SIMPOTATO PERFORMANCE IN WARM AND COOL ARID CLIMATES: COLUMBIA BASIN AND SAN LUIS VALLEY

by
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Crop growth simulation models may potentially be used to solve a number of the environmental concerns facing modern agriculture, particularly through optimizing applications of water and nitrogen. Possible roles for these models include minimizing or preventing contamination of ground water and developing and testing best management practices for growers or regulatory agencies. However, first the models must be shown to accurately simulate interactions between environmental variables and crop growth processes. The effects of temperature on leaf and tuber growth of potato is one such interaction that will be the topic of this paper.

Leaf and tuber growth of potato are quite sensitive to air temperature and to soil temperature around the tubers. We may think of temperature as effecