOG10(TTDIST)
                                                                          3850
*
                                                                          3860
٠
                                                                          3870
* CONFIRM INITIAL VALUES OF VARIABLES WHICH MAY BE CHANGED. ASK FOR
                                                                          3880
* ANY NEW VALUES.
                                                                          3890
                                                                          3900
     PRINT 101
                                                                          3910
101
     FORMAT(+0++5X++THESE ARE THE INITIAL VALUES+)
                                                                          3920
     PRINT 102, TTDIST
                                                                          3930
102 FORMAT(+0++10X++TOMATO-TOMATO DISTANCE IN METERS++F10+2)
                                                                          3940
     PRINT 103, BEDIST
                                                                          3950
103 FORMAT(+0+,10X,+BEAN-BEAN DISTANCE IN METERS+,F14.2)
                                                                          3960
     PRINT 104, BNPLANT
                                                                          3970
1C4 FORMAT(+0++10X++BEAN PLANTING DATE IN HODEL DAYS++I10)
                                                                          3980
     PRINT 105. HARVEST
                                                                          3990
105 FORMAT(+0+,10X,+BEAN HARVEST DATE IN MODEL DAYS+,111)
                                                                          4000
      PRINT 106. PRINTYP
                                                                          4010
106 FORMAT(+0+,10X,+PRINT TYPE ( 1 = DAILY AT 1200 AND 2400 HR, 2 = DA4020
    +ILY AT 2400 HR. 3 = FINAL VALUES ONLY. 4 = FINAL YIELD ONLY )*, I3)4030
     PRINT 107
                                                                          4040
107 FORMAT(+0+•5X++DO YOU WANT TO MAKE ANY CHANGES+ YES OR NO?+)
                                                                          4050
     READ 108. I1
                                                                          4060
108 FORMAT(A2)
                                                                          407C
     IF(I1.EQ.2HNO) GO TO 129
                                                                          4080
     PRINT 109
                                                                          4090
109 FORMAT(*0*•5X•*CHANGE TOMATO-TOMATO CISTANCE• YES OR NO?*)
                                                                          4100
     READ 110, 12
                                                                          4110
110 FORMAT(A2)
                                                                          4120
      IF(I2.EQ.2HNO) GO TO 112
                                                                          4130
     PRINT 111
                                                                          4140
111 FORMAT(+0++10X++TYPE NEW VALUE OF TTCIST ( IN METERS )+)
                                                                          4150
     READ*+ TTDIST
                                                                          4160
112 PRINT 113
                                                                          4170
113 FORMAT(+0+,5X,+CHANGE BEAN-BEAN DISTANCE, YES OR NO?+)
                                                                          4180
     READ 114, I3
                                                                          4190
114 FORMAT(A2)
                                                                          4200
      IF(I3.EQ.2HNO) GO TO 116
                                                                          4210
     PRINT 115
                                                                          4220
115 FORMAT(+0++10X++TYPE NEW VALUE OF BBDIST ( IN METERS )+)
                                                                          4230
      READ*,BBDIST
                                                                          4240
116
     PRINT 117
                                                                          4250
117 FORMAT(+0++5X++CHANGE BEAN PLANTING DATE+ YES OR NO?+)
                                                                          4260
      READ 118, 14
                                                                          4270
118 FORMAT(A2)
                                                                          4280
      IF(I4.EQ.2HNO) GO TO 120
                                                                          4290
     PRINT 119
                                                                          4300
119 FORMAT(+0+,10X,+TYPE NEW VALUE OF BNPLANT ( IN MODEL DAYS )+)
                                                                          4310
     READ*. BNPLANT
                                                                          4320
120
     PRINT 121
                                                                          4330
121 FORMAT(+0++5X++CHANGE BEAN HARVEST DATE, YES OR NO?+)
                                                                          4340
     READ 122, 15
                                                                          4350
122 FORMAT(A2)
                                                                          4360
```

IF(I5.EC.2HNO) GO TO 124 4370 PRINT 123 4380 123 FORMAT(*C*+10X+*TYPE NEW VALUE OF BEAN HARVEST (IN MODEL DAYS)*)4390 READ+, HARVEST 440G 124 PRINT 125 4410 125 FORMAT(+0++5X++CHANGE PRINT TYPE+ YES OR NO?+) 4420 READ 126, 16 4430 126 FORMAT(A2) 4440 IF(I6.E0.2HNO) GO TO 129 4450 PRINT 127 4460 FORMAT(+0+,10X,+TYPE NEW VALUE OF PRINTYP+) 127 4470 READ+, PRINTYP 4480 4490 * 129 HBBDIST=BBDIST/2. 4500 HTTDIST=TTDIST/2. 4510 4520 4530 PRINT 130 ******************* 4550 4560 * THE FOLLOWING DO LOOP CONTROLS THE SIMULATION. VARIABLE VALUES ARE 4570 STORED EACH 12 HOURS AND PRINTED IN ONE BLOCK AFTER THE RUN IS ŧ 4580 + COMPLETED. 4590 460C * +4620 +4630 ٠ * COMMENCE DO LOOP 4640 4650 I = 0 4660 4670 DO 100 K=1,81 4680 4690 DAY=K 4700 4710 ٠ CALL WEATHER 4720 4730 ٠ DO 200 IHR=1,24 474C 4750 ٠ COUNTER=IHR 4760 4770 * IF(COUNTER.EQ.12.OR.COUNTER.EQ.24) I=I+1 4780 4790 * CALL WATER 4800 4810 CALL PHOTO 4820 4830 CALL BNPART 4840 4850 CALL TOMPART 4860 4870 * CALL CANOPY 4880 4890 CALL YIELD 4900 4910 CONTINUE 200 4920 CONTINUE 4930 100 +4940 ٠ + +4950 4970

```
4980
* PRINT HOURLY, DAILY OR SEASONAL VALUES AS REQUESTED BY PRINTYP
                                                                                                                                      4990
                                                                                                                                      5000
          PRINT***CONTINUE OUTPUT ON DECURITER??*
                                                                                                                                      5010
          READ 1234, IANS
                                                                                                                                      5020
 1234 FORMAT(A1)
                                                                                                                                      5030
           IF(IANS.EG.1HY) GO TO 1235
                                                                                                                                      5040
          CALL DISCON (6LOUTPUT)
                                                                                                                                      5050
 1235 CONTINUE
                                                                                                                                      5060
          IF(PRINTYP.EQ.1) GO TO 900
                                                                                                                                      5070
           IF(PRINTYP.EQ.2) GO TO 910
                                                                                                                                      5080
           IF(PRINTYP.EC.3) GO TO 920
                                                                                                                                      5090
          IF(PRINTYP.EQ.4) GO TO 925
                                                                                                                                      5100
٠
                                                                                                                                      5110
                                                                                                                                      5120
*
      .
             . . . . . . . . . .
                                                                      .
                                                                                           * * *
                                                                                                                                      5130
                                                                                                                                      5140
                                                                                                                                      5150
*
                                                                                                                                      5160
                                              *****************
•
                                                                                                                                      5170
                                                    12 HOURLY PRINT
                                                                                                                                      5180
                                                                                                                                      5190
                                                                                                                                      5200
                                              *****************
                                                                                                                                      5210
* THIS SECTION PRINTS VARIABLE VALUES EVERY 1200 HR AND 2400 HR.
                                                                                                                                      5220
                                                                                                                                      5230
* PRINT FOR SUBROUTINE PHOTO
                                                                                                                                      5240
                                                                                                                                      5250
٠
 900
          PRINT 150
                                                                                                                                      5260
          FORMAT(+112 HOURLY PRINT FOR SUBROUTINE PHOTO+)
 150
                                                                                                                                      527 C
          PRINT 21
                                                                                                                                      5280
 21
          FORMAT(*-DAY I COUNTER ENERGY TEMP RAIN RELHUM WINDSPD MONTH DAT5290
         +E JMONTH JDATE IMONTH IDATE
                                                                          I BNPLANT HARVEST+)
                                                                                                                                      5300
          PRINT 22. (XDAY(I).XI(I).XCCUNTR(I).XENERGY(I).XTEMP(I).XRAIN(I).
                                                                                                                                      5310
         +XRELHUM(I),XUINDSP(I),XMONTH(I),XDATE(I),XJMONTH(I),XJDATE(I),
                                                                                                                                      5320
         +XIMONTH(I),XIDATE(I),XI(I),XBNPLAN(I),XHARVES(I),I=1,162,161)
                                                                                                                                      5330
 22
         FORMAT(I3,2X,I3,1X,I4,4X,F5.1,2X,F4.1,1X,F4.2,1X,F5.2,1X,F7.1,2X,
                                                                                                                                      5340
         +I4,2X,I3,4X,I4,1X,I4,2X,I4,3X,I4,3X,I8,4X,I2,6X,I2)
                                                                                                                                      5350
          PRINT 701
                                                                                                                                      5360
 701 FORMAT(+1 I DAY CANDRES DELTA EVAPOTN VOLS1
                                                                                                           DVOL
                                                                                                                          DSWC
                                                                                                                                     5370
         SWC RTDEPTH SWPOT LEWPOTL CUMIRGN CUMRAIN CUMEVAP
                                                                                                                      VAPSAT V5380
         +APTEMP+)
                                                                                                                                      5390
          PRINT 702, (XI(I), XDAY(I), XCANDRE(I), XDELTA(I), XEVAPOT(I), XVOLS1(I)5400
         +,XDVOL(I),XDSWC(I),XSWC(I),XRTDEPT(I),XSWPOT(I),XLFWPOT(I),
                                                                                                                                      5410
         +XCUHIRG(I),XCUMRAI(I),XCUMEVA(I),XVAPSAT(I),XVAPTEH(I),I=1,162)
                                                                                                                                      5420
 702 FORMAT(1X+I3+1X+I3+1X+F7-2+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3+1X+F7-3
                                                                                                                                      5430
         +F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F7.2,1X,F7.2,1X,F7.2,1X,
                                                                                                                                      5440
         +F7.3.1X.F7.2)
                                                                                                                                      5450
          PRINT 23
                                                                                                                                      5460
          FORMAT(+1 I DAY ENERGY AVENRGY
 23
                                                                         $1
                                                                                        $2
                                                                                                     $3
                                                                                                                   S4
                                                                                                                                $5 5470
                  S6
                              S7 TLFRESP TPNRATE TPHSATE TCUMPHD*)
                                                                                                                                      5480
          PRINT 24.(XI(I).XDAY(I).XENERGY(I).XAVENGY(I).XS1(I).XS2(I).
                                                                                                                                      5490
         +XS3(I),XS4(I),XS5(I),XS6(I),XS7(I),XTLFRSP(I),XTPNRTE(I),
                                                                                                                                      5500
         *XTPHSTE(I),XTCUMPH(I),I=1,162)
                                                                                                                                      5510
 24
          FORMAT(1X+I3+1X+I3+1X+F6+2+1X+F7+2+1X+F6+2+1X+F6+2+1X+F6+2+1X+
                                                                                                                                      5520
         +F6.201X+F6.201X+F6.201X+F6.201X+F7.401X+F7.401X+F7.401X+F7.40
                                                                                                                                      5530
          PRINT 25
                                                                                                                                      5540
                             I DAY BLFRESP BPNRATE BPHSATE BCUMPHD BNHIGHT BNSHADE 5550
 25
          FORMAT(+1
         +TSHADE TGRSHDE STPNRTE TPNRTE SHACE TRESP BRESP+)
                                                                                                                                      5560
          PRINT 26+(XI(I)+XDAY(I)+XBLFRSP(I)+XBPNRTE(I)+XBPHSTE(I)+
                                                                                                                                      5570
         *XBCUMPH(I),XBNHIGH(I),XBNSHDE(I),XTSHADE(I),XTGRSHD(I),
                                                                                                                                      5580
```

+XSTPNRT(I),XTPNRTE(I),XSHADE(I),XTRESP(I),XBRESP(I),I=1,162) 5590 26 FORMAT(1X, I3, 1X, I3, 1X, F7, 4, 1X, F7, 4, 1X, F7, 4, 1X, F7, 4, 1X, F7, 3, 1X, 5600 +F7.3,1X,F6.3,1X,F7.5,1X,F7.4,1X,F7.4,1X,F4.2,1X,F5.3,1X,F5.3) 5610 5620 PRINT FOR SUBROUTINE BNPART 5630 5640 PRINT 151 5650 FORMAT(+112 HOURLY PRINT FOR SUBROUTINE BNPART+) 151 5660 PRINT 27 5670 FORMAT(*- I DAY COUNTER BPHSATE BCSTORE POOLCHK BCHODMD BCPOOL BT5680 27 •RLCTE BERDMD BLFDMD BRTDMD BSTDMD BRERDMD BRLFDMD BRRTDMD BRSTDMD 5690 +BSUMDM0+) 5700 PRINT 28.(XI(I), XDAY(I), XCOUNTR(I), XBPHSAT(I), XBCSTOR(I), XPOOLCK(I5710 +),XBCHODM(I),XBCPOOL(I),XBTRLCT(I),XBFRDMD(I),XBLFDMD(I),XBRTDMD(I5720 +) + XBSTDMC(I) + XBRFRDM(I) + XBRLFDM(I) + XBRRTDM(I) + XBRSTDM(I) + XBSUMDM(I5730 5740 +) • I=1 • 162) FORMAT(1X, I3, 1X, I2, 3X, I2, 4X, F7.4, 1X, F 28 5750 **+**F6.3,1X,F7.4,1X,F5.2,1X,F6.2,1X,F6.3,1X,F6.2,1X,F7.4,1X, 5760 +F7.4,1X,F7.4,1X,F7.4,1X,F7.3) 5770 PRINT 29 5780 FORMAT(+1 I DAY COUNTER BERINCE BLEINCE BETINCE BSTINCE BDRYFE BC5790 29 +RYLF BORYRT BORYST+) 5800 PRINT 30,(XI(I),XDAY(I),XCOUNTR(I),XBFRINC(I),XBLFINC(I),XBRTINC(I5810 +),XBSTINC(I),XBDRYFR(I),XBDRYLF(I),XEDRYRT(I),XEDRYST(I), 5820 +I=1.162) 5830 30 5840 5850 **+F6.2**,1X,F6.2,1X,F6.2,1X,F6.2) 5860 *** PRINT FOR SUBROUTINE TOMPART** 5870 5880 PRINT 152 5890 152 FORMAT(+112 HOURLY PRINT FOR SUBROUTINE TOMPART+) 5900 5910 PRINT 31 31 FORMAT(+- I DAY COUNTER TPHSATE TCSTORE POOLCHK TCHODMD TCPOCL TT5920 +RLCTE TFROMD TLFOND TRTDMD TSTDMD TRFROMD TRLFDMD TRRTDMD TRSTDMD 5930 +TSUMDMD+) 5940 PRINT 32,(XI(I),XDAY(I),XCOUNTR(I),XTPHSAT(I),XTCSTOR(I),XPOOLCH(15950 +),XTCHODH(I),XTCPOOL(I),XTTRLCT(I),XTFRDMD(I),XTLFDMD(I),XTRTDMD(I5960 +) • XTSTDMD(I) • XTRFRDM(I) • XTRLFDM(I) • XTRRTDM(I) • XTRSTDM(I) • XTSUMCM(I5970 +),I=1,162) 5980 32 5996 **+F6.3**,1X,F7.4,1X,F6.2,1X,F6.2,1X,F6.3,1X,F6.2,1X,F7.4,1X, 6000 +F7.4,1X,F7.4,1X,F7.4,1X,F7.3) 6010 PRINT 33 6020 FORMAT(+1 I DAY COUNTER TFRINCR TLFINCR TRTINCR TSTINCR TDRYFR TD6030 33 +RYLF TDRYRT TDRYST+) 6040 PRINT 34,(XI(I),XDAY(I),XCOUNTR(I),XTFRINC(I),XTLFINC(I),XTRTINC(I6050 +) • XTSTINC(I) • XTDRYFR(I) • XTDRYLF(I) • XTDRYRT(I) • XTDRYST(I) • 6060 +I=1,162) 6070 FORMAT(1X,13,1X,12,3X,12,4X,F7.4,1X,F7.4.1X,F7.4.1X. 34 6080 +F7.4,1X,F6.2,1X,F6.2,1X,F6.2,1X,F6.2) 6090 6100 PRINT FOR SUBROUTINE CANOPY 6110 6120 PRINT 153 6130 FORMAT(+112 HOURLY PRINT FOR SUBROUTINE CANOPY+) 6140 153 PRINT 35 6150 DAY COUNTER MODE BNRADA BNRADB BGRAREA BDRYLF EBDRYLF6160 35 FORMAT(= I + BLFAREA BLAI BBOVLP BOVAREA BOVFRCT BNFLAG*) 6170 PRINT 36.(XI(I).XDAY(I).XCOUNTR(I).IMODE(I).XBNRADA(I).XBNRADB(I).6180 +XBGRARA(I),XBDRYLF(I),XEBDRYL(I),XBLFARA(I),XBLAI(I),XBBOVLP(I), 6190

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15	4	1	FC)R	Μ.	A 1	(*	1	12	?	H	cυ	IR	LY	,	PI	R]	[N	T.	F	OR	2	SU	B	RO	U	ΤI	N	E	Y:	ΙE	L	D *)												6	320
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		+	XE	3 Y	L	D٢	12	(I),	X	5.3	YL	D	нс	: (I),	, X	TF	R	FS	۲	(1)	• X	T	۲L	D	НΧ	(I)	•)	ΧT	YI	D	Μ2	2 (I)	•							6	450
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SVC RTCEPTH SWPOT LEWPOTL CUMIRGN CUMRAIN CUMEVAP VAPSAT V6810 +APTEMP+) 6820 PRINT 704, (XI(I), XDAY(I), XCANDRE(I), XDELTA(I), XEVAPOT(I), XVOLS1(I)6830 +,XDVOL(I),XDSWC(I),XSWC(I),XRTDEPT(I),XSWPOT(I),XLFWPOT(I), 6840 +XCUMIRG(I),XCUMRAI(I),XCUMEVA(I),XV4PSAT(I),XV4PTEM(I),I=2,162,2) 6850 704 FORMAT(1X+13+1X+I3+1X+F7.2+1X+F7.3 6860 +F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F7.2,1X,F7.2,1X,F7.2,1X 6870 +F7.3,1X,F7.2) 6880 PRINT 45 6890 I DAY ENERGY AVENRGY 45 FORMAT(#1 S 1 S2 S 3 **S4** S5 6900 **\$6** TLFRESP TPNRATE TPHSATE TCUMPHD*) \$7 6910 PRINT 46.(XI(I),XDAY(I),XENERGY(I),XAVENGY(I),XS1(I),XS2(I), 6920 *XS3(I) *XS4(I) *XS5(I) *XS6(I) *XS7(I) *XTLFRSP(I) *XTPNRTE(I) * 6930 6940 +XTPHSTE(I),XTCUMPH(I),I=2,162,2) 6950 46 FORMAT(1X+I3+1X+I3+1X+F6+2+1X+F7+2+1X+F6+2+1X+F6+2+1X+F6+2+1X+ +F6.2,1X,F6.2,1X,F6.2,1X,F6.2,1X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4) 6960 PRINT 47 6970 47 FORMAT(+1 I DAY BLFRESP BPNRATE BPHSATE BCUMPHD BNHIGHT BNSHADE 6980 ***TSHADE TGRSHDE STPNRTE TPNRTE SHADE TRESP BRESP*)** 6990 PRINT 48,(XI(I),XDAY(I),XBLFRSP(I),XBFNRTE(I),XBPHSTE(I), 7000 *XBCUMPH(I),XBNHIGH(I),XBNSHDE(I),XTSHADE(I),XTGRSHD(I), 7010 *XSTPNRT(I) *XTPNRTE(I) *XSHADE(I) *XTRESP(I) *XBRESP(I) *I=2*162*2) 7020 48 FORMAT(1X+I3+1X+I3+1X+F7+4+1X+F7+4+1X+F7+4+1X+F7+4+1X+F7+3+1X+ 7030 *F7.391X9F6.391X9F7.591X9F7.491X9F7.491X9F4.291X9F5.391X9F5.3) 7040 7050 * PRINT FOR SUBROUTINE BNPART 7060 7070 PRINT 156 7080 156 FORMAT(+1DAILY PRINT FOR SUBROUTINE ENPART+) 7090 PRINT 49 7100 49 FORMAT(=- I DAY COUNTER BPHSATE BCSTORE POOLCHK BCHODMD BCPOOL BT7110 **+RLCTE BFRDMD BLFDMD BRTDMD BSTDMD BRFRDMD BRLFDMD BRRTDMD BRSTCMD 7120** +BSUMDMD+) 7130 PRINT 50+(XI(I)+XDAY(I)+XCOUNTR(I)+XPHSAT(I)+XBCSTOR(I)+XPOOLCK(I7140 +) + XBCHODM(I) + XBCPOOL(I) + XBTRLCT(I) + XBFRDMD(I) + XBLFDMD(I) + XBRTDMD(I7150 +) + XBSTDMD(I) + XBRFRDM(I) + XBRLFDM(I) + XBRRTDM(I) + XBRSTDM(I) + XBSUMDM(I7160 +),I=2,162,2) 7170 50 FORMAT(1X,13,1X,12,3X,12,4X,F7,4,1X,F7,4,1X,F7,4,1X,F7,4,1X,F7,4,1X, 7180 ***F6.3**,1X,F7.4,1X,F6.2,1X,F6.2,1X,F6.3,1X,F6.2,1X,F7.4,1X, 7190 +F7.4,1X,F7.4,1X,F7.4,1X,F7.3) 7200 PRINT 51 7210 51 FORMAT(+1 I DAY COUNTER BFRINCR BLFINCR BRTINCR BSTINCR BDRYFR BD7220 +RYLF BDRYRT BDRYST*) 7230 PRINT 52+(XI(I)+XDAY(I)+XCOUNTR(I)+XBFRINC(I)+XBLFINC(I)+XBRTINC(I7240 *) * XBSTINC(I) * XBDRYFR(I) * XBDRYLF(I) * XBDRYRT(I) * XBDRYST(I) * 7250 +I=2+162+2) 7260 52 FORMAT(1X+I3,1X+I2+3X+I2+4X+F7+4+1X+F7+4+1X+F7+4+1X+F7+4+1X+F7+4+1X+ 7270 +F6.2,1X,F6.2,1X,F6.2,1X,F6.2) 7280 7290 *** PRINT FOR SUBROUTINE TOMPART** 7300 7310 PRINT 157 7320 157 FORMAT(+1CAILY PRINT FOR SUBROUTINE TOMPART+) 7330 PRINT 53 7340 53 FORMAT(-- I DAY COUNTER TPHSATE TCSTORE POOLCHK TCHODMD TCPOOL TT7350 ***RLCTE TFRDMD TLFDMD TRTDMD TSTDMD TRFRDMD TRLFDMD TRRTDMD TRSTDMD 7360** +TSUMDMD+) 7370 PRINT 54,(XI(I),XDAY(I),XCOUNTR(I),XTPHSAT(I),XTCSTOR(I),XPOOLCH(I7380 +) +XTCHODM(I) +XTCPOOL(I) +XTTRLCT(I) +XTFROMD(I) +XTLFDMD(I) +XTRTDMD(I7390 +> *XTSTDMD(I) *XTRFRDM(I) *XTRLFDM(I) *XTRRTDM(I) *XTRSTDM(I) *XTSUMDM(I7400 $+) \cdot I = 2 \cdot 162 \cdot 2)$ 7410

54 7420 **+F6.3**,1X,F7.4,1X,F6.2,1X,F6.2,1X,F6.3,1X,F6.2,1X,F7.4,1X, 7430 7440 +F7.4.1X.F7.4.1X.F7.4.1X.F7.3) PRINT 55 7450 FORMAT(*1 I DAY COUNTER TERINCR TLEINCR TRTINCR TSTINCR TDRYFR TD7460 55 +RYLF TDRYRT TDRYST*) 7470 PRINT 56 (XI(I) + XDAY(I) + XCOUNTR(I) + XTFRINC(I) + XTLFINC(I) + XTRTINC(I7480 +),XTSTINC(I),XTDRYFR(I),XTDRYLF(I),XTDRYRT(I),XTDRYST(I), 7490 +I=2,162,2) 7500 56 FORMAT(1X,13,1X,12,3X,12,4X,F7,4,1X,F7,4,1X,F7,4,1X, 7510 +F7.4.1X.F6.2.1X.F6.2.1X.F6.2.1X.F6.2. 7520 7530 ٠ * PRINT FOR SUBROUTINE CANOPY 7540 7550 PRINT 158 7560 158 FORMAT(+1DAILY PRINT FOR SUBROUTINE CANOPY +) 7570 PRINT 57 7580 FORMAT (*- I DAY COUNTER MODE BNRADA BNRADB BGRAREA BDRYLF EBDRYLF7590 57 + ELFAREA BLAI BBOVLP BOVAREA BOVFRCT BNFLAG*) 7600 PRINT 58+(XI(I)+XDAY(I)+XCOUNTR(I)+IMODE(I)+XBNRADA(I)+XBNRADE(I)+7610 *X8GRARA(I),X8DRYLF(I),X8BDRYL(I),X8LFARA(I),X8LAI(I),X8B0VLP(I), 7620 *XBOVARA(I),XBOVFRC(I),XBNFLAG(I),I=2,162,2) 7630 58 FORMAT(1X:13+1X+12+4X+12+5X+11+2X+F6+3+1X+F6+3+1X+F7+5+1X+ 7640 +F6.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F6.3,1X,F7.3,1X,F7.5,1X,F6.2) 7650 PRINT 59 7660 59 FORMAT(*1 1 TRAD TGRAREA TDRYLF TLFAREA TLAI TBOVLP*) 7670 PRINT 60,(XI(I),XTRAD(I),XTGRARA(I),XTDRYLF(I),XTLFARA(I), 7680 +XTLAI(I), XTBOVLP(I), 1=2,162,2) 7690 60 FORMAT(1X+I3+F4+2+1X+F7+3+1X+F6+1+1X+F7+3+1X+F4+1+1X+F6+3) 7700 7710 * PRINT FOR SUBROUTINE YIELD 7720 7730 PRINT 159 7740 FORMAT(+1DAILY PRINT FOR SUBROUTINE YIELD+) 7750 159 PRINT 61 7760 FORMAT(+- I DAY COUNTER HTTDIST BBDIST HEXAREA HEXPHEC HEXCIRC TP7770 61 +OPLIN BPOPHEX BPOPHEC TOTLPOP+) 7780 PRINT 62,(XI(I),XDAY(I),XCOUNTR(I),XHTTDIS(I),XBBDIST(I), 7790 +XHEXARE(I),XHEXPHE(I),XHEXCIR(I),XTPOPLT(I),XBPOPHX(I),XBPOPHC(I),7800 *XTOTLPO(I),I=2,162,160) 7810 FORMAT(1X, I3, 1X, I2, 3X, I2, 6X, F4.2, 3X, F4.2, 3X, F5.3, 3X, 62 7820 +F6.0,1X,F7.2,1X,F7.0,1X,F7.0,1X,F7.0,1X,F7.0) 7830 PRINT 63 7840 63 FORMAT(*1 I DAY COUNTER SFRFRT BYLDHEX BYLDM2 BYLDHEC TFRFRT TYLD7850 +HEX TYLOM2 TYLDHEC SYLDHEX SYLCH2 SYLDHEC+) 7860 PRINT 64.(XI(I),XDAY(I).XCOUNTR(I).XBFRFRT(I).XBYLDHX(I). 7870 +XBYLDM2(I),XBYLDHC(I),XTFRFRT(I),XTYLDHX(I),XTYLDM2(I), 7880 +XTYLDHC(I),XSYLDHX(I),XSYLDM2(I),XSYLDHC(I),I=2,162,2) 7890 FORMAT(1X,13,1X,12,3X,12,4X,F6.3,1X,F7.3,1X,F6.3,1X,F7.0,1X, 64 7900 +F6.3,1X,F7.3,1X,F6.3,1X,F7.0,1X,F7.3,1X,F6.3,1X,F7.0) 7910 7920 ٠ GO TO 930 7930 7940 ٠ * * * * * * * * * * * * * * 7950 7960 ٠ 7970 7980 7990 * * * * * * * * * * ٠ 8000 8010 * ********************* 8020

8030 FINAL VALUES PRINT 8040 8050 8060 8070 * THIS SECTION PRINTS FINAL VALUES ONLY FOR ALL VARIABLES REPRESENTED 8080 * IN THE TWO PRECEDING PRINT SECTIONS. 8090 8100 * PRINT FOR SUBROUTINE PHOTO 8110 8120 920 I=162 8130 8140 PRINT 160 8150 160 FORMAT(+1FINAL VALUES PRINT FOR SUBROUTINE PHOTO+) 8160 PRINT 65 8170 65 FORMAT(+-DAY I COUNTER ENERGY TEMP RAIN RELHUM VINUSPD MONTH DAT8180 +E JMONTH JDATE IMONTH IDATE I BNPLANT HARVEST+) 8190 PRINT 66, (XDAY(I), XI(I), XCOUNTR(I), XENERGY(I), XTEMP(I), XRAIN(I), 8200 *XRELHUM(I),XWINDSP(I),XMONTH(I),XDATE(I),XJMONTH(I),XJDATE(I), 8210 *XIMONTH(I) *XIDATE(I) *XI(I) *XBNPLAN(I) *XHARVES(I)) 8220 FORMAT(I3,2X,I3,1X,I4,4X,F5.1,2X,F4.1,1X,F4.2,1X,F5.2,1X,F7.1,2X, 66 8230 +I4.2X.I3.4X.I4.1X.I4.2X.I4.3X.I4.3X.I8.4X.I2.6X.I2) 8240 PRINT 705 8250 705 FORMAT(+1 T DAY CANDRES DELTA EVAPOTN VOLSI DVOL DSWC 8260 SWPOT LEWPOTL CUMIRGN CUMRAIN CUMEVAP + SWC RTDEPTH VAPSAT V8270 +APTEMP+) 8280 PRINT 7C6+(XI(I)+XDAY(I)+XCANDRE(I)+XDELTA(I)+XEVAPOT(I)+XVOLS1(I)8290 +•XDVGL(I)•XDSUC(I)•XSWC(I)•XRTDEPT(I)•XSWPOT(I)•XLFWPOT(I)• 8300 *XCUMIRG(I),XCUMRAI(I),XCUMEVA(I),XVAPSAT(I),XVAPTEM(I)) 8310 8320 +F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F7.2,1X,F7.2,1X,F7.2,1X,F7.2,1X, 8330 +F7.3.1X.F7.2) 8340 PRINT 67 8350 67 FORMAT(#1 I DAY ENERGY AVENRGY \$1 \$2 \$4 \$5 8360 \$3 TLFRESP TPNRATE TPHSATE TCUMPHD*) \$7 **S6** 8370 PRINT 68,(XI(I),XDAY(I),XENERGY(I),XAVENGY(I),XS1(I),XS2(I), 8380 *XS3(I) *XS4(I) *XS5(I) *XS6(I) *XS7(I) *XTLFRSP(I) *XTPNRTE(I) * 8390 +XTPHSTE(I),XTCUMPH(I)) 8400 FORMAT(1X, I3, 1X, I3, 1X, F6.2, 1X, F7.2, 1X, F6.2, F6. 68 8410 +F6.2,1X,F6.2,1X,F6.2,1X,F6.2,1X,F7.4,1X,F7.4,1X,F7.4,1X,F7.4, 8420 PRINT 69 8430 I DAY BLFRESP BPNRATE BPHSATE BCUMPHD BNHIGHT BNSHADE 8440 69 FORMAT(#1 +TSHADE TGRSHCE STPNRTE TPNRTE SHADE TRESP BRESP*) 8450 PRINT 70.(XI(I).XDAY(I).XBLFRSP(I).XBPNRTE(I).XBPHSTE(I). 8460 +XBCUMPH(I),XBNHIGH(I),XBNSHDE(I),XTSHADE(I),XTGRSHD(I), 8470 *XSTPNRT(I),XTPNRTE(I),XSHADE(I),XTRESP(I),XBRESP(I)) 8480 FORMAT(1X+I3+1X+I3+1X+F7+4+1X+F7+4+1X+F7+4+1X+F7+4+1X+F7+3+1X+ 70 8490 +F7.301X+F6.301X+F7.501X+F7.401X+F7.491X+F4.201X+F5.301X+F5.3) 8500 8510 PRINT FOR SUBROUTINE BNPART ÷ 8520 8530 ٠ PRINT 161 8540 FORMAT(+1FINAL VALUES PRINT FOR SUBROUTINE BNPART+) 161 8550 8560 PRINT 71 FORMAT(+- I DAY COUNTER BPHSATE BCSTORE POOLCHK BCHODMD BCPOOL BT8570 71 +RLCTE BFRDMD BLFDMD BRTCMD BSTDMD BRFRDMD BRLFDMD BRRTDMD BRSTCMD 8560 +BSUMDMD+) 8590 PRINT 72,(XI(I),XDAY(I),XCOUNTR(I),XPHSAT(I),XBCSTOR(I),XPOOLCK(I8600 +),XBCHODM(I),XBCPOOL(I),XBTRLCT(I),XEFRDMD(I),XBLFDMD(I),XBRTDMD(I8610 +),XBSTDMD(I),XERFRDM(I),XBRLFDM(I),XERRTDM(I),XBRSTDM(I),XBSUMDM(I8620 +)) 8630

72 8640 *F6.3+1X+F7.4+1X+F6.2+1X+F6.2+1X+F6.3+1X+F6.2+1X+F7.4+1X+ 8650 +F7.4.1X.F7.4.1X.F7.4.1X.F7.3) 8660 PRINT 73 8670 FORMAT(-- I DAY COUNTER BERINCE BLEINCE BETINCE BETINCE BERYFE BD8600 73 +RYLF BDRYRT BDRYST+) 8690 PRINT 74+(XI(I)+XDAY(I)+XCOUNTR(I)+XBFRINC(I)+XBLFINC(I)+XBRTINC(I8700 +),XBSTINC(I),XBDRYFR(I),XBDRYLF(I),XPDRYRT(I),XBDRYST(I)) 8710 8720 74 +F6.2,1X,F6.2,1X,F6.2,1X,F6.2) 8730 8740 *** PRINT FOR SUBROUTINE TOMPART** 8750 8760 PRINT 162 8770 FORMAT(+1FINAL VALUES PRINT FOR SUBROUTINE TOMPART*) 8780 162 PRINT 75 8790 FORMAT(*- I DAY COUNTER TPHSATE TCSTORE POOLCHK TCHODMD TCPOOL TT8800 75 ◆RLCTE TFRDHD TLFDHD TRTDHD TSTDHD TRFRDHD TRLFDHD TRRTDHD TRSTCHD 8810 +TSUMDHD+) 8820 PRINT 76,(XI(I),XDAY(I),XCOUNTR(I),XTPHSAT(I),XTCSTOR(I),XPOOLCH(I8830 +),XTCH00M(J),XTCP00L(I),XTTRLCT(I),XTFRDMD(I),XTLFDMD(I),XTRTDMD(I8840 +) *XTSTDMD(I) *XTRFRDM(I) *XTRLFDM(I) *XTRRTDM(I) *XTRSTDM(I) *XTSUMDM(I8850 +)) 8860 76 FORMAT(1X+I3+1X+I2+3X+J2+4X+F7+4+1X+F7+1X+F7+1X+F7+1X+F7+4X+F7+1X+F7+4+1X+F7+1 8870 +F6.3,1X,F7.4,1X,F6.2,1X,F6.2,1X,F6.3,1X,F6.2,1X,F7.4,1X, 8880 +F7.4,1X,F7.4,1X,F7.4,1X,F7.3) 2890 8900 PRINT 77 77 FORMAT(*- I DAY COUNTER TERINCE TLEINCE TERINCE TERINCE TDEYER TD8910 +RYLF TORYRT TORYST*) 8920 PRINT 78,(XI(I),XDAY(I),XCOUNTR(I),XTFRINC(I),XTLFINC(I),XTRTINC(I8930 *) • XTSTINC(I) • XTDRYFR(I) • XTDRYLF(I) • XTDRYRT(I) • XTDRYST(I)) 8940 FORMAT(1X, I3, 1X, I2, 3X, I2, 4X, F7, 4, 1X, F7, 4, 1X, F7, 4, 1X, 78 8950 +F7.4.1X.F6.2.1X.F6.2.1X.F6.2.1X.F6.2.1X.F6.2) 8960 8970 PRINT FOR SUBROUTINE CANOPY * 8980 8990 ٠ FORMAT (+1FINAL VALUES PRINT FOR SUBROUTINE CANOPY+) 163 9000 PRINT 163 9010 PRINT 79 9020 79 FORMAT(*- I DAY COUNTER MODE BNRADA BNRADB BGRAREA BDRYLF EEDRYLF9030 BLAI BBOVLP BCVAREA BOVFRCT BNFLAG*) + BLFARFA 9040 PRINT 80+(XI(I)+XDAY(I)+XCOUNTR(I)+IMODE(I)+XBNRADA(I)+XBNRADB(I)+9050 +XBGRARA(I),XBDRYLF(I),XEBDRYL(I),XBLFARA(I),XBLAI(I),XBBOVLP(I), 9060 +XBOVARA(I),XBOVFRC(I),XBNFLAG(I)) 9070 8.0 FORMAT(1X+I3+1X+I2+4X+I2+5X+I1+2X+F6+3+1X+F6+3+1X+F7+5+1X+ 9080 +F6.3,1X,F7.3,1X,F7.3,1X,F7.3,1X,F6.3,1X,F7.3,1X,F7.5,1X,F6.2) 9090 PRINT 81 9100 81 FORMAT(+- I TRAD TGRAREA TDRYLF TLFAREA TLAI TBOVLP+) 9110 PRINT 82, (XI(I), XTRAD(I), XTGRARA(I), XTDRYLF(I), XTLFARA(I), 9120 +XTLAI(I),XTBOVLP(I)) 9130 82 FORMAT(1X+I3+F4-2+1X+F7-3+1X+F6-1+1X+F7-3+1X+F4-1+1X+F6-3) 9140 9150 PRINT FOR SUBROUTINE YIELD * 9160 9170 PRINT 164 9180 FORMAT(+1FINAL VALUES PRINT FOR SUBROUTINE YIELD+) 164 9190 PRINT 83 9200 FORMAT(*- I DAY COUNTER HTTDIST BBDIST HEXAREA HEXPHEC HEXCIRC TP9210 83 +OPLTN BPOPHEX BPOPHEC TOTLPOP+) 9220 PRINT 84, (XI(I), XDAY(I), XCOUNTR(I), XHTTDIS(I), XEBDIST(I), 9230 +XHEXARE(I),XHEXPHE(I),XHEXCIR(I),XTPOPLT(I),XBPOPHX(I),XBPOPHC(I),9240

+XTOTLFO(I)) 9250 84 FORMAT(1X, I3, 1X, I2, 3X, I2, 6X, F4, 2, 3X, F4, 2, 3X, F5, 3, 3X, 9260 +F6.0,1X,F7.2,1X,F7.0,1X,F7.0,1X,F7.0,1X,F7.0) 9270 PRINT 85 9280 85 FORMAT(+- I DAY COUNTER BFRFRT BYLDHEX BYLDH2 BYLDHEC TFRFRT TYLD9290 +HEX TYLDM2 TYLDHEC SYLDHEX SYLDM2 SYLDHEC*) 9300 PRINT 86.(XI(I).XDAY(I).XCOUNTR(I).XBFRFRT(I).XBYLDHX(I). 9310 *XBYLDM2(I),XBYLDHC(I),XTFRFRT(I),XTYLDHX(I),XTYLDM2(I), 9320 *XTYLDHC(I),XSYLDHX(I),XSYLDM2(I),XSYLDHC(I)) 9330 86 FORMAT(1X+I3+1X+I2+3X+I2+4X+F6+3+1X+F7+3+1X+F6+3+1X+F7+0+1X+ 9340 ***F6.3**,1X,F7.3,1X,F6.3,1X,F7.0,1X,F7.3,1X,F6.3,1X,F7.0) 9350 9360 GO TO 930 9370 9380 * * * * * * * * 9390 9400 9410 9420 9430 . . 9440 9450 *********** 9460 9470 YIELD PRINT 9480 9490 9500 ************** 9510 THIS SECTION PRINTS FINAL VALUES ONLY FOR THOSE VARIABLES PERTINENT TO9520 * YIELD. THIS INCLUDES SUCH VARIABLES AS THOSE FOR DAY, HEXAGON SIZE, 9530 * HEXAGON NUMBER, ETC. 9540 9550 925 I=162 9560 ٠ 9570 PRINT 87 9580 FORMAT(*-DAY I COUNTER ENERGY TEMP RAIN RELHUM WINDSPD MONTH DAT9590 87 +E JMONTH JDATE IMONTH IDATE I BNPLANT HARVEST*) 9600 PRINT 88+(XDAY(I)+XI(I)+XCOUNTR(I)+XENERGY(I)+XTEMP(I)+XRAIN(I)+ 9610 +XRELHUH(I),XWINDSP(I),XHONTH(I),XDATE(I),XJMONTH(I),XJDATE(I), 9620 +XIMONTH(I),XIDATE(I),XI(I),XBNPLAN(I),XHARVES(I)) 9630 88 FORMAT(I3,2X,I3,1X,I4,4X,F5,1,2X,F4,1,1X,F4,2,1X,F5,2,1X,F6,2,3X, 9640 +I4+2X+I3+4X+I4+1X+I4+2X+I4+3X+I4+3X+I8+4X+I2+6X+I2) 9650 PRINT 89 9660 89 FORMAT (+- I DAY COUNTER HTTDIST BBDIST HEXAREA HEXPHEC HEXCIRC TP9670 +OPLTN BPCPHEX BPOPHEC TOTLPOP+) 9680 PRINT 90,(XI(I),XDAY(I),XCOUNTR(I),XHTTDIS(I),XBBDIST(I), 9690 +XHEXARE(I),XHEXPHE(I),XHEXCIR(I),XTPOPLT(I),XBPOPHX(I),XBPOPHC(I),9700 +XTOTLPO(I)) 9710 90 FORMAT(1X+I3+1X+I2+3X+I2+6X+F4+2+3X+F4+2+3X+F5+3+3X+ 9720 +F6.0,1X,F7.2,1X,F7.0,1X,F7.0,1X,F7.0,1X,F7.0) 9730 PRINT 91 9740 91 FORMAT(+- I DAY COUNTER BERERT BYLDHEX BYLDHE2 BYLDHEC TERERT TYLD9750 +HEX TYLDM2 TYLDHEC SYLDHEX SYLDM2 SYLDHEC*) 9760 PRINT 92,(XI(I),XDAY(I),XCOUNTR(I),XBFRFRT(I),XBYLDHX(I), 9770 +XBYLDM2(I),XBYLDHC(I),XTFRFRT(I),XTYLDHX(I),XTYLDM2(I), 9780 *XTYLDHC(I) *XSYLDHX(I) *XSYLDM2(I) *XSYLDHC(I)) 9790 92 FORMAT(1X+I3+1X+I2+3X+I2+4X+F6-3+1X+F7-3+1X+F6-3+1X+F7-0+1X+ 9800 ***F6.3**,1X,F7.3,1X,F6.3,1X,F7.0,1X,F7.3,1X,F6.3,1X,F7.0) 9810 9820 930 CONTINUE 9830 9840 * * * * * * * * * * * * * * * * * 9850

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9860
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                                                              9870
    PRINT 939
                                                              9880
9900
    ENDFILE 61
                                                              9910
     CALL CONNEC (6LOUTPUT)
                                                              9920
                                                              9930
    PRINT 940
940 FORMAT(+0+,5X,+DO YOU WANT TO RUN AGAIN, YES OR NO?+)
                                                              9940
     READ 941. E
                                                              9950
941 FORMAT(A2)
                                                              9960
    IF(E.EQ.2HYE) GO TO 1000
                                                              9970
                                                              9980
    9990
٠
 .
                                                              10000
٠
     END
                                                              10010
                                                              10020
                                                              10030
*
   *****************
                     **********************************
**
                                                            + + 10040
                                                             +10050
                                                             +10060
٠
٠
                      ***************
                                                              10070
                                                              10080
                     SUBROUTINE WEATHER +
                                                              10090
٠
                                                              10100
                          *************
                                                              10110
                                                              10120
    SUBROUTINE WEATHER
                                                              10130
                                                              10140
٠
٠
                                                             +10160
              DEFINITION OF CONSTANTS AND VARIABLES
                                                             +10170
                                                             +10180
* COUNTER = COUNT OF NUMBER OF ITERATIONS DURING A PARTICULAR DAY
                                                             +10190
+ DÁY
        = DAYS AFTER COMMENCEMENT OF THE SIMULATION (FIRST DAY
                                                             +10200
         IS DEFINED AS DAY 1) DAY
٠
                                                             +10210
* ENERGY = LIGHT FLUX DENSITY INCIDENT AT TOP OF CANOPY
                                                  ₩ M**-2
                                                             +10220
+ TDAY
        = VARIANT OF DAY
                                                             +10230
+ IMONTH = VARIANT OF MONTH
                                                             +10240
        = VARIANT OF DAY
+ JDAY
                                                             +10250
* JMCNTH = VARIANT OF MONTH
                                                             +10260
* MONTH = MONTH OF THE YEAR
                                                             +10270
+ RAIN
        = PRECIPITATION M
                                                             +10280
* RELHUM = RELATIVE HUMIDITY
                                                             +10290
        = DRY BULB TEMPERATURE C
 TEMP
٠
                                                             +10300
* WINDSPD = WIND SPEED M S**-1
                                                             +10310
                                                             +10320
10340
* ESTABLISH REAL AND INTEGER VARIABLES
                                                              10350
                                                              10360
    INTEGER COUNTER+DAY+PRINTYP+XCCUNTR+XDAY+XI+XMONTH+XDATE+XJMONTH+ 10370
    XJDATE,XIMONTH,XIDATE,DATE,BNPLANT,HARVEST,XBNPLAN,XHARVES
                                                              10380
     REAL MONRADB, LFWPOTL
                                                              10390
                                                              10400
* ESTABLISH COMMON BLOCKS
                                                              10410
                                                              10420
     COMMON /MAIN/ BBDIST, BORYFR, BDRYLF, BCRYRT, BDRYST, BGRAREA, BLAI,
                                                              10430
    +BNRADA, BNRADB, BPHSATE, COUNTER, ENERGY (24), HTTDIST, RAIN,
                                                              10440
    +RELHUM(24),TDRYFR,TDRYLF,TDRYRT,TDRYST,TEMP(24),TGRAREA,TLAI,
                                                              10450
    *TPHSATE,TRAD,TTDIST,WINDSPD(24),I,SHADE(101,8),IHR,DAY,LFWPOTL.
                                                              10460
```

+H6BDIST+MONTH,DATE, IMONTH, IDATE, JMONTH, JDATE, 6NPLANT, HARVEST 10470 ٠ 10480 * 10490 * READ TEMPERATURE, WINDSPEED AND RELATIVE HUMIDITY DATA FROM NATIONAL 10500 * WEATHER SERVICE FILE EXTRACTS ON PERMANENT FILE. THE FOLLOWING DO 10510 * LOOPS POSITION THE START OF THE READ AT THE CORRECT DATE. 10520 10530 555 READ(10,100)MONTH, DATE, (TEMP(J), WINDSPD(J), RELHUM(J), J=1,24) 10540 100 FORMAT(16X+12+1X+12+20X+F2+0+1X+F2+0+1X+F3+0+23(6X+F2+0+1X+F2+0+1X10550 +,F3.0)) 10550 IF(MONTH.LT.6) GO TO 555 10570 IF(MONTH.GT.6) GO TO 333 10580 IF(DATE.LT.23) GO TO 555 10590 ٠ 10600 * READ PRECIPITATION DATA FROM A PERMANENT FILE. 10610 10620 333 READ(30,300) JMONTH, JDATE, RAIN 10630 300 FORMAT(12+12+F4+2) 10640 IF(JMONTH.LT.6) GO TO 333 10650 IF(JMONTH.GT.6) GO TO 777 10660 IF(JDATE+LT+23) GO TO 333 10670 ٠ 10680 * READ ENERGY DATA FROM A PERMANENT FILE. 10690 10700 777 READ(20,200)IMONTH, IDATE, (ENERGY(K), K=1,24) 10710 200 FORMAT(6X+212+24F4-1) 10720 IF(IMONTH.LT.6) GO TO 777 10730 IF(IMONTH.GT.6) GO TO 888 10740 IF(IDATE.LT.23) GO TO 777 10750 888 CONTINUE 10760 * 10776 RETURN 10780 END 10790 +10800 +10810 ***** ٠ 10830 10840 10850 **** +10870 +10880 ***************** 10890 10900 SUBROUTINE WATER * 10910 ٠ 10920 ٠ ******************* 10930 10940 SUBROUTINE WATER 10950 10960 ******************** +10980 DEFINITION OF CONSTANTS AND VARIABLES +10990 ٠ +11000 BLAI = BEAN LEAF AREA INDEX
 BNRADB = BEAN RADIUS IN THE DIRECTION PERPENDICULAR TO THE ROW
 ATMORES = ATMOSPHERIC DIFFUSION RESISTANCE S CM**-1 +11010 M *11020 *11030 * CANDRES = CANOPY DIFFUSION RESISTANCE S CH++-1 +11040 * CUMEVAP = CUMULATIVE EVAPOTRANSPIRATION M +11050 * CUMIRGN = CUMULATIVE IRRIGATION M
* CUMRAIN = CUMULATIVE PRECIPITATION M +11060 M +11070

```
= CHANGE OF SATURATION VAPOR PRESSURE WITH TEMPERATURE
* CELTA
                                                                  MR
                                                                      +11080
* DSVC
         = CHANGE IN SOIL MOISTURE IN A GIVEN VOLUME OF SOIL
                                                                      ±11090
                                                          M HR \pm \pm = 1
                                                                      +11100
         = CHANGE IN SOIL VOLUME OCCUPIED BY THE ROOT SYSTEM M**3
· DVOL
                                                                      *11110
* ENERGY = LIGHT FLUX DENSITY INCIDENT AT TOP OF CANOPY
                                                          ₩ M**-2
                                                                      +11120
* EVAPOTN = ACTUAL EVAPOTRANSPIRATION RATE M HR**-1
                                                                      +11130
         = CONSTANT MB
* GAMMA
                                                                      +11140
٠
 IRRIGTN = IRRIGATION M
                                                                      ±11150
* LFWPOTL = LEAF WATER POTENTIAL
                                  BAR
                                                                      +11160
         = PHOTOSYNTHETICALLY ACTIVE RADIATION INCIDENT AT TOP OF
+ PAR
                                                                      +11170
           CANOPY
                   ERG CM**-2 S**-1
                                                                      +11180
* RTDEPTH = ROOT SYSTEM DEPTH
                               M
                                                                      +11190
* RAIN = PRECIPITATION M
                                                                      +11200
* RELHUM = RELATIVE HUMIDITY
                                                                      +11210
* RHMSAVE = STORED VALUE OF RELHUM TO ALLOW FOR MISSING VALUES IN
                                                                      *11220
           THE WEATHER DATA
                                                                      +11230
* SOILBD = SOIL BULK DENSITY
                               G CM++-3
                                                                      +11240
                                                                      +11250
* SVC
         = VOLUMETRIC SOIL WATER CONTENT
+ SWPOT
         = SOIL WATER POTENTIAL
                                 BAR
                                                                      +11260
+ TEMP
         = DRY BULB TEMPERATURE
                                  С
                                                                      *·1270
TMPSAVE = STORED VALUE OF TEMP TO ALLOW FOR MISSING VALUES IN THE
                                                                      *11280
           WEATHER DATA
                                                                      *11290
* VAPSAT = SATURATED VAPOR PRESSURE AT CURRENT TEMPERATURE
                                                             BAR
                                                                      +11300
* VAPTEMP = VAPOR PRESSURE AT CURRENT TEMPERATURE BAR
                                                                      +11310
* VOLS1
         = SOIL VCLUME OCCUPIED BY ROOT SYSTEM
                                                 H**3
                                                                      *11320
* VOLS2
         = NEW VALUE OF VOLS1
                                                                      +11330
* WINDCON = CONSTANT
                                                                      +11340
* WINDSPD = WIND SPEED
                         M S++-1
                                                                      +11350
* WNDSAVE = STORED VALUE OF WINDSPD TO ALLOW FOR MISSING VALUES IN
                                                                      +11360
           THE WEATHER DATA
                                                                      +11370
                                                                      +11380
11400
* ESTABLISH REAL AND INTEGER VARIABLES
                                                                       11410
                                                                       11420
     INTEGER COUNTER.DAY.PRINTYP.XCOUNTR.XDAY.XI.XMONTH.XDATE.XJMCNTH. 11430
    *XJDATE,XIMONTH,XIDATE,DATE,BNPLANT,HARVEST,XBNPLAN,XHARVES
                                                                       11440
     REAL MBNRADB, LFVPOTL
                                                                       11450
                                                                       11460
* ESTABLISH COMMON BLOCKS
                                                                       11470
                                                                       11460
     COMMON /MAIN/ BBDIST.BDRYFR.BDRYLF.BDRYRT.BDRYST.BGRAREA.BLAI.
                                                                       11490
    +BNRADA, BNRADB, BPHSATE, COUNTER, ENERGY (24), HTTDIST, RAIN,
                                                                       11500
    +RELHUM(24),TDRYFR,TDRYLF,TDRYRT,TDRYST,TEMP(24),TGRAREA,TLAI,
                                                                       11510
    *TPHSATE,TRAD,TTDIST,WINDSPD(24),I,SHADE(101,8),IHR,DAY,LFWPOTL,
                                                                       11520
    +HBBDIST,MONTH,DATE,IMONTH,IDATE,JMONTH,JDATE,BNPLANT,HARVEST
                                                                       11530
٠
                                                                       11540
     COMMON /WATER/XCANDRE(180),XCUMEVA(180),XCUMIRG(180),XCUMRAI(180),11550
    *XDELTA(180),XDSWC(180),XDVOL(180),XEVAPOT(180),XLFWPOT(180),
                                                                       11560
    *XRTDEPT(180),XSWC(180),XSWPOT(180),XVOLS1(180),XVAPSAT(180),
                                                                       11570
    +XVAPTEN(180)
                                                                       11580
                                                                       11590
* INITIALIZE CONSTANTS AND VARIABLES
                                                                       11600
                                                                       11610
     IF(I.GT.O.OR.COUNTER.GT.1) GO TO 10
                                                                       11620
•
                                                                       11630
     BLAI=1.
                                                                       11640
     BNRADB=.05
                                                                       11650
     CUMEVAP=0.
                                                                       11660
     CUMIRGN=0.
                                                                       11670
     CUMRAIN=0.
                                                                       11680
```

```
GAMMA=.66
                                                                            11690
      IRRIGTN=0.
                                                                            11700
      RHMSAVE=50.
                                                                            11710
      RTDEPTH=.3
                                                                            11720
      SOILBD=1.25
                                                                            11730
                                                                            11740
      SWC=.15
      TLAI=BLAI
                                                                           11750
      TMPSAVE=20.
                                                                            11760
      TRAD=.1
                                                                            11770
      VCLS2=1.047*(BNRADB*+2.)*RTDEPTH
                                                                            11780
      VOLS1 = VOLS2
                                                                           11790
      WINDCON=82.8
                                                                            11800
      WNDSAVE=360.
                                                                            11810
                                                                            11820
      CONTINUE
10
                                                                            11830
                                                                            11840
٠
                                                                           11850
*
                           **************
٠
                                                                           11860
                           ٠
                                              ٠
                              WEATHER INPUT
                                             *
                                                                            11870
                               ADJUSTMENTS
                                              ٠
                                                                            11880
*
                           ٠
                                                                           11890
                                                                           11900
                           ****************
                                                                            11910
* CONVERT WEATHER VARIABLES TO CORRECT UNITS AND PROTECT AGAINST
                                                                           11920
* MISSING DATA
                                                                            11930
                                                                           11940
* ENERGY IS CONVERTED FROM LANGLEY (CAL CM**-2) RECEIVED IN 1 HR, TO
                                                                            11950
* W M**-2.
                                                                           11960
٠
                                                                            11970
      PAR=ENERGY(IHR)/120.
                                                                            11980
      ENERGY(IHR)=ENERGY(IHR) +11.625
                                                                           11990
                                                                           12000
* RAIN CONVERTED FROM INCHES TO M
                                                                            12010
                                                                            12020
      RAIN=RAIN+.0254
                                                                           12030
      IF(COUNTER.GT.1) RAIN=0.
                                                                            12040
                                                                           12050
 TEMPERATURE CONVERTED FROM FARENHEIT TO CENTIGRADE
                                                                            12060
٠
                                                                           12070
      TEMP(IHR) = (TEMP(IHR) - 32.) *.55556
                                                                            12080
                                                                           12090
*
*
 WINDSPEED CONVERTED FROM KNOTS TO M HR++-1
                                                                            12100
                                                                           12110
      WINDSPD(IHR)=WINDSPD(IHR) +.5148
                                                                           12120
                                                                           12130
 STORE WEATHER VARIABLE VALUES TO PROTECT AGAINST GAPS IN THE RECORD. 12140
٠
                                                                           12150
      IF(RELHUM(IHR).LT..0001) RELHUM(IHR)=RHMSAVE
                                                                           12160
      RHMSAVE=RELHUM(IHR)
                                                                           12170
      IF(TEMP(IHR).LT..0001) TEMP(IHR)=TMPSAVE
                                                                            12180
      TMPSAVE=TEMP(IHR)
                                                                            12190
      IF(WINDSPD(IHR).LT..0001) WINDSPD(IHR)=WNDSAVE
                                                                           12200
      WNDSAVE=WINDSPD(IHR)
                                                                            12210
٠
                                                                           12220
٠
                                                                            12230
*
                        *********************
                                                                            12240
*
                        ٠
                                                ٠
                                                                            12250
                           EVAPOTRANSPIRATION
٠
                                                                           12260
                                               *
*
                                                ٠
                                                                            12270
*
                        ***************
                                                                           12280
                                                                            12290
```
* THE EVAPOTRANSPIRATION, SOIL WATER AND LEAF WATER POTENTIAL SECTIONS 12300 * OF THIS SUBROUTINE ARE ADAPTED FROM SUBROUTINE WATER IN SOYMOD/OARDC, 12310 * PUBLISHED BY G. E. HEYER, R. B. CURRY, J. G. STREETER AND 12320 H. J. MEDERSKI, OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER. 12330 * RESEARCH BULLETIN 1113, DECEMBER 1979. THE ACTIVE ASSISTANCE 12340 RECEIVED FROM DR. BRUCE CURRY IN PROVIDING AND EXPLAINING THE CODE 12350 * IS GRATEFULLY ACKNOWLEDGED. MODIFICATIONS HAVE BEEN MADE TO ADAPT 12360 THE LOGIC TO THE REQUIREMENTS AND INPUTS OF MULTICROP. HOWEVER. THE 12370 * SECTION REMAINS ESSENTIALLY THE SAME AS SOYMOD/OARDC. 12380 12390 * COMPUTE ATMOSPHERIC AND CANOPY DIFFUSION RESISTANCES 12400 12410 * ATMOSPHERIC DIFFUSION RESISTANCE FUNCTION IS AFTER C. T. DE WIT. 12420 * AGR. RES. REP. #663, CENTER FOR AGRICULTURAL PUBLICATIONS AND 12430 * DOCUMENTATION, WAGENINGEN, 1965. 12446 12450 ٠ ATMDRES=8.28/WINDSPD(IHR) 12460 IF(ENERGY(IHR).LT..001) GO TO 100 12470 12480 * STOMATAL DIFFUSION RESISTANCE FUNCTION IS FROM DATA BY 12490 * P. E. RIJTEMA, AGR. RES. REP. #659, CENTER FOR AGRICULTURAL 12500 + PUBLICATIONS AND DOCUMENTATION, WAGENINGEN, 1965. 12510 12520 STOMRES=34.5 - 17.2*ALOG10(ENERGY(IHR)) 12530 IF(STOMRES.LT.2.) STOMRES=2. 12540 GO TO 110 12550 100 STOMRES=34.5 12560 110 CONTINUE 12570 ٠ 12580 STOMRES - LAI RELATIONSHIP IS AFTER T. A. BLACK, C. B. TANNER, AND 12590 ÷ * W. R. GARDNER, AGRONOMY J. 62:66-69, 1970. 12600 CANDRES=STOMRES/(2.+BLAI) 12610 IF(DAY-LT-BNPLANT-OR-DAY-GT-HARVEST) CANDRES=STOMRES/(2.*TLAI) 12620 IF(CANDRES.LT.2.) CANDRES=2. 12630 CANDRES=CANDRES/36. 12640 12650 * COMPUTE SATURATION VAPOR PRESSURE AT THE CURRENT TEMPERATURE. COMPUTE 12660 * ACTUAL VAPOR PRESSURE AT THE CURRENT TEMPERATURE GIVEN RELATIVE 12670 + HUMIDITY. 12680 ٠ 12690 VAPSAT=EXP(1.806 + .0712*TEMP(IHR) - .0002298*TEMP(IHR)**2.) 12700 VAPTEMP=RELHUM(IHR) +VAPSAT/100. 12710 12720 * COMPUTE EVAPOTRANSPIRATION USING A MODIFIED PENMAN EQUATION AFTER 12730 ***** J. L. MONTEITH, SOC. EXPER. BIOL. 19 (205-234), 1965. 12740 12750 DELTA=(.0712 - .0004596+TEMP(IHR))+VAPSAT 12760 PART1=DELTA + GAMMA+(1. + CANDRES/ATMORES) 12770 PART2=DELTA+1.5+PAR + 290.+(VAPSAT - VAPTEMP)/ATMORES 12780 EVAPOTN=(PART2*1.E-6)/(PART1*585.) 12790 IF(EVAPOTN.LT.O.) EVAPOTN=0. 12800 ÷ 12810 ********************* ٠ 12820 12830 ÷ * SOIL WATER * 12840 AND 12850 ٠ LEAF WATER POTENTIAL ٠ 12860 * 12870 ٠ ******** 12880 12890

12900

* COMPUTE CHANGE IN SOIL WATER CONTENT

155

```
12910
      DSWC=(3.1416+BNRADB++2.)+1.E-4+(RAIN + IRRIGTN - EVAPOTN)
                                                                          12920
      IF(DAY.LT.BNPLANT.OR.DAY.GT.HARVEST) DSWC=(3.1416+TRAD**2.)
                                                                          12930
     **1.E-4*(RAIN + IRRIGTN - EVAPOTN)
                                                                          12940
      SWC=SWC + DSWC/VOLS1
                                                                          12950
                                                                          12960
* ADJUST SOIL VOLUME OCCUPIED BY THE ROOTS AND PLACE LIMITS ON SOIL
                                                                          12970
+ WATER CONTENT
                                                                          12980
٠
                                                                          12990
      VOLS2=1.047*(BNRAD8**2.)*RTDEPTH
                                                                          13000
      IF (DAY.LT.BNPLANT.OR.DAY.GT.HARVEST) VOLS2=1.047*(TRAD**2.)*RTDEPTH13010
      DVOL=VOLS2-VOLS1
                                                                          13020
      SWC=(.15+DVOL + SWC+VOLS1)/VOLS2
                                                                          13030
      VOLS1=VOLS2
                                                                          13040
      IF(SWC.GT..3) SWC=.3 '
                                                                          13050
      IF(SWC.LT..1) SWC=.1
                                                                          13060
                                                                          13070
* INCREMENT CUMULATIVE VALUES FOR EVAPOTRANSPIRATION, IRRIGATION
                                                                          13080
+ AND RAIN
                                                                          13090
٠
                                                                          13100
      CUMEVAP=CUMEVAP + EVAPOTN
                                                                          13110
      CUMIRGN=CUMIRGN + IRRIGTN
                                                                          13120
      CUMRAIN=CUMRAIN + RAIN
                                                                          13130
                                                                          13140
* COMPUTE SOIL WATER POTENTIAL FROM SOIL WATER CONTENT AND BULK
                                                                          13150
* DENSITY. FUNCTION IS FOR WOGSTER SILT LOAM, AND IS DERIVED FROM DATA 13160
* BY R. A. BRADY. F. M. GOLTZ, W. L. POWERS AND E. T. KANEMASU,
                                                                          13170
+ AGRON. J. 69 (97-99), 1977.
                                                                          13180
                                                                          13190
      SWPOT=42.61*EXP(-15.27*SWC/SOILBD)
                                                                          13200
٠
                                                                          13210
* COMPUTE LEAF WATER POTENTIAL FROM SOIL WATER POTENTIAL. FUNCTION IS
                                                                          13220
* FOR SOYBEAN, AND COMES FROM BRADY ET AL, AS ABOVE.
                                                                          13230
                                                                          13240
      LFWPOTL=2.61*EXP(.161*SWPOT)
                                                                          13250
*
                                                                          13260
                                                                          13270
٠
* PLACE VARIABLE VALUES INTO ARRAYS FOR LATER PRINTING. ALL'VARIABLE
                                                                          13280
* NAMES STARTING WITH X ARE USED FOR PRINTING ONLY.
                                                                          13290
٠
                                                                          13300
      IF(COUNTER.NE.12.AND.COUNTER.NE.24) GO TO 999
                                                                          13310
*
                                                                          13320
      XCANDRE(I)=CANDRES
                                                                          13330
      XCUMEVA(I)=CUMEVAP
                                                                          13340
      XCUMIRG(I)=CUMIRGN
                                                                          13350
      XCUMRAI(I)=CUMRAIN
                                                                          13360
      XDELTA(I)=CELTA
                                                                          13370
      XDSVC(I)=DSVC
                                                                          13380
      XDVOL(I)=DVOL
                                                                          13390
      XEVAPOT(I) = EVAPOTN
                                                                          13400
      XLFWPOT(I)=LFWPOTL
                                                                          13410
      XRTDEPT(I)=RTDEPTH
                                                                          13420
      XSWC(I)=SWC
                                                                          13430
      XSWPOT(I)=SWPOT
                                                                          13440
      XVAPSAT(I)=VAPSAT
                                                                          13450
      XVAPTEM(I)=VAPTEMP
                                                                          13460
      XVOLS1(I)=VOLS1
                                                                          13470
                                                                          13480
999 CONTINUE
                                                                          13490
                                                                          13500
      RETURN
                                                                          13510
```

END 13520 +13530 +13540 **13550 13560 13570 13580 ***** ***13590 +13600 +13610 13620 ****** 13630 SUBROUTINE PHOTO + 13640 13650 13660 13670 SUBROUTINE PHOTO 13680 13690 ********13700 +.3710 DEFINITION OF CONSTANTS AND VARIABLES +13720 +13730 * AVENRGY = AVERAGE LIGHT FLUX DENSITY INCIDENT AT TOP OF CANOPY +13740 DURING PREVIOUS WEEK ₩ M**=2 +13750 * BA = CONSTANT *13760 = CONSTANT . + 88 +13770 * BCUMPHD = BEAN CUMULATIVE PHOTOSYNTHESIS PER DAY MG CO2 +13780 * BEXCOEF = BEAN CANOPY EXTINCTION COEFFICIENT +13790 * BGRAREA = AREA UNDER THE BEAN CANOPY M**2 +13800 * BLAI = BEAN LEAF AREA INDEX +13810 * ELFRESP = BEAN LEAF DARK RESPIRATION RATE PER UNIT GROUND AREA *13820 MG CO2 M+ +-2 S++-1 +13830 * BNHIGHT = HEIGHT OF THE BEAN CANOPY M +1384C BNPLANT = BEAN PLANTING DATE IN MOCEL DAYS BNRADB = BEAN RADIUS IN THE DIRECTION PERPENDICULAR TO THE ROW +13850 м *13860 BNSHADE = HORIZONTAL LENGTH OF THE BEAN CANOPY SHADOW M *13870 * BPHSATE = BEAN NET PHOTOSYNTHATE EXPRESSED AS GLUCOSE G +13889 BPNRATE = BEAN NET PHOTOSYNTHESIS RATE PER UNIT GROUND AREA +13890 MG CO2 M**-2 S**-1 +13900 * BRESP = BEAN TOTAL DARK RESPIRATION RATE PER UNIT GROUND AREA +13910 MG CO2 M**-2 S**-1 +13920 * BSTRESP = BEAN STRUCTURE DARK RESPIRATION RATE PER UNIT GROUND +13930 * BTRANS = BEAN LEAF TRANSMISSION COEFFICIENT * BUTILT7 = BEAN LEAF TRANSMISSION COEFFICIENT +13940 +13950 BUTILIZ = BEAN LEAF LIGHT UTILIZATION EFFICIENCY MG CO2 J**-1 +13960 = CONSTANT * BX +13970 BY = CONSTANT +13980 • COUNTER = COUNT OF NUMBER OF ITERATIONS DURING A PARTICULAR DAY +13990 = CO2 CONCENTRATION MG CO2 M**-3 C02 +14000 CUMENDY = CUMULATIVE ENERGY OVER THE DAY W M++-2 ٠ +14010 = DAYS AFTER COMMENCEMENT OF THE SIMULATION (FIRST DAY * DAY +14020 IS DEFINED AS DAY 1) DAY +14030 ECOUNT = COUNT OF EVENT WHEN ENERGY EXCEEDS .01 , SET TO ZERO ٠ +14040 EACH DAY WHEN COUNTER = U. USED TO COMPUTE S1 IN PHOTO. +14050 * ENERGY = LIGHT FLUX DENSITY INCIDENT AT TOP OF CANOPY W M**-2 +14060 ENSTORE = STORED VALUE OF ENERGY FOR THAT ITERATION W M**-2 +14070 HARVEST = BEAN HARVEST DATE IN MODEL DAYS +14080 HTTDIST = HALF THE TOMATO-TOMATO PLANTING DISTANCE M ۰ +14090 + THR = SAME AS COUNTER. +14100 KOUNTER = SPECIAL VERSION OF COUNTER WHICH RUNS FROM 1 TO 8 AND IS * +14110 USED IN CALLING SHADE +14120 * RATIOE = LESSER VALUE OF RATIOP AND RATIOT. USED TO SCALE DOWN +14130 PHOTOSYNTHETIC RATE +14140 * RATION = ADJUSTMENT TO TOMATO PHOTOSYNTHETIC RATE DUE TO AGE OF +14150 THE CANOPY +14160 = ADJUSTMENT TO PHOTOSYNTHETIC RATE DUE TO LEAF WATER RATIOP +14170 POTENTIAL DIFFERENCES FROM THE OPTIMUM +14180 ٠ RATIOT = ADJUSTMENT TO PHOTOSYNTHETIC RATE DUE TO TEMPERATURE +14190 DIFFERENCES FROM THE OPTIMUM +14200 * S = AVERAGE ENERGY RECEIVED DURING A 3 HOUR PERIOD FOR ONE +14210 OF THE PREVIOUS 7 DAYS +14220 * SHADE = RATIO OF AN OBJECT"S SHADOW LENGTH TO THE HEIGHT OF +14230 THE OBJECT +14240 STPNRTE = SHADED TOMATO NET PHOTOSYNTHESIS RATE PER UNIT GROUND +14250 MG CO2 M**-2 S**-1 +14260 ARFA TA = CONSTANT +14270 * ٠ TR = CONSTANT +14280 TCUMPHD = TOMATO CUMULATIVE PHOTOSYNTHESIS PER DAY MG CO2 +14290 ٠ = CONVERSION OF DAY TO REAL FOR RATIOM CALCULATION +14300 • TDAY = TOMATO CANOPY DIAMETER TDIAM +14310 * M TEMP = DRY BULB TEMPERATURE C +14320 ٠ * TEXCOEF = TOMATO CANOPY EXTINCTION COEFFICIENT +14330 TGRAREA = AREA UNDER THE TOMATO CANOPY M**2 TGRSHDE = GROUND AREA OF THE TOMATO CANOPY SHADED BY THE +14340 ٠ +14350 M**2 BEAN CANOPY +14360 + TIAT = TOMATO LEAF AREA INDEX +14370 TLFRESP = TOMATO LEAF DARK RESPIRATION RATE PER UNIT GROUND AREA * +14380 MG CO2 M++-2 S++-1 +14390 * TPHSATE = TOMATO NET PHOTOSYNTHATE EXPRESSED AS GLUCOSE +14400 G TPNRATE = TOMATO NET PHOTOSYNTHESIS RATE PER UNIT GROUND AREA ٠ +14410 MG CO2 M**-2 S**-1 +14420 TRAD = TOMATO CANOPY RADIUS *14430 * M = TOMATO TOTAL DARK RESPIRATION RATE PER UNIT GROUND AREA TRESP +14440 ٠ MG CO2 N++-2 S++-1 +14450 TSHADE = HORIZCNTAL ENCROACHMENT DISTANCE OF THE BEAN SHADOW ٠ +14460 ONTO THE TOMATO GROUND AREA M +14470 TSTRESP = TOMATO STRUCTURE DARK RESPIRATION RATE PER UNIT GROUND +14420 AREA (ROOT, STEM AND FRUIT) MG CO2 M**-2 S**-1 +14490 = TOMATO LEAF TRANSMISSION COEFFICIENT TTRANS +14500 ٠ TUTILIZ = TOMATO LEAF LIGHT UTILIZATION EFFICIENCY ٠ MG CO2 J++-1 +14510 = CONSTANT * TX +14520 * TY = CONSTANT +14530 +14540 ***14550 ** 14560 ٠ ESTABLISH REAL AND INTEGER VARIABLES 14570 14580 INTEGER COUNTER, DAY, PRINTYP, XCOUNTR, XDAY, XI, XMONTH, XDATE, XJMONTH, 14590 *XJDATE,XIMONTH,XIDATE,DATE,BNPLANT,HARVEST,XBNPLAN,XHARVES 14600 REAL MBNRADS, LFWPOTL 14610 14620 * ESTABLISH COMMON BLOCKS 14630 14640 COMMON /MAIN/ BBDIST.BDRYFR.BDRYLF.BDRYRT.BDRYST.BGRAREA.BLAI. 14650 +BNRADA, BNRADB, BPHSATE, COUNTER, ENERGY (24), HTTDIST, RAIN, 14660 *RELHUM(24),TDRYFR,TDRYLF,TDRYRT,TDRYST,TEMP(24),TGRAREA,TLAI, 14670 *TPHSATE,TRAD,TTDIST,WINDSPD(24),I,SHADE(101,8),IHR,DAY,LFWPOTL, 14680 +HBBDIST.MONTH.DATE.IMONTH.IDATE.JMONTH.JDATE.BNPLANT.HARVEST 14690 ٠ 14700 COMMON /PHOTO/XDAY(180),XSHADE(180),XCOUNTR(180),XAVENGY(180), 14710 *XBCUMPH(120),XBLFRSP(180),XBNHIGH(180),XBNSHDE(180),XBPHSTE(180), 14720 *XBPNRTE(180),XBRESP(180),XENERGY(180),XS1(180),XS2(180),XS3(180), 14730

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	+X\$4(180)•X\$5(180)•X\$6(180)•X\$7(180)•X\$TPNRT(180)•XTCUMPH(180)•	14740
	+YTGRSHD(180), YTLERSP(180), YTPHSTE(180), YTPNRTE(180), YTRESP(180),	14750
		14760
	**************************************	14/60
	+X1(180),XMONTH(180),XDATE(190),XJMONTH(180),XJDATE(180),	14770
	+XIMONTH(180),XIDATE(180),XBNPLAN(180),XHARVES(180)	14780
*		14790
*	INITIAL 175 CONSTANTS AND VARIABLES	14800
		14010
		14810
	IF (I.GT.U.OR.COUNTER.GT.I) GO TO 10	14820
*		14830
	AVENRGY=322.	14840
	BA=8-5F-5	14850
		14040
		14000
		14870
	BGRAREA=•015	14880
	BLAI=1.	14890
	BNHIGHT=•07	14900
		14910
		14000
		14920
	BTRANS=.12	14930
	BUTILIZ=11.5E-3	14940
	BX=2•4E-3	14950
	BY=1.9E-2	14960
		14970
		14770
	51=242.	14980
	S2=389•	14990
	S3=108.	15000
	S4=465•	15010
	\$5=544.	15020
	\$4-201	15020
		12030
	57=303	15040
	TA=8.5E-5	15050
	TB=2.1E-2	15060
	TEXCOEF=.5	15070
	TGRARFA==03	15080
		15000
		15090
		15100
	TRAD=•1	15110
	TSHADE=0.	15120
	TTRANS=+15	15130
	10111 17=11-55=3	15140
	TY-0.45-3	15150
		12120
	IT=107L=2	15160
*		15170
	10 CONTINUE	15180
*		15190
*	RESET KOUNTER EVERY 3 HOURS. THIS MEANS THAT SHADE IS CALLED ONLY	15200
	FVERY 3 HOURS.	15200
-	EVERT 0 HUGNJO	12510
		15220
	IF(COUNTER.LE.3) KOUNTER=1	15230
	IF(COUNTER.GE.4) KOUNTER=2	15240
	IF(COUNTER.GE.7) KOUNTER=3	15250
	IF(COUNTER.GE.10) KOUNTER=4	15260
	IF(COUNTER-GE-13) KOUNTER-5	15270
	TELEGUATER CE 1/2 KOURTER-2	. 19270
	IF COUNTER OF ID A NUMIERED	15280
	IF(COUNTER-GE-19) KOUNTER=7	15290
	IF(COUNTER.GE.22) KOUNTER=3	15300
*		15310
*	SET TOUMPHO AND BOUMPHD TO D. AT THE REGINNING OF FACH DAY	15320
+		15220
-	TEACOUNTED OF 11CO TO TOO	15550
	ITYLUUNIEN-GI-IJGU IU SUU	15340

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TCUMPHD=0.
                                                                       15350
     BCUMPHD=0.
                                                                       15360
300
    CONTINUE
                                                                       15370
                                                                       15380
*
 INITIALIZE AND THEN INCREMENT CUMENDY OVER THE DAY
                                                                       15390
                                                                       15400
     IF(COUNTER.EQ.1)CUMENDY=ENERGY(IHR)
                                                                       15410
     IF(COUNTER.GE.2)CUMENDY=CUMENDY+ENERGY(IHR)
                                                                       15420
     IF(COUNTER.EG.1) ECOUNT=0.
                                                                       15430
     IF(ENERGY(IHR).GT..01) ECOUNT=ECOUNT+1.
                                                                       15440
                                                                       15450
                                                                       15460
                                                                       15470
٠
                     ٠
*
                        RESPIRATION
                                               *
                                                                       15480
                                                                       15490
٠
                                                                       15500
                                                                       15510
* COMPUTE TLFRESP AND TSTRESP. TLFRESP FUNCTION IS FROM B. ACOCK
                                                                       15520
* ET AL, J. EXP. BOT. 29 (815-627), 1978, EQUATION 9. SECOND TERM IN
                                                                       15530
* TRESP FUNCTION IS Q10=2., FROM D. A. HOLT ET AL, PURDUE UNIVERSITY
                                                                       15540
*
 AGRICULTURAL EXPERIMENT STATION RESEARCH BULLETIN 907. 1975.
                                                                       15550
٠
                                                                       15560
     TLFRESP=(TX/(TY+TEXCOEF))+ALOG(((1-TTRANS)+(TY+AVENRGY+TEXCOEF))/(15570
                                                                       15580
    +(1-TTRANS)+(TY*AVENRGY+TEXCOEF*CXP(-(TEXCOEF*TLAI))))
     TSTRESP=TLFRESP/3.
                                                                       15590
     TRESP=(TLFRESP+TSTRESP)*(2**((TEMP(IHR)-25.)/10.))
                                                                       15600
                                                                       15610
* COMPUTE BLFRESP AND BSTRESP. SOURCES OF THE EXPRESSIONS ARE THE
                                                                       15620
 SAME AS FOR TLFRESP AND TRESP ABOVE.
*
                                                                       15630
٠
                                                                       15640
     IF(DAY.LT.BNPLANT.OR.DAY.GT.HARVEST) GO TO 110
                                                                       15650
*
                                                                       15660
     BLFRESP=(BX/(BY+BEXCOEF))*ALOG(((1-BTRANS)+(BY+AVENRGY+BEXCOEF))/(15670
    +(1-BTRANS)+(BY*AVENRGY*BEXCOEF*EXP(-(BEXCOEF*BLAI))))
                                                                       15680
     BSTRESP=ELFRESP/3.
                                                                       15690
     BRESP=(BLFRESP+BSTRESP) + (2 + + ((TEMP(IHR) - 25))/10))
                                                                       15700
                                                                       15710
*
     GO TO 120
                                                                       15720
٠
                                                                       15730
110
     BLFRESP=0.
                                                                       15740
     BSTRESP=0.
                                                                       15750
     BRESP=0.
                                                                       15760
120
     CONTINUE
                                                                       15770
                                                                       15780
*
             15790
*
                                                                       15800
                PHOTOSYNTHETIC
*
                                              RATE
                                                       *
                                                                       15810
                                                                       15820
             15830
                                                                       15840
* IF ENERGY EGUALS ZERO, SET TPNRATE, STPNRTE AND BPNRATE EQUAL TO THE 15850
*
 NEGATIVE OF THE APPROPRIATE RESPIRATION RATES. THIS ALLOWS RESPIRATION15860
 TO PROCEED WHEN PHOTOSYNTHESIS IS SHUT DOWN IN THE DARK. TPHSATE AND 15870
ŧ
* BPHSATE MAY THEREFORE TAKE ON NEGATIVE VALUES.
                                                                       15880
                                                                       15890
      IF(ENERGY(IHR).GT..01) GO TO 310
                                                                       15900
     TPNRATE=-TRESP
                                                                       15910
      STPNRTE=0.
                                                                       15920
      IF(DAY.LT.BNPLANT.OR.DAY.GT.HARVEST) GO TO 130
                                                                       15930
     BPNRATE=-BRESP
                                                                       15940
     GO TO 140
                                                                       15950
```

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15960
130 BPNRATE=C.
                                                                           15970
140
     GO TO 385
                                                                           15980
310
     CONTINUE
                                                                           15990
 COMPUTE BPNRATE. FUNCTION IS FROM B. ACOCK ET AL. J. EXP.BOT. 29
                                                                           16000
*
 (815-827), 1978, EQUATION 8. BPNRATE IS ADJUSTED FOR TEMPERATURE
                                                                           16010
*
* EFFECT. TEMPERATURE FUNCTION IS DERIVED FROM P. J. C. KUIPER. PLANT
                                                                           16020
 PHYSIOL. 40 (915-918), 1965, FIGURE 2.
                                                                           16030
٠
٠
                                                                           16040
      RATIOT=-.858 + .139*TEMP - .0026*TEMP**2.
                                                                           16050
      RATIOE=RATIOT
                                                                           16060
      RATIOP=3.75 - 3.3+ALOG10(LFNPOTL)
                                                                           16070
      IF(LFWPOTL.LT.6.9) RATIOP=1.
                                                                           16080
      IF(RATICP.LT..001) RATIOP=.001
                                                                           16090
      IF(RATICP.LT.RATIUE) RATIOE=RATIOP
                                                                           16100
                                                                           16110
      IF(DAY.LT.BNPLANT.OR.DAY.GT.HARVEST) GO TO 150
                                                                          . 16120
                                                                           16130
      BPART1=(1.-BTRANS)*(BUTILIZ*ENERGY(IHR)+BA*AVENRGY*C02)
                                                                           16140
      BPART2=BB+BUTILIZ+ENERGY(IHR) + AVENRGY+BEXCOEF
                                                                           16150
      BPART3=(BA+CO2)/(BB+BEXCOEF)
                                                                           16160
      BPART4=EXP(-BEXCOEF*BLAI)
                                                                           16170
      BPNRATE=(BPART3*ALOG((BPART2+BPART1)/(BPART2+SPART4+BPART1)))*RATI16180
     +OE - BRESP
                                                                           16190
                                                                           16200
      GO TO 160
                                                                           16210
150
     BPNRATE=0.
                                                                           16220
                                                                           16230
• COMPUTE TPNRATE WITH FULL ENERGY INPUT. SOURCE OF THE EXPRESSION
                                                                           16240
* IS THE SAME AS FOR THE BPNRATE ABOVE. MATURITY FACTOR REDUCES TOMATO
                                                                          16250
 PN RATE AFTER 50 DAYS, AND IS ADAPTED FROM D. A. HOLT ET AL, PURCUE
٠
                                                                           16260
★ UNIVERSITY AGRICULTURAL EXPERIMENT STATICN RESEARCH BULLETIN 907.
                                                                           16270
+ 1975.
                                                                           16280
                                                                           16290
٠
      TDAY=DAY
                                                                           16300
160
      RATIOM=4.30 - 1.94 + ALOG10(TDAY)
                                                                           16310
      IF(DAY.LT.50) RATIOM=1.
                                                                           16320
                                                                           16330
      TPART1=(1.-TTRANS) + (TUTILIZ*ENERGY(IHR)+TA*AVENRGY*C02)
                                                                           16340
      TPART2=TB*TUTILIZ*ENERGY(IHR)*AVENRGY*TEXCOEF
                                                                           16350
      TPART3=(TA+CO2)/(TB+TEXCOEF)
                                                                           16360
      TPART4=EXP(-TEXCOEF +TLAI)
                                                                           16370
      TPNRATE=((TPART3*ALOG((TPART2+TPART1)/(TPART2*TPART4+TPART1)))*RAT16380
     +IOE) + RATION - (TRESP + RATION)
                                                                           16390
                                                                           16400
* COMPUTE BPNRATE AND TPNRATE (CALLED SEPNRTE AND STPNRTE) WITH REDUCED 16410
 ENERGY INPUT DUE TO SHADING. ENERGY IS REDUCED TO 40 PERCENT FULL SUN-16420
*
٠
                                                                           16430
      ENSTORE=ENERGY(IHR)
                                                                           16440
                                                                           16450
      ENERGY(IHR)=ENERGY(IHR) + .4
                                                                           16460
      IF(DAY+LT+BNPLANT+OR+DAY+GT+HARVEST) GO TO 161
                                                                           16465
                                                                           16466
      BPART1=(1.-BTRANS)*(BUTILI2*ENERGY(IHR)+BA*AVENRGY*C02)
                                                                           16470
      BPART2=BE*BUTILIZ*ENERGY(IHR)*AVENRGY*BEXCOEF
                                                                           16480
      SBPNRTE=(BPART3*ALOG((BPART2+BPART1)/(BPART2+BPART4+BPART1)))*RATI16490
     +OE - BRESP
                                                                           16500
      GO TO 162
                                                                           16505
                                                                           16510
161 SBPNRTE=0.
                                                                           16512
                                                                           16514
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162 CONTINUE 16516 16517 TPART1=(1.-TTRANS)*(TUTILI2*ENERGY(IHR)+TA*AVENRGY*CO2) 16520 TPART2=TB*TUTILIZ*ENERGY(IHR)*AVENRGY*TEXCOEF 16530 STPNRTE=((TPART3*ALGG((TPART2*TPART1)/(TPART2*TPART4+"PART1)))*RAT16540 +IOE) + RATION - (TRESP + RATION) 16550 16560 IF(DAY.LT.ENPLANT.OR.DAY.GT.HARVEST) STPNRTE=0. 16570 16580 ENERGY(IHR)=ENSTORE 16590 16600 ********************************* 16610 16620 AND TOMATO BEAN 16630 + SHADING 16640 * 16650 ٠ ************************************ 16660 ٠ 16670 COMPUTE BEAN HEIGHT. REGRESSION COMES FROM 1980 FIELD DATA. 16680 16696 ٠ 16700 385 TDIAM=2.+TRAD IF (DAY-LT-BNPLANT-OR-DAY-GT-HARVEST) GO TO 590 16710 BNHIGHT=.0337 + .572*(BNRADB*2.) 16720 16730 ٠ * COMPUTE HORIZONTAL LENGTH OF THE BEAN SHADOW. THE RATIO IS SPECIFIC 16740 * FOR 42 DEGREE LATITUDE. TIME OF YEAR AND HOUR. 16750 16760 ٠ BNSHADE=BNHIGHT+SHADE(DAY,KOUNTER) 16770 IF(BNSHADE.GE.HTTDIST) GO TO 500 16780 TSHADE=TRAD-(HTTDIST-BNSHADE) 16790 GO TO 550 16800 500 TSHADE=TRAD+(BNSHADE-HTTDIST) 16810 * 16820 COMPUTE TOHATO GROUND AREA SHADED BY BEAN * 16830 16840 * 550 IF(BNSHADE.GT.(HTTDIST+TRAD)) GO TO 595 16850 IF(BNSHADE.GE.HTTDIST) GO TO 560 16860 IF(TSHADE.LT.J.) GO TO 590 16870 16880 * TGRSHDE=(TRAD++2.)+ACOS((TRAD-TSHADE)/TRAD)-((TRAD-TSHADE)+TRAD+ 16890 +SIN(ACOS((TRAD-TSHADE)/TRAD))) 16900 GO TO 600 16910 560 IF(BNSHADE.GT.HTTDIST) GO TO 570 16920 TGRSHDE=(3.1416*(TRAD**2.))/2. 16930 GO TO 600 16940 TGRSHDE=3.1416*(TRAD**2.) - ((TRAD**2.)*ACOS((TRAD-(BNSHADE-HTTDIS16950 570 +T))/TRAD - (TRAD-(BNSHADE-HTTDIST))*TRAD*SIN(ACOS((TRAD-(ENSHADE- 16960))) +HTTDIST))/TRAD)))) 16970 GO TO 600 16980 590 TGRSHDE=0. 16990 TSHADE=0. 17000 GO TO 600 17010 595 TGRSHDE=TGRAREA 17020 600 CONTINUE 17030 17040 ٠ IF(BNSHADE.LT.(TTDIST-BNRADB)) GO TO 710 17050 IF(BNSHADE.GE.(TTDIST-BNRADB).AND.BNSHADE.LT.TTDIST) GO TO 720 17060 IF(BNSHADE.GE.TTDIST) GO TO 730 17070 710 BCANSHD=0. 17080 BFRCTSH=0. 17090 GO TO 760

17100

162

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BCANSHD=((ENSHADE - TTDIST + BNRADB)+SNHIGHT)/BNSHADE
 720
                                                                             17110
      GO TO 750
                                                                             17120
      BCANSHD=((BNSHADE - TTDIST + BNRADB)+BNHIGHT)/BNSHADE
 730
                                                                             17130
      IF(BCANSHD.GT.ENHIGHT) BCANSHD=BNHIGHT
 750
                                                                             17140
      BFRCTSH=BCANSHD/BNHIGHT
                                                                             17150
      CONTINUE
 760
                                                                             17160
                                                                             17170
٠
*
                     ***********************
                                                                             17180
*
                                                                             17190
                     ٠
                        PHOTOSYNTHATE
                                                                             17200
                     ٠
                                                     ٠
                                                                             17210
                     *****************************
                                                                             17220
٠
                                                                             17230
COMPUTE THE SUM OF THE TOMATO PHOTOSYNTHATE PRODUCED IN THE SHADED
                                                                             17240
* AND UNSHADED PORTIONS OF THE CANOPY BY MULTIPLYING TPNRATE AND
* STPNRATE BY GROUND AREA. THE CONSTANT, 2.46, CONVERTS PHOTOSYNTHETIC
                                                                             17250
                                                                            17260
* RATE FROM S**-1 TO HR**-1, AND MG CO2 TO G GLUCOSE.
                                                                             17270
•
                                                                             17280
      IF(ENERGY(IHR).LT..01) GO TO 390
                                                                             17290
      TPHSATE=(TPNRATE*(TGRAREA-TGRSHDE) STPNRTE*TGRSHDE) *2.46
                                                                             17300
      TCUMPHD=TCUMPHD+TPHSATE
                                                                             17310
      GO TO 395
                                                                             17320
      TPHSATE=TPNRATE+TGRAREA+2.46
 390
                                                                             17330
      TCUMPHD=TCUMPHD+TPHSATE
                                                                             17340
                                                                             17350
* COMPUTE BPHSATE FROM SPARATE MULTIPLIED BY GROUND AREA. THE CONSTANT, 17360
* 2.46. IS THE SAME AS FOR TPHSATE.
                                                                             17370
                                                                             17380
 395 IF(DAY-LT-BNPLANT-OR-DAY-GT-HARVEST) GO TO 180
                                                                             17390
      IF(ENERGY(IHR).LT..01) GO TO 356
                                                                             17400
      BPHSATE=(BPNRATE*(BGRAREA*(1 - BFRCTSH)) + SBPNRTE*(BGRAREA*BFRCTS17410
     +H))*2.46
                                                                            17420
      BCUMPHD=BCUMPHD + BPHSATE
                                                                             17430
      60 TO 397
                                                                             17440
      BPHSATE=BPNRATE+BGRAREA+2.46
 396
                                                                             17450
      BCUMPHD=BCUMPHD + BPHSATE
                                                                             17460
      CONTINUE
 397
                                                                             17470
      GO TO 190
                                                                             17480
 180 BCUMPHD=0.
                                                                             17490
      BNHIGHT=0.
                                                                             17500
      BNSHADE=0.
                                                                             17510
      BPHSATE=0.
                                                                             17520
      TGRSHDE=0.
                                                                            17530
      TSHADE=0.
                                                                             17540
                                                                             17550
٠
                                                                             17560
* PLACE VARIABLE VALUES INTO ARRAYS FOR LATER PRINTING. ALL VARIABLE
                                                                            17570
* NAMES STARTING WITH X ARE USED FOR PRINTING ONLY.
                                                                            17580
٠
                                                                             17590
190 IF(COUNTER.NE.12.AND.COUNTER.NE.24) GO TO 999
                                                                             17600
٠
                                                                             17610
      XAVENGY(I)=AVENRGY
                                                                            17620
      XBCUMPH(I)=8CUMPHD
                                                                             17630
      XBLFRSP(I)=BLFRESP
                                                                            17640
      XBNHIGH(I)=BNHIGHT
                                                                             17650
      XBNPLAN(I)=ENPLANT
                                                                             17660
      XBNSHDE(I)=BNSHADE
                                                                             17670
      XBPHSTE(I)=BPHSATE
                                                                             17680
      XBPNRTE(I)=BPNRATE
                                                                            17690
      XBRESP(I)=BRESP
                                                                            17700
      XCOUNTR(I)=COUNTER
                                                                             17710
```

```
XDATE(I)=DATE
                                                                   17720
     XDAY(I)=DAY
                                                                   17730
     XENERGY(I)=ENERGY(IHR)
                                                                   17740
     XHARVES(I)=HARVEST
                                                                   17750
     XI(I)=I
                                                                   17760
     XIDATE(I)=IDATE
                                                                   17770
     XIMONTH(I)=IMONTH
                                                                   17780
     XJDATE(I)=JDATE
                                                                   17790
     XJMONTH(I)=JMONTH
                                                                   17800
     XMONTH(I)=MONTH
                                                                   17810
     XRAIN(I)=RAIN
                                                                   17820
     XRELHUM(I)=RELHUM(IHR)
                                                                   17830
     XS1(I)=S1
                                                                   17840
     XS2(I)=S2
                                                                   17850
     XS3(I)=S3
                                                                   17860
     XS4(I)=S4
                                                                   17870
     XS5(I)=S5
                                                                   17880
     XS6(I)=S6
                                                                   17890
     XS7(I)=S7
                                                                   17900
     XSHADE(I)=SHADE(DAY,KOUNTER)
                                                                   17910
     XSTPNRT(I)=STPNRTE
                                                                   17920
     XTCUMPH(I)=TCUMPHD
                                                                   17930
     XTEMP(I)=TEMP(IHR)
                                                                   17940
     XTGRSHD(I)=TGRSHDE
                                                                   17950
     XTLFRSP(I)=TLFRESP
                                                                   17960
     XTPHSTE(I)=TPHSATE
                                                                   17970
     XTPNRTE(I)=TPNRATE
                                                                   17980
     XTRESP(I)=TRESP
                                                                   17990
     XTSHADE(I)=TSHADE
                                                                   18000
     XWINDSP(I) = WINDSPD(IHR)
                                                                   18010
                                                                   18020
999
    CONTINUE
                                                                   18030
٠
                                                                   18040
     IF(COUNTER.NE.24) GO TO 350
                                                                   18050
٠
                                                                   18060
* UPDATE AVENRGY TO INCLUDE THE DAY JUST COMPLETED. PREVIOUS VALUE FCR
                                                                   18070
* S7 IS REPLACED BY PREVIOUS S6, AND SO ON DOWN TO S2. S1 TAKES THE
                                                                   18080
* NEW VALUE OF AVERAGE ENERGY FOR THAT DAY.
                                                                   18090
                                                                   18100
٠
     $7=$6
                                                                   18110
     $6=$5
                                                                   18120
     $5=S4
                                                                   18130
     $4=$3
                                                                   18140
     $3=$2
                                                                   18150
     S2=S1
                                                                   18160
     S1=CUMENDY/ECOUNT
                                                                   18170
     AVENRGY=($1+$2+$3+$4+$5+$6+$7)/7.
                                                                   18180
                                                                   18190
350
     CONTINUE
                                                                   18200
٠
                                                                   18210
     RETURN
                                                                   18220
     END
                                                                   18230
                                                                  ±18240
                                                                  *18250
*
**
     18270
٠
                                                                   18280
                                                                   18290
*
                                                                  +18310
.
                                                                  +18320
```

18330 ********************** 18340 SUBROUTINE BNPART 18350 (BEAN PARTITIONING) * 18360 18370 18380 18390 SUBROUTINE BNPART 18400 18410 +18430 DEFINITION OF CONSTANTS AND VARIABLES +18440 +18450 * BCHODMD = BEAN CARBOHYDRATE DEMAND FOR LONGTERM STORAGE G +18460 * BCPOOL = BEAN SHORTTERM CARBOHYDRATE STORAGE G +18470 • BCSTORE = BEAN LONGTERM CARBOHYDRATE STORAGE G +18480 * BDRYFR = BEAN FRUIT DRY WEIGHT G +18490 BORYLF = BEAN CANOPY LEAF DRY WEIGHT 6 +18500 BDRYRT = BEAN ROOT DRY WEIGHT G
 BDRYST = BEAN STEM DRY WEIGHT G
 BFRDMD = BEAN FRUIT DEMAND FUNCTION FOR PARTITIONING +18510 +18520 +18530 CARBOHYDRATE +18540 G * BFRINCR = BEAN FRUIT DRY MATTER INCREASE G +18550 * BLFDHD = BEAN LEAF DEMAND FUNCTION FOR PARTITIONING +18560 CARBOHYDRATE G +18570 * BLFINCR = BEAN LEAF DRY MATTER INCREASE +18580 G * BNPLANT = BEAN PLANTING DATE IN MODEL DAYS +18590 BPHSATE = BEAN NET PHOTOSYNTHATE EXPRESSED AS GLUCOSE G *18600 BRFRDHD = BEAN RELATIVE FRUIT DEMAND FOR PARTITIONING OF +18610 CARBOHYDRATE +18620 * BRLFDMD = BEAN RELATIVE LEAF DEMAND FOR PARTITIONING OF +18630 CARBOHYDRATE +18640 BRRTDMD = BEAN RELATIVE ROOT DEMAND FOR PARTITIONING OF +18650 CARBOHYDRATE +18660 BRSTDMD = BEAN RELATIVE STEM DEMAND FOR PARTITIONING OF +18670 CARBOHYDRATE +18680 BRTDMD = BEAN ROOT DEMAND FUNCTION FOR PARTITIONING +18690 CAREOHYDRATE G +18700 * BRTINCR = BEAN ROOT DRY MATTER INCREASE G +18710 * BSTDMD = BEAN STEM DEMAND FUNCTION FOR PARTITIONING +18720 CARBOHYDRATE G +18730 BSTINCR = BEAN STEM DRY MATTER INCREASE G *18740 • BSUMDMD = BEAN SUM OF THE COMPONENT PARTITIONING DEMANDS FOR +18750 CARBOHYDRATE G +18760 * BTRLCTE = BEAN CARBOHYDRATE REMOVED FROM SHORTTERM STORAGE FOR *18770 TRANSLOCATION TO THE VARIOUS COMPONENTS G *18780 * COUNTER = COUNT OF NUMBER OF ITERATIONS DURING A PARTICULAR DAY *18790 DAY = DAYS AFTER COMMENCEMENT OF THE SIMULATION (FIRST DAY +18800 IS DEFINED AS DAY 1) DAY ***18810** HARVEST = BEAN HARVEST DATE IN MODEL DAYS +18820 • IBNDAY = NUMBER OF BEAN DAYS AFTER BNPLANT +18830 ♦ POOLCHK = MINIMUM CARBOHYDRATE LEVEL ALLOWED IN SHORTTERM STORAGE G +18840 +18850 ********* ***18860 18870 * ESTABLISH REAL AND INTEGER VARIABLES 18880 18890 INTEGER CCUNTER, DAY, PRINTYP, XCOUNTR, XDAY, XI, XMONTH, XDATE, XJMONTH, 18900 *XJDATE *XIMONTH *XIDATE *DATE *BNPLANT *HAR VEST *XBNPLAN * XHARVES 18910 REAL MBNRADB.LFWPOTL 18920 18930

* ESTABLISH COMMON BLOCKS 18940 18950 COMMON /MAIN/ BBDIST, BDRYFR, BDRYLF, BDRYRT, BDRYST, BGRAREA, BLAI, 18960 +BNRADA, BNRADB, BPHSATE, COUNTER, ENERGY (24), HTTDIST, RAIN, 18970 +RELHUM(24),TDRYFR,TDRYLF,TDRYRT,TDRYST,TEMP(24),TGRAREA,TLAI, 18980 +TPHSATE, TRAD, TTDIST, WINDSPD(24), I, SHADE(101,8), IHR, DAY, LFWPOTL, 18990 +HBBDIST,MONTH,DATE, IMONTH, IDATE, JMONTH, JDATE, BNPLANT, HARVEST 19000 19010 COMMON /BNPART/XPOOLCK(180),XBCHODM(180),XBCPOOL(180), 19020 +XBCSTOR(180),XBDRYFR(180),XBDRYRT(180),X3DRYST(180),XBDRYLF(180), 19030 *XBFRDMD(180),XBFRINC(180),XBLFDMD(180),XBLFINC(180),XBPHSAT(180), 19040 +XBRFRDM(180),XBRLFDM(180),XBRRTDM(180),XBRSTDM(180),XBRTDMD(180), 19050 *XBRTINC(180),XBSTDMD(180),XBSTINC(180),XBSUMDM(180),XBTPLCT(180) 19060 19070 INITIALIZE CONSTANTS AND VARIABLES 19080 19090 19100 BTRLCTE=0. 19110 IF(I.GT.O.OR.COUNTER.GT.1) GO TO 10 19120 19130 BCPOOL=0. 19140 BCSTORE=0. 19150 BDRYFR=0. 19160 BDRYLF=0. 19170 BDRYRT=0. 19180 BDRYST=0. 19190 BFRDMD=0. 19200 BFRINCR=0. 19210 BRFRCMD=0. 19220 19230 10 IF(DAY.NE.SNPLANT.OR.COUNTER.NE.1) GO TO 11 19240 BCP001 = . 05 19250 BCSTORE=.1 19260 **BDRYFR=0**. 19270 BDRYLF=.3 19280 BDRYRT=.1 19290 BDRYST=.15 19300 BFRDMD=0. 19310 BFRINCR=0. 19320 BRFRDMD=0. 19330 19340 11 IF(DAY.LT.BNPLANT.OR.DAY.GT.HARVEST) GO TO 500 19350 19360 * CHECK IF PHOTOSYNTHATE IS GREATER THAN ZERO. IF NOT, NO DEMAND IS 19370 * MADE FOR LONGTERM CARBOHYDRATE STORAGE. 19380 19390 IF(BPHSATE.GT.0.) GO TO 100 19400 * 19410 BCHODMD=0. 19420 GO TO 150 19430 19440 * PLACE 25 PERCENT OF PHOTOSYNTHATE INTO LONGTERM STORAGE WHEN IT IS 19450 * AVAILABLE. 19460 ٠ 19470 100 SCHODMD=8PHSATE+.25 19480 BCSTORE=BCSTORE + BCHODMD 150 19490 19500 * ADD BALANCE OF PHOTOSYNTHATE TO SHORTTERM CARBOHYDRATE STORAGE. THE 19510 BALANCE MAY HAVE EITHER POSITIVE OR NEGATIVE VALUES. * 19520 19530 BCPOOL= BCPCOL + BPHSATE - BCHCDMD 19540

```
19550
* CHECK IF SHORTTERM STORAGE HAS BECCME LESS THAN 10 PERCENT OF
                                                                           19560
* LONGTERM STORAGE LEVEL
                                                                          19570
٠
                                                                           19580
      POOLCHK=BCSTORE+.1
                                                                          19590
      IF(BCPOOL.GE.POOLCHK) GO TO 200
                                                                           19600
                                                                          19610
* REMOVE THE SHORTTERM STORAGE DEFICIT FROM LONGTERM STORAGE
                                                                          19620
                                                                          19630
      BCSTORE=BCSTORE + BCPOOL
                                                                          19640
                                                                          19650
* ADD 10 PERCENT OF LONGTERM STORAGE TO SHORTTERM STORAGE
                                                                          19660
                                                                          19670
      BCPOOL=POOLCHK
                                                                          19680
      BCSTORE=BCSTORE-BCPOOL
                                                                           19690
200
     CONTINUE
                                                                          19700
                                                                           19710
* COMPUTE THE INDIVIDUAL PLANT COMPONENT DEMANDS FOR PHOTOSYNTHATE.
                                                                          19720
★ THE FUNCTIONS ARE FITTED CURVES DERIVED FROM GROWTH CURVE DATA
                                                                          19730
+ COLLECTED BY THE AUTHOR.
                                                                          19740
٠
                                                                          19750
      IBNDAY=DAY - BNPLANT + 1
                                                                          19760
      BLFDMD=10++(-.407 + .0425+IBNDAY)
                                                                          19770
      BSTDMD=10**(-.84 + .0466*IBNDAY)
                                                                          19780
      BFRDMD=156.3 - 8.73+IBNDAY + .122+(IENDAY++2.)
                                                                          19790
      IF(IBNDAY.LT.37) BFRDMD=0.
                                                                          19800
      IF(IBNDAY.LT.20) BRTDHD=.16*(BSTDMD + BLFDMD + BFPDMD)
                                                                          19810
      IF(IENDAY.GE.21.AND.IBNDAY.LE.48) BRTDMD=.11+(BSTDMD + BLFDMD +
                                                                          19820
     +BFRDND)
                                                                          19830
      IF(IBNDAY.GE.49) BRTDND=.08*(BSTDMD + BLFDMD + BFRDMD)
                                                                          19840
                                                                          19850
* BALANCE THE VARIOUS DEMANDS TO OBTAIN THEM AS A FRACTION OF 1
                                                                          19860
                                                                          19870
      BSUMDMD=BRTDMD + BSTDMD + BLEDMD + BERDMD
                                                                          19880
                                                                          19890
      BRRTDMD=BRTDMD/BSUMDMD
                                                                          19900
      BRSTDMD=ESTDMD/BSUMDMD
                                                                          19910
      BRLEDMD=BLEDMD/BSUMDMD
                                                                          19920
      BRFRDHD=BFRDHD/BSUMDHD
                                                                           19930
                                                                          19940
• CHECK IF SHORTTERM STORAGE IS GREATER THAN 10 PERCENT OF LONGTERM
                                                                          19950
* STORAGE. WHEN IT IS NOT, ALL THE SHORTTERM STORAGE IS ALLOCATED TO
                                                                          19960
* THE PLANT COMPONENTS AND THE SHORTTERM STORAGE GOES TO ZERO.
                                                                          19970
*
                                                                          19980
      IF(BCPOOL.NE.POOLCHK) GO TO 250
                                                                          19990
                                                                          20000
      BRTINCR=BRRTDMD+BCPOOL
                                                                          20010
      BSTINCR=BRSTDMD+BCPOOL
                                                                          20020
      BLFINCR=BRLFDMD+BCP00L
                                                                          20030
      BFRINCR=BRFRCMD+BCPOOL
                                                                          20040
      BCPOOL=BCPOOL - (BRTINCR + BSTINCR + BLFINCR + BFRINCR)
                                                                          20050
٠
                                                                          20060
* SCALE COMPONENT INCREASES BACK TO ACCOUNT FOR SYNTHESIS RESPIRATION
                                                                          20070
* LOSSES AND THE PRESENCE OF NON-CARBOHYDRATE MATTER IN THE TISSUES.
                                                                          20080
                                                                          20090
      BRTINCR=BRTINCR+.75
                                                                          20100
      BSTINCR=BSTINCR+.75
                                                                          20110
      BLFINCR=ELFINCR+.75
                                                                          20120
      BFRINCR=8FRINCR+.75
                                                                          20130
      GO TO 300
                                                                          20140
                                                                          20150
```

* WHEN SHORTTERM STORAGE EXCEEDS 10 PERCENT OF LONGTERM STORAGE. THEN 20160 * 67 PERCENT OF SHORTTERN STORAGE IS TRANSLOCATED. THIS REPRESENTS UP TO20170 * 50 PERCENT OF THE ORIGINAL PHOTOSYNTHATE PRODUCED IN THE PARTICULAR 20180 * ITERATION. 20190 20200 * 250 CONTINUE 20210 BTRLCTE=ECPOOL+.67 20220 BCPOOL=BCPOOL - BTRLCTE 20230 20246 * BRTINCR=BRRTDMD+BTRLCTE+.75 20250 BSTINCR=BRSTDHD+BTRLCTE+.75 20260 BLFINCR=BRLFDMD+BTRLCTE+.75 20270 BFRINCR=BRFRDMD+BTRLCTE+.75 20280 20290 300 CONTINUE 20300 20310 * ADD COMPONENT INCREASES TO THEIR APPROPRIATE STATE VARIABLES. 20320 20330 BDRYRT=SDRYRT + BRTINCR 20340 BDRYST=EDRYST + BSTINCR 20350 BDRYLF=BDRYLF + BLFINCR 20360 BDRYFR=BDRYFR + BFRINCR 20370 20380 * * PLACE VARIABLE VALUES INTO ARRAYS FOR LATER PRINTING. ALL VARIABLE 20390 * NAMES STARTING WITH X ARE USED FOR PRINTING ONLY. 20400 20410 500 IF(COUNTER.NE.12.AND.COUNTER.NE.24) GO TO 999 20420 20430 IF(DAY.GE.BNPLANT) GO TO 510 20440 20450 ٠ XBCHODM(I)=0. 20460 XBCPOOL(I)=0. 20470 XBCSTOR(I)=0. 20480 XBDRYFR(I)=0. 20490 XBDRYLF(I)=0. 20500 XBDRYRT(I)=0. 20510 XBDRYST(I)=0. 2052C XBFRDMD(I)=0. 20530 XBFRINC(I)=0. 20540 XBLFDMD(I)=0. 20550 XBLFINC(I)=0. 20560 XBPHSAT(I)=0. 20570 XBRFRDM(I)=0. 20580 XBRLFDM(I)=0. 20590 XBRRTDM(I)=0. 20600 XBRSTDM(I)=0. 20610 XBRTDMD(I)=0. 20620 XBRTINC(I)=0. 20630 XBSTDMD(I)=0. 20640 XBSTINC(I)=0. 20650 XBSUMDM(I)=0. 20660 XBTRLCT(I)=0. 20670 XPOOLCK(I)=0. 20680 60 TO 999 20690 20700 510 IF(DAY.GT.HARVEST) GO TO 520 20710 20720 XBCHODM(I)=8CHODMD 20730 XBCPOCL(I)=8CPOOL 20740 XBCSTOR(I)=BCSTORE 20750 XBDRYFR(I)=BDRYFR 20760

	YRORYLE(T)-ROPYLE		20770
			20170
	ABURTRICIJ=BURTRI		20780
	XBORYST(I)=BORYST		20790
	XBFROMD(I)=2FRDMD		20800
	XBFRINC(I)=BFRINCR		20810
	XELFDMD(I)=BLFDMD		20820
	XELFINC(I) = PLFINCR		20830
	YRPHSAT(T)=4PHSATE		20840
			20050
			20850
	XBRLFDH(I)=BRLFDMD		20860
	XBRRIDM(I)=BRRIDMD		20870
	XBRSTDM(I)=BRSTDMD		20880
	XBRTDMD(I)=BRTDMD		20890
	XBRTINC(I)=BRTINCR		20900
	X8STDMD(T)=ESTDMD		20910
	YBSTINC(I)=BSTINCR		20920
			20020
			20930
	XBIRLUI(I)=EIRLUIE		20940
	XPOOLCK(I)=PCOLCHK		20950
*			20 960
520	IF(DAY.LE.HARVEST)	GO TO 999	20970
*			20980
	XBCHODM(I)=0.		20990
	XBCP001 (1)=BCP001		21000
			21010
			21010
			21020
	XBURTLF (I)=BURTLF		21030
	XBURYRT(I)=EURYRT		21040
	XBDRYST(I)=BDRYST		21050
	XBFRDMD(I)=0.		21060
	XBFRINC(I)=0.		21070
	XBLFDMD(I)=0.		21080
	XBLFINC(I)=0.		21090
	XBPHSAT(T)=0.		21100
	XBREROM(I)=BREROMO		21110
	YPRI FON(T)-PRI FONO		21120
			21120
	XBRRIUH(I)=BRRIUHU		21150
	XBRSTDM(I)=BRSTDMD		21140
	XBRTDMD(I)=0.		21150
	XBRTINC(I)=0.		21160
	XBSTDMD(I)=0.		21170
	XBSTINC(I)=0.		21180
	XBSUMDM(T)=0.		21190
	YBTRICT(I)=0.		21200
			21210
			21210
•			21220
999	CONTINUE		21230
*			21240
	RETURN		21250
	END		21260
*			+21270
*			+21280
*****	***************	*****	**21290
*			21300
•			21310
•			21230
-		· · · · · · · · · · · · · · · · · · ·	U2612 12612
****		~~~~~~~ ~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~	**21330
*			*21540
			*21350
*	***	*************	21360
*	*	*	21370

SUBROUTINE TOMPART 21380 * (TOMATO PARTITIONING) + 21390 ٠ 21400 ************************ 21410 SUBROUTINE TOMPART 21420 21430 ************* +21450 DEFINITION OF CONSTANTS AND VARIABLES +21460 *21470 * COUNTER = COUNT OF NUMBER OF ITERATIONS DURING A PARTICULAR DAY +21480 = DAYS AFTER COMMENCEMENT OF THE SIMULATION (FIRST DAY +21490 + DAY IS CEFINED AS DAY 1) DAY *21500 ٠ * POOLCHK = MINIMUM CARBOHYDRATE LEVEL ALLOWED IN SHORTTERM STORAGE G +21510 * TCHODMD = TOMATO CARBOHYDRATE DEMAND FOR LONGTERM STORAGE G +21520 * TCPOOL = TOMATO SHORTTERM CARBOHYDRATE STORAGE G * TCSTORE = TOMATO LONGTERM CARBCHYDRATE STORAGE G +21530 +21540 * TDRYFR = TOMATO FRUIT DRY WEIGHT G +21550 * TDRYLF = TOMATO CANOPY LEAF DRY WEIGHT G +21560 = TOMATO ROOT DRY WEIGHT * TDRYRT G +21570 * TDRYST = TOMATO STEM DRY WEIGHT G +21580 * TFRDMD = TOMATO FRUIT DEMAND FUNCTION FOR PARTITIONING *21590 CARBOHYDRATE +21600 G * TFRINCR = TOMATO FRUIT DRY MATTER INCREASE G *21610 TLFDMD = TOMATO LEAF DEMAND FUNCTION FOR PARTITIONING ٠ +21620 CARECHYDRATE G +21630 * * TLFINCR = TOMATO LEAF DRY MATTER INCREASE G *21640 * TPHSATE = TOMATO NET PHOTOSYNTHATE EXPRESSED AS GLUCOSE G *21650 * TRFRDMD = TOMATO RELATIVE FRUIT DEMAND FCR PARTITIONING OF *21660 CARBOHYDRATE +21670 TRLFDMD = TOMATO RELATIVE LEAF DEMAND FOR PARTITIONING OF *21680 * CARBOHYDRATE +21690 * TRRTDND = TOMATO RELATIVE ROOT DEMAND FOR PARTITIONING OF +21700 * CARBOHYDRATE +21710 * TRSTDMD = TOMATO RELATIVE STEM DEMAND FOR PARTITIONING OF +21720 CAREOHYDRATE \$21730 ★ TRTDMD = TOMATO ROOT DEMAND FUNCTION FOR PARTITIONING *21740 CARBOHYDRATE G *21750 * TRTINCR = TOMATO ROOT DRY MATTER INCREASE G +21760 TSTDMD = TOMATO STEM DEMAND FUNCTION FOR PARTITIONING +21770 CARBOHYDRATE G ٠ +21780 * TSTINCR = TOMATO STEM DRY MATTER INCREASE G +21790 * TSUMDMD = TOMATO SUM OF THE COMPONENT PARTITIONING DEMANDS FOR +21800 CARBOHYDRATE G +21810 • TTRLCTE = TOMATO CARBOHYDRATE REMOVED FROM SHORTTERM STORAGE FOR +21820 TRANSLOCATION TO THE VARIOUS COMPONENTS G +21830 +21840 21860 21870 * ESTABLISH REAL AND INTEGER VARIABLES 21880 INTEGER COUNTER+DAY+PRINTYP+XCCUNTR+XDAY+XI+XMONTH+XDATE+XJMONTH+ 21890 ***XJDATE**,XIMONTH,XIDATE,DATE,BNPLANT,HARVEST,XBNPLAN,XHARVES 21900 REAL MBNRADS, LFWPOTL 21910 21920 ESTABLISH COMMON BLOCKS 21930 21940 COMMON /MAIN/ BBDIST,BDRYFR,BDRYLF,BDRYRT,BDRYST,BGRAREA,BLAI, 21950 +BNRADA, BNRADE, BPHSATE, COUNTER, ENERGY (24), HTTDIST, RAIN, 21960 *RELHUM(24) *TDRYFR*TDRYLF*TDRYRT*TDRYST*TEMP(24) *TGRAREA*TLAI* 21970 *TPHSATE,TRAD,TTDIST,WINDSPD(24),I,SHADE(101,8),IHR,DAY,LFWPOTL, 21980

◆HBBDIST MONTH DATE DIMONTH DATE JMONTH DATE BNPLANT HARVEST 21990 22000 ٠ COMMON /TOMPART/XPOOLCH(180) .XTCHODM(180) . 22010 +XTCPOCL(180),XTCSTOR(180),XTDRYFR(180),XTORYRT(180),XTDRYLF(180), 22020 *XTDRYST(18C),XTFRDMD(180),XTFRINC(180),XTLFDMD(180),XTLFINC(180), 22030 +XTPHSAT(180),XTRFRDH(180),XTRLFDH(180),XTRRTDH(130),XTRSTDH(180), 22040 +XTRTDMD(180),XTRTINC(180),XTSTDMD(180),XTSTINC(180),XTSUMDM(180), 22050 +XTTRLCT(180) 22060 22070 INITIALIZE CONSTANTS AND VARIABLES 22080 ÷ 22090 22100 TTRLCTE=0. 22110 IF(I.GT.O.OR.COUNTER.GT.1) GO TO 10 22120 22130 TCP00L=.05 22140 TCSTORE=.2 22150 TDRYFR=0. 22160 TDRYLF=.5 22170 TDRYRT=.15 22180 TDRYST=.4 22190 TFRDMD=0. 22200 TERINCR=0. 22210 TRFRDMD=0. 22220 22230 10 CONTINUE 22240 22250 * CHECK IF PHOTOSYNTHATE IS GREATER THAN ZERO. IF NOT, NO DEMAND IS 22260 * MADE FOR LONGTERM CARBOHYDRATE STORAGE. 22270 22280 ٠ IF(TPHSATE.GT.0.) GO TO 100 22290 22300 * 22310 TCHODMD=0. 60 TO 150 22320 22330 * PLACE 25 PERCENT OF PHOTOSYNTHATE INTO LONGTERM STORAGE WHEN IT IS 22340 * AVAILABLE. 22350 22360 TCHODMD=TPHSATE+.25 100 22370 150 TCSTORE=TCSTORE + TCHODMD 22380 22390 ADD BALANCE OF PHOTOSYNTHATE TO SHCRTTERM CARBOHYDRATE STORAGE. THE • 22400 BALANCE MAY HAVE EITHER POSITIVE OR NEGATIVE VALUES. ٠ 22410 22420 ٠ TCPOOL= TCPOOL + TPHSATE - TCHODND 22430 22440 ٠ * CHECK IF SHORTTERM STORAGE HAS BECOME LESS THAN 10 PERCENT OF 22450 * LONGTERM STORAGE LEVEL 22460 22470 POOLCHK=TCSTORE+.1 22480 IF(TCPOCL.GE.POOLCHK) GO TO 200 22490 22500 * REMOVE THE SHORTTERM STORAGE DEFICIT FROM LONGTERM STORAGE * 22510 22520 TCSTORE=TCSTORE + TCPOOL 22530 22540 ADD 10 PERCENT OF LONGTERM STORAGE TO SHORTTERM STORAGE 22550 * 22560 TCPOOL=PCOLCHK 22570

22580

22590

TCSTORE=TCSTORE-TCPOOL

200

CONTINUE

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22600
* COMPUTE THE INDIVIDUAL PLANT COMPONENT DEMANDS FOR PHOTOSYNTHATE.
                                                                          22610
* THE FUNCTIONS ARE FITTED CURVES DERIVED FROM GROWTH CURVE DATA
                                                                          22620
 COLLECTED BY THE AUTHOR.
*
                                                                          22630
                                                                          22640
      TLFDMD=+882 + +308+DAY + +0269+(DAY++2+)
                                                                          22650
      TSTDMD=1.17 + .274+DAY + .0161+(DAY++2.)
                                                                          22660
      TFRDMD=47.3 - 5.1*DAY + .138*(DAY**2.)
                                                                          22670
      IF(DAY.LT.19) TFRDMD=0.
                                                                          22680
      IF(DAY.LT.20) TRTDMD=.16*(TSTDMD + TLFDMD + TFRDMD)
                                                                          22690
      IF(DAY.GE.21.AND.DAY.LE.48) TRTDMD=.11*(TSTDMD + TLFDMD + TFRDMD) 22700
                                                                          22710
      IF(DAY.GE.49) TRTDMD=.08*(TSTDMD + TLFDMD + TFRDMD)
                                                                          22720
* BALANCE THE VARIOUS DEMANDS TO OBTAIN THEM AS A FRACTION OF 1
                                                                          22730
                                                                          22740
      TSUMDMD=TRTDMD + TSTDMD + TLFDMD + TFRDMD
                                                                          22750
                                                                          22760
      TRRTDMD=TRTDMD/TSUMDMD
                                                                          22770
      TRSTDMD=TSTCMD/TSUMDMD
                                                                          22780
      TRLFDMD=TLFDMD/TSUMDMD
                                                                          22790
      TRFROMD=TFRCMD/TSUMDMD
                                                                          22800
                                                                          22810
* CHECK IF SHORTTERM STORAGE IS GREATER THAN 10 PERCENT OF LONGTERM
                                                                          22820
* STORAGE. WHEN IT IS NOT, ALL THE SHORTTERM STORAGE IS ALLOCATED TO
                                                                          22830
THE PLANT COMPONENTS AND THE SHORTTERM STORAGE GOES TO ZERO.
                                                                          22840
*
                                                                          22850
      IF(TCPOOL.NE.POOLCHK) GO TO 250
                                                                          22860
                                                                          22870
      TRTINCR=TRRTDMD+TCPOOL
                                                                          22880
      TSTINCR=TRSTDMD+TCPOOL
                                                                          22890
      TLFINCR=TRLFDMD*TCP00L
                                                                          22900
      TFRINCR=TRFRDMD+TCPOOL
                                                                          22910
      TCPOOL=TCPOOL - (TRTINCR + TSTINCR + TLFINCR + TFRINCR)
                                                                          22920
                                                                          22930
 SCALE COMPONENT INCREASES BACK TO ACCOUNT FOR SYNTHESIS RESPIRATION
+
                                                                          22940
* LOSSES AND THE PRESENCE OF NON-CARBOHYDRATE MATTER IN THE TISSUES.
                                                                          22950
                                                                          22960
      TRTINCR=TRTINCR+.75
                                                                          22970
      TSTINCR=TSTINCR+.75
                                                                          22986
      TLFINCR=TLFINCR+.75
                                                                          22990
      TFRINCR=TFRINCR+.75
                                                                          23000
      GO TO 300
                                                                          23010
                                                                          23020
* WHEN SHORTTERM STORAGE EXCEEDS 10 PERCENT OF LONGTERM STORAGE, THEN
                                                                          23030
* 67 PERCENT OF SHORTTERM STORAGE IS TRANSLOCATED. THIS REPRESENTS UP TO 23040
* 50 PERCENT OF THE ORIGINAL PHOTOSYNTHATE PRODUCED IN THE PARTICULAR
                                                                          23050
ITERATION.
                                                                          23060
                                                                          23070
      CONTINUE
250
                                                                          23080
      TTRLCTE=TCPOOL+.67
                                                                          23090
      TCPOOL=TCPOOL - TTRLCTE
                                                                          23100
                                                                          23110
      TRTINCR=TRRTDMD+TTRLCTE+.75
                                                                          23120
      TSTINCR=TRSTDMD+TTRLCTE+.75
                                                                          23130
      TLFINCR=TRLFDMD+TTRLCTE+.75
                                                                          23140
      TFRINCR=TRFRDMD+TTRLCTE+.75
                                                                          23150
                                                                          23160
300 CONTINUE
                                                                          23170
                                                                          23180
* ADD COMPONENT INCREASES TO THEIR APPROPRIATE STATE VARIABLES.
                                                                          23190
                                                                          23200
```

172

	1	DRY	'RT=	= T DI	RYR	T	+ 1	TR	TIN	CR														23210
	1	TORY	'ST=	= T D	RYS	T ·	+ 1	TS	TIN	CR														23220
	1	DRY	LF:	= T D I	RYL	. F	+ 1	TL	FIN	CR														23230
	1	DRY	FR:	= T D	RYF	R	• '	TF	RIN	CR														23240
*																								23250
* F	PLACE	: VA	RI/	VBL	ΕV	AL	UES	S	INT	0 4	ARR.	AYS	FO	RL	ATER	PF	RIN	TING	;. A	LL	VAR	I ABL	.2	23260
* 1	IAME:	5 51	ARI	TIN	Gk	IT	H)	X	ARE	US	SED	F0	RP	RIN	TING	01	NLY	•						23270
*	_	_	_			_												_						23280
]	FCC	:001	ITE	R • N	IE •	12	• A	ND.	cοι	JNT	ER •	NE .	24)	GO	TO	99	9						23290
)	(POC	LCI	101) = P	00	LCI	HK																23300
	,	(TCF	IOD	101)=1	CH	ODI	MD																23310
	,	CTCF	000) = 1	CP	001																	23320
	2	(TCS	TOF) = 1	CS	TOP	RE																23330
	2) =	DR	1	ĸ																23340
) = \ _ 7	UK		r T																23330
) = 1	08	TR	 +																23360
			(13)) = \ _ 7	UR	15	1																23370
		(- 8) = (7 K.	UMI	U Cn																23380
)=(\1	- F K																		23390
		(L / T E			1 = 1			U C D																23400
		(1 L F / T D L	L A L	- \ 1 T / T	/ - / \ - 1	L.F.	CA.	UR TE																23420
			DON	4 X T	/ - (\ - 1		on Dni																	23420
		(T D I	EDI	1 1 1) - 1) - 1		EDI	MD																23440
				ACT) = 1	.00	יט י וחד	MD																23450
			10	1 V I	/ - 1) - 1		101	MD																23450
		1103		101) = 1	PPT	<u>п м</u> і	n																23400
	,	(TR1	TNO	111) = 1	RT	TN	C R																23480
	,	1701	DM0) = 1	ST.	лм I	n																23490
		(TST	TNO	- 11) = 1	ST	TN	C R																23500
		CTSI	IMD	4(1)=1	su	MD	MD																23510
	3	CTTR	LCI	rei) = 1	TR	LC.	TE																23520
99	99 (CONT	INU	JE				. –																23530
*																								23540
	,	RETU	IRN																					23550
	8	END																						23560
+																							1	23570
*																							,	23580
***	****	***	**1	***	* * 4	**	**1	**	* * *	* * 1	***	* * *	***	***	****	***	* * *	****	***	***	***1	***	****	23590
*																								23600
*																								23610
*																								23620
***	****	****	***	* * *	* * 1	**	**	**	* * *	**1	***	* * *	***	***	****	**1	* * *	****	***	***	***	***	****	*23630
*																							•	+23640
*																								*2365 0
*									***	**1	***	***	***	***	****	**								23660
*									*							*								23670
*									*	SUE	380	UTI	NE	CAN	OPY	*								23680
*									*							*								23690
*									***	**1	***	***	***	***	* * * *	**								23700
*							•••																	23/10
•	:	SURF	00	IIN	2 (A N	UP'	T																23720
							 .	• •					 .								***			23130
							-	# #		# # 1		***	***	***		= = 1					***			= 23140 + 2275 0
-							TM	τŦ	TON	^	. r	ONE	TAN	TC		VAC								- 2JIJU - 23720
-					Ľ	, c , r	T IA	* 1	TON	U	L	0143	TAN	1.3	-110	TH	IN L A		2					- 2JIOV • 23770
- -	RADI	T	= 4	RFA	N - 1) F A	N	PI		TN	. n	TST		F	N									- 23110 • 23720
- c	RRMAN				н — с Т М I	, L, A 1M	AL 1	10		15	ົດບ	FRI	ARC	0F	IT. RFAN	- 85	FΔM			FS	м			-23700 •23701
	BROV	P	= (OVF	RI	P	OF	- T	HE	BFI	AN-	BFA	NC	ANO	PIFS		M							+23800
*	BDRY	F	= 1	BEA	NC	AN	0P	γĊ	LFA	FI		- NF	IGH	T	. <u>.</u>		••							+23810
		-•	- 1					•						•	•									20010

•

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* BGRAREA = AREA UNDER THE BEAN CANOPY M**2
                                                                      +23820
         = BEAN LEAF AREA INDEX
* BLAI
                                                                      +23830
* BLFAREA = BEAN CANCPY LEAF AREA
                                  M*+2
                                                                      +23840
* BNFLAG = FLAG TO DECLARE THAT BEAN-BEAN OVERLAP HAS REACHED THE
                                                                      +23850
           MAXIMUM ALLOWABLE DISTANCE
                                                                      +23850
* BNPLANT = BEAN PLANTING DATE IN MODEL DAYS
                                                                      + 23870
* BNRADA = BEAN CANOPY RADIUS IN THE DIRECTION OF THE ROW M
                                                                      +23880
* BNRADB = BEAN RADIUS IN THE DIRECTION PERPENDICULAR TO THE ROW
                                                                   M +23890
 BOVAREA = SUM OF OVERLAP GROUND AREA ON BOTH SIDES OF BEAN
                                                                      +23900
٠
           CANOPY M**2
                                                                      +23910
BOVFRCT = BEAN-BEAN OVERLAP AREA AS A FRACTION OF BEAN GROUND AREA
                                                                      +23920
• EBDRYLF = EFFECTIVE BEAN LEAF DRY WEIGHT DUE TO BEAN-BEAN
                                                                     +23930
           OVERLAP
                                                                     +23940
                     G
* HARVEST = BEAN HARVEST DATE IN MODEL CAYS
                                                                      +23950
* HBBDIST = HALF THE BEAN-BEAN PLANTING DISTANCE M
                                                                      +23960
٠
 MBNRADB = MAXIMUM ALLOWABLE BEAN CANOPY RADIUS PERPENDICULAR TO
                                                                     +23970
           THE ROW M
                                                                      +23980
         = TYPE OF BEAN GROWTH
+ MODE
                                                                      +23990
* TBMOVLP = MAXIMUM ALLOWABLE OVERLAP OF TOMATO-BEAN CANOPIES
                                                              м
                                                                     +24000
 TBOVLP = OVERLAP OF THE TOMATO-BEAN CAROPIES M
                                                                      +24010
* TDRYLF = TOMATO CANOPY LEAF DRY WEIGHT G
                                                                      +24020
* TGRAREA = AREA UNDER THE TOMATO CANOPY M**2
                                                                      +24030
         = TOMATO LEAF AREA INDEX
* TLAT
                                                                     +24040
* TLFAREA = TOMATO CANOPY LEAF AREA
                                     M**2
                                                                     +24050
+ TRAD
        = TOMATO CANOPY RADIUS M
                                                                     +24060
+ TTDIST = TOMATO-TOMATO PLANTING DISTANCE
                                             M
                                                                     +24070
                                                                     +24080
24100
* ESTABLISH REAL AND INTEGER VARIABLES
                                                                       24110
                                                                       24120
     INTEGER COUNTER.DAY.PRINTYP.XCOUNTR.XDAY.XI.XMONTH.XCATE.XJMONTH. 24130
    *XJDATE,XIMONTH,XIDATE,DATE,BNPLANT,HARVEST,XBNPLAN,XHARVES
                                                                       24140
     REAL MBNRADB.LFVPOTL
                                                                       24150
                                                                       24160
* ESTABLISH COMMON BLOCKS
                                                                       24170
                                                                       24180
     COMMON /MAIN/ BBDIST.BDRYFR.BDRYLF.BCRYRT.BDRYST.BGRAREA.BLAI.
                                                                       24190
    *BNRADA,BNRADB,EPHSATE,COUNTER;ENERGY(24),HTTDIST,RAIN,
                                                                       24200
     +RELHUM(24),TDRYFR,TDRYLF,TDRYRT,TDRYST,TEMP(24),TGRAREA,TLAI,
                                                                      24210
    +TPHSATE,TRAD,TTDIST,WINDSPD(24),I,SHADE(101,8),IHR,DAY,LFWPOTL,
                                                                       24220
     +HBBDIST,MONTH,DATE,IMONTH,IDATE,JMONTH,JDATE,BNPLANT,HARVEST
                                                                      24230
                                                                       24240
     COMMON /CANOPY/IMODE(180) + XENRADA(180) + XENRADB(180) + XEGRARA(180) + 24250
     *XEBDRYL(180),XBLFARA(180),XBLAI(180),XBBOVLP(180),
                                                                      24260
    *XBOVARA(180),XBOVFRC(180),XBNFLAG(180),XTRAD(180),XTGRARA(180),
                                                                       24270
     *XTLFARA(180),XTLAI(180),XTBOVLP(180)
                                                                       24280
                                                                       24290
 INITIALIZE CONSTANTS AND VARIABLES
                                                                       24300
                                                                       24310
     IF(I.GT.O.CR.COUNTER.GT.1) GO TO 10
                                                                       24320
                                                                       24330
     BBMOVLP=.05
                                                                       24340
     BBOVLP=0.
                                                                       24350
     BNFLAG=0.
                                                                       24360
     BNRADA=0.
                                                                       24370
     BOVAREA=0.
                                                                       24380
     BOVFRCT=0.
                                                                       24390
     MBNRADB=.327 + .632+ALOG10(TTDIST)
                                                                       24400
     MODE=1
                                                                      24410
     TBOVLP=0.
                                                                       24420
```

```
TBMOVLP=.1
                                                                         24430
                                                                         24440
10
     IF(DAY.NE.BNPLANT.OR.COUNTER.NE.1) GC TO 11
                                                                         24450
                                                                         24460
     BBMOVLP=.05
                                                                         24470
     BBOVLP=0.
                                                                         24480
     BNFLAG=0.
                                                                         24490
     BNRADA=.03
                                                                         24500
     BOVAREA=0.
                                                                         24510
     BOVFRCT=0.
                                                                         24520
     MENRADB=.327 + .632*ALOG10(TTDIST)
                                                                         24530
     MODE=1
                                                                         24540
     TBOVLP=0.
                                                                         24550
     TBMOVLP=.1
                                                                         24560
                                                                         24570
+
     CONTINUE
11
                                                                         24580
                                                                         24590
                                                                         24600
                                                                         24610
٠
*
                       TOMATO
                                     CANOPY
                                                  *
                                                                         24620
                                                                         24630
                                                                         24640
                    **
                      ------
                                                                         24650
* IF TOMATO-BEAN OVERLAP EXCEEDS THE MAXIMUM ALLOWABLE DO NOT INCREMENT 24660
 GROUND AREA FURTHER. LEAF AREA INDEX ONLY INCREASES.
                                                                         24670
                                                                         24680
.
      IF(TBOVLP.GE.TBMOVLP) GO TO 100
                                                                         24690
                                                                         24700
.
* COMPUTE NEW TOMATO GROUND AREA. FUNCTION COMES FROM A REGRESSION OF
                                                                         24710
* 1980 FIELD DATA BY THE AUTHOR.
                                                                         24720
                                                                         24730
      TGRAREA=10.**(-1.62 + .685*ALOG10(TDRYLF))
                                                                         24740
                                                                         24750
* COMPUTE NEW TCMATO RADIUS FROM GROUND AREA
                                                                         24760
                                                                         24770
.
      TRAD=SQRT(TGRAREA/3.1416)
                                                                         24780
     IF(TRAD.GT..5) TRAD=.5
                                                                         24790
100 CONTINUE
                                                                         24800
                                                                         24810
* COMPUTE TONATO LEAF AREA FROM TOMATO LEAF DRY WEIGHT. FUNCTION COMES 24820
* FROM A REGRESSION OF 1980 FIELD DATA BY THE AUTHOR.
                                                                         24830
                                                                         24840
٠
      TLFAREA=.0243+TDRYLF - .0143
                                                                         24850
      IF(TLFAREA.LT..008) TLFAREA=.008
                                                                         24860
                                                                         24870
* COMPUTE TOMATO LEAF AREA INDEX FROM LEAF AREA AND GROUND AREA
                                                                         24880
                                                                         24890
     TLAI=TLFAREA/TGRAREA
                                                                         24900
                                                                         24910
     IF(DAY.LT.BNPLANT.OR.DAY.GT.HARVEST) GO TO 400
                                                                         24920
                                                                         24930
                      ************************
                                                                         24940
                                                                         24950
٠
                      ٠
                                   CANOPY
                         BEAN
                      ٠
                                                *
                                                                         24960
                                                                         24970
                      ************************
                                                                         24980
٠
                                                                         24990
* IF BEAN RADIUS B EXCEEDS THE MAXIMUM ALLOWABLE LENGTH. DO NOT
                                                                         25000
* INCREMENT BEAN RADIAL GROWTH IN THE B DIRECTION. GO TO MODE 4.
                                                                         25010
                                                                         25020
      MBNRADB=.327 + .632+ALOG10(TTDIST)
                                                                         25030
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175
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IF(BNRADB.GE.MBNRADB) GO TO 300
                                                                           25040
                                                                           25050
* COMPUTE NEW BEAN GROUND AREA. FUNCTION COMES FROM A REGRESSION OF
                                                                           25060
 1980 FIELD DATA BY THE AUTHOR.
٠
                                                                           25070
*
                                                                           25080
      BGRAREA=10.**(-1.79 + .779*AL0G10(BDRYLF))
                                                                           25090
                                                                           25100
★ IF REAN-BEAN OVERLAP EXCEEDS THE MAXIMUM ALLOWABLE DISTANCE, SWITCH
                                                                           25110
* TO NODE 3. IN MODE 3. BEAN RADIUS B IS INCREMENTED WHILE BEAN
                                                                           25120
•
 RADIUS A IS HELD CONSTANT.
                                                                           25130
                                                                           25140
٠
      IF(BNFLAG.GE.98.) GO TO 200
                                                                           25150
                                                                           25160
                           . . . . . .
                                                                           25170
٠
                                       •
                                              ٠
                                                                           25180
                           *
                               MODE
                                         1
                                              .
                                                                           25190
                                                                           25200
                                                                           2521C
                           ŧ
                              •
                                * * * *
                                                                           25220
* IN MODE 1. BEAN GROWTH IS CIRCULAR WITH EQUAL INCREASE IN ALL RADII.
                                                                           25230
 THERE IS NO BEAN-BEAN OVERLAP, AND RADIUS A AND RADIUS B ARE EQUAL.
                                                                           25240
٠
                                                                           25250
+
 COMPUTE BEAN RADIUS & AND SET RADIUS B EQUAL TO IT
                                                                           25260
                                                                           25270
      ENRADA=SQRT(BGRAREA/3.1416)
                                                                           25280
      BNRADB=BNRADA
                                                                           25290
٠
                                                                           25300
 IF BEAN RADIUS A EXCEEDS ONE HALF OF THE BEAN-BEAN DISTANCE THEM
*
                                                                           25310
 OVERLAP HAS OCCURRED. PROCEED TO MODE 2.
٠
                                                                           25320
                                                                           25330
      IF(BNRADA.GE.HBEDIST) GO TO 150
                                                                           25340
٠
                                                                           25350
 SET EFFECTIVE BEAN DRY LEAF EQUAL TO BEAN DRY LEAF
*
                                                                           25360
                                                                           25370
٠
      EBDRYLF=BCRYLF
                                                                           25380
.
                                                                           25390
 COMPUTE BEAN LEAF AREA FROM BEAN LEAF DRY WEIGHT. FUNCTION COMES
*
                                                                           25400
 FROM A REGRESSION OF 1980 FIELD DATA BY THE AUTHOR.
*
                                                                           25410
                                                                           25420
      BLFAREA=.0241*BDRYLF - .0062
                                                                           25430
      IF(BLFAREA.LT..0009) BLFAREA=.0009
                                                                           25440
                                                                           25450
  COMPUTE BEAN LEAF AREA INDEX FROM LEAF ARCA AND GROUND AREA
                                                                           25460
                                                                           25470
      BLAI=BLFAREA/BGRAREA
                                                                           25480
                                                                           25490
  COMPUTE TOMATO-BEAN OVERLAP (SHOULD BE NEGATIVE HERE)
                                                                           25500
٠
                                                                           25510
      TBOVLP=(TRAD+BNRADB)-TTDIST/2.
                                                                           25520
      MODE=1
                                                                           25530
      GO TO 400
                                                                           25540
                                                                           25550
                           .
                                              .
                                                                           25560
                                                                           25570
                               MODE
                                                                           25580
                           ٠
                                         2
                           ٠
                                                                           25590
                                                                           25600
                                                                           25610
* IN MODE 2. BEAN GROWTH IS CIRCULAR WITH EQUAL INCREASE IN ALL RADII.
                                                                           25620
* THERE IS BEAN-BEAN OVERLAP, AND RADIUS A AND RADIUS B ARE EQUAL.
                                                                           25630
                                                                           25640
```

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* COMPUTE BEAN-BEAN OVERLAP
                                                                          25650
                                                                          25660
150 BBOVLP=2.+(ENRADA-HBBDIST)
                                                                          25670
                                                                          25680
* SET FLAG FOR SWITCHING TO MODE 3 GROWTH ON THE NEXT ITERATION
                                                                          25690
                                                                          25700
      IF(BBOVLP.GE.BBMOVLP) BNFLAG=99.
                                                                          25710
                                                                          25720
* COMPUTE BEAN-BEAN OVERLAP AREA ON BOTH SIDES OF THE PLANT
                                                                          25730
                                                                          25740
      BOVAREA=4.*((BNRADA++2.)+ACOS(BBDIST/(2.+BNRADA))-(B6DIST/2.)+BNRA25750
     +DA+SIN(ACOS(BBDIST/(2.+BNRADA))))
                                                                          25760
                                                                          25770
 COMPUTE BEAN-BEAN OVERLAP FRACTION
                                                                          25780
*
                                                                          25790
      BOVFRCT=BOVAREA/BGRAREA
                                                                          25800
                                                                          25810
* COMPUTE EFFECTIVE BEAN DRY LEAF DUE TO BEAN-BEAN OVERLAP. THE
                                                                          25820
 PERCENTAGE IS SCALED DOWN TO 1/3 TO ACCOUNT FOR THE UNEVEN
                                                                          25830
* DISTRIBUTION OF THE CANOPY OVER THE GROUND AREA. THE LEAF AREA INDEX
                                                                          25840
 AT THE EDGES OF THE PLANT. WHERE THE OVERLAP OCCURS. IS MUCH LESS
                                                                          25850
* THAN IN THE CENTER. THIS SAME PATTERN IS FOLLOWED IN THE REST OF
                                                                          25860
 THE CANOPY SUBROUTINE.
                                                                          25870
                                                                          25880
      EBDRYLF=(BOVFRCT+BDRYLF+.33)+BDRYLF
                                                                          25890
                                                                          25900
                                                                          25910
 COMPUTE EFFECTIVE BEAN LEAF AREA FROM EFFECTIVE DRY LEAF WEIGHT
                                                                          25920
٠
      BLFAREA=.0241*EBDRYLF - .0062
                                                                          25930
      IF(BLFAREA.LT..0009) BLFAREA=.0009
                                                                          25940
                                                                          25950
  COMPUTE EFFECTIVE BEAN LEAF AREA INDEX FROM LEAF AREA AND GROUND AREA 25960
                                                                          25970
      BLAI=BLFAREA/BGRAREA
                                                                          25980
                                                                          25990
 COMPUTE TOMATO-BEAN OVERLAP (SHOULD BE NEGATIVE HERE)
                                                                          26000
*
                                                                          26010
      TBOVLP=(TRAD+BNRADB)-TTDIST/2.
                                                                          26020
      MODE=2
                                                                          26030
      GO TO 400
                                                                          26040
                                                                          26050
                                                                          26060
                                                                          26070
                              MODE
                                         3
                                                                          26080
                          *
                                                                          26090
                          ۰
                                  . . . .
                                                                          26100
                                                                          26110
◆ IN MODE 3, BEAN GROWTH IS ELLIPTICAL WITH INCREASES ONLY IN BEAN
                                                                          26120
• RADIUS B. THERE IS BEAN-BEAN OVERLAP, AND RADIUS A IS HELD CONSTANT. 26130
                                                                          26140
* COMPUTE BEAN RADIUS B FROM BEAN GROUND AREA, HOLDING RADIUS A
                                                                          26150
* CONSTANT. EXPRESSION IS THE STANDARD FORMULA FOR AN ELLIPSE.
                                                                          26160
٠
                                                                          26170
200 BNRADB=EGRAREA/(3.1416+BNRADA)
                                                                          26180
                                                                          26190
* COMPUTE BEAN-BEAN OVERLAP GROUND AREA ON BOTH SIDES. PARTS A. B ANC C 26200
* ARE USED ONLY FOR COMPUTING CONVENIENCE.
                                                                          26210
٠
                                                                          26220
      PARTA=SQRT(4.*BNRADA**2.-BBDIST**2.)
                                                                          26230
      PARTB=PARTA/BBDIST
                                                                          26240
      PARTC=(BNRADB+BBDIST)/(4.+BNRADA)
                                                                          26250
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BOVAREA=4.*(BNRADA*BNRADB*ATAN(PARTB)-(PARTC*PARTA))
                                                                           26260
                                                                           26270
* COMPUTE BEAN-BEAN OVERLAP FRACTION
                                                                          26280
                                                                          26290
     BOVFRCT=POVAREA/BGRAREA
                                                                          26300
                                                                           26310
* COMPUTE EFFECTIVE BEAN DRY LEAF DUE TO BEAN-BEAN OVERLAP
                                                                          26320
                                                                          26330
      EBDRYLF=(BOVFRCT+BDRYLF+.33)+BDRYLF
                                                                           26340
                                                                           26350
* COMPUTE EFFECTIVE BEAN LEAF AREA FROM EFFECTIVE DRY LEAF WEIGHT
                                                                          26360
                                                                          26370
      BLFAREA=.0241*EBDRYLF - .0062
                                                                          26380
                                                                          26390
* COMPUTE EFFECTIVE BEAN LEAF AREA INDEX FROM LEAF AREA AND GROUND AREA 26400
                                                                          26410
      BLAI=BLFAREA/BGRAREA
                                                                          26420
                                                                          26430
* COMPUTE TOMATO-BEAN OVERLAP (MAY BECOME POSITIVE AT SOME POINT IN
                                                                          26440
+ THIS MODE)
                                                                           26450
٠
                                                                           26460
      TBOVLP=(TRAD+BNRADB)-TTDIST/2.
                                                                           26470
      MODE=3
                                                                           26480
      GO TO 400
                                                                          26490
                                                                           26500
                                                                           26510
                                      *
                                        * * *
                                                                          26520
٠
                              MODE
                          *
                                                                          26530
                          ٠
                                                                           26540
                                                                           26550
*
                                                                          26560
* IN MODE 4, THERE IS NO FURTHER LATERAL BEAN GROWTH. BEAN CANOPY
                                                                          26570
* INCREASES ARE IN LEAF AREA INDEX ONLY.
                                                                           26580
                                                                          26590
* COMPUTE EFFECTIVE BEAN DRY LEAF DUE TO OVERLAP. BEAN-BEAN OVERLAP
                                                                          26600
* RETAINS ITS VALUE FROM LAST ITERATION THROUGH HODE 3.
                                                                          26610
٠
                                                                          26620
300 EBDRYLF=(BOVFRCT+BDRYLF+.33)+BDRYLF
                                                                          26630
                                                                          26640
٠
* COMPUTE EFFECTIVE BEAN LEAF AREA FROM EFFECTIVE DRY WEIGHT
                                                                          26650
-
                                                                          26660
      BLFAREA=.0241*EBDRYLF - .0062
                                                                          26670
                                                                          26680
★ COMPUTE EFFECTIVE BEAN LEAF AREA INDEX FROM LEAF AREA AND GROUND AREA 26690
                                                                          26700
٠
      BLAI=BLFAREA/BGRAREA
                                                                          26710
                                                                          26720
٠
* COMPUTE TOMATO-BEAN OVERLAP. THIS VALUE MAY CHANGE IN THIS MODE DUE
                                                                          26730
* TO INCREASES IN THE TOMATO RADIUS.
                                                                          26740
                                                                          26750
      TBOVLP=(TRAD+BNRADB)-TTDIST/2.
                                                                          26760
     MODE=4
                                                                          26770
400
    IF(DAY.GT.HARVEST) TBOVLP=0.
                                                                          26780
٠
                                                                          26790
* PLACE VARIABLE VALUES INTO ARRAYS FOR LATER PRINTING. ALL VARIABLE
                                                                          26800
* NAMES STARTING WITH X OR I ARE USED FOR PRINTING ONLY.
                                                                          26810
٠
                                                                          26820
      IF(COUNTER.NE.12.AND.COUNTER.NE.24) GO TO 999
                                                                          26830
                                                                          26840
      IF(DAY.GE.ENPLANT) GO TO 510
                                                                          26850
                                                                           26860
```

	IMODE(I) =MODE	26870
	XBNRADA(I)=0.	26880
	XBNRADB(I)=0.	26890
	XBGRARA(I)=0.	26900
	XEBDRYL(I)=0.	26910
	XBLFARA(I)=0.	26920
	XBLAI(I) =0.	26930
		26940
		26950
		26960
		20700
		20715
		20700
		20770
		27000
		27010
		27020
	GO TO 999	27030
*		27040
510	CONTINUE	27050
*		27060
	IMODE(I) =MODE	27070
	XBNRADA(I)=BNRADA	270 80
	XBNRADB(I)=9NRADB	27090
	XBGRARA(I)=BGRAREA	27100
	XEBDRYL(I)=EBDRYLF	27110
	XBLFARA(I)=BLFAREA	27120
	XBLAI(I) =BLAI	27130
	XBBOVLP(I)=BEOVLP	27140
	XBOVARA(I)=BOVAREA	27150
	XBOVFRC(I)=BOVFRCT	27160
	XBNFLAG(I)=BNFLAG	27170
	XTRAD(I) =TRAD	27180
	XTGRARA(I)=TGRAREA	27190
	XTLFARA(I)=TLFAREA	27200
		27210
		27220
•		27230
~ 999	CONTINUE	27240
•		27250
-	DETIIDN	27260
		27200
•		497900
-		-27200
		-27230
		07710
-		21310
		21320
-		21330
*****		= 2134U + 97250
		21330
		2/360
*		21310
*		27380
*	* SUBROUTINE TIELO *	2/390
*	* *	27400
*	*****	27410
*		27420
	SUBROUTINE YIELD	27430
*		27440
*****	***************************************	+27450
*		+27460
*	DEFINITION OF CONSTANTS AND VARIABLES	*27470

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28090
     IF(DAY.GT.HARVEST) GO TO 100
     IF(TDRYFR.LT..0001) TFRFRT=0.
                                                                        28100
     BFRFRT=+014+BDRYFR
                                                                        28110
                                                                        28120
٠
                                                                        28130
                      *****************
                                                                        28140
                      ٠
                                             ٠
                            HEXAGON AREA
                                                                        28150
                                 AND
                                                                        28160
                         PLANT POPULATIONS
                                             *
                                                                        28170
                                                                        28180
                      28190
                                                                        28200
* AREA PER HEXAGON
                                                                        28210
                                                                        28220
100 IF(I.GT.O.OR.COUNTER.GT.1) GO TO 200
                                                                        28230
                                                                        28240
     HEXAREA=3.464*(HTTDIST**2.)
                                                                        28250
                                                                        28260
* NUMBER OF HEXAGONS PER HECTARE
                                                                        28270
                                                                        28280
     HEXPHEC=10000./HEXAREA
                                                                        28290
                                                                        28300
* TOMATO POPULATION PER HECTARE
                                                                        28310
                                                                        28320
     TPOPLIN=HEXPHEC
                                                                        28330
                                                                        28340
 BEAN POPULATION PER HEXAGON AND PER HECTARE
                                                                        28350
٠
                                                                        28360
     HEXCIRC=6.929*HTTDIST
                                                                        28370
                                                                        28380
     BPOPHEX=HEXCIRC/BBDIST
                                                                        28390
                                                                        28400
     BPOPHEC=(HEXPHEC*BPOPHEX)/2.
                                                                        28410
                                                                        28420
 TOTAL POPULATION PER HECTARE
                                                                        28430
                                                                        28440
     TOTLPOP=TPOPLTN + BPOPHEC
                                                                        28450
                                                                        28460
                           *************
                                                                        28470
                                                                        28480
                             FRESH FRUIT *
                           ٠
                                                                        28490
                           *
                                YIELD
                                           *
                                                                        28500
                           *
                                           *
                                                                        28510
                           **************
                                                                        28520
                                                                        28530
 YIELD PER HEXAGON
                                                                        28540
                                                                        28550
200 TYLDHEX=TFRFRT
                                                                        28560
                                                                        28570
     BYLDHEX=(BFRFRT+BPOPHEX)/2.
                                                                        28590
                                                                        28590
 YIELD PER UNIT AREA (M++-2)
                                                                        28600
                                                                        28610
     TYLDM2=TFRFRT/HEXAREA
                                                                        28620
                                                                        28630
     BYLDM2=(BFRFRT+BPOPHEX)/(2.+HEXAREA)
                                                                        28640
                                                                        28650
* YIELD PER HECTARE
                                                                        28660
                                                                        28670
     TYLDHEC=TYLDM2+10000.
                                                                        28680
                                                                        28690
```

		BYLDHEC=BYLDM2+10000.	28700
*	.		28710
*	SUM	OF VILLUS OF BOTH SPECIES	28720
	YTE	I D PER HEXAGON	28740
			28750
		SYLDHEX=TYLDHEX + BYLDHEX	28750
*			28770
*	YIE	LD PER UNIT AREA (M++-2)	28780
*			28790
		SYLDM2=TYLDM2 + BYLDM2	28800
*			28810
*	YIE	LD PER HECTARE	28820
*			28850
		STEDHEL - BTEDHEL	20050
-			28860
*		CE VARIARIE NAMES INTO ARRAYS FOR LATER PRINTING. ALL VARIABLE	28870
*	NAM	ES STARTING WITH X ARE USED FOR PRINTING ONLY.	28880
*	•••••		28890
		IF(COUNTER.NE.12.AND.COUNTER.NE.24) GO TO 999	28900
		XBBDIST(I)=EEDIST	28910
		XBFRFRT(I)=EFRFRT	28920
		XBPOPHC(1)=BPOPHEC	28930
		XBPOPHX(I)=BPOPHEX	28940
		XBYLDHC(I)=BYLDHEC	28950
		XBYLDIX(I)=BYLDHEX	28960
		X81LUN2(1)=01LUN2 Vuevas(1)-uevas(a	20770
		ANE AARE \ 1 / - NE AAREA YHE YY CT D (1) - HE YY CT D C	26760
			29000
			29010
		XSYLDHC(I)=SYLDHEC	29020
		XSYLDHX(I)=SYLDHEX	29030
		XSYLDM2(I)=SYLDM2	2904C
		XTFRFRT(I)=TFRFRT	29050
		XTOTLPO(I)=TOTLPOP	29060
		XTPOPLT(I)=TPOPLTN	29070
		XTYLDHC(I)=TYLDHEC	29080
		XTYLDHX(I)=TYLDHEX	29090
		XITLUM2(1)=ITLUM2	29100
*	777	CUNITNUE	29110
*		PETHON	27120
		FND	29140
*			+29150
*			+29160
*	****		**29170

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LIST OF REFERENCES

.

LIST OF REFERENCES

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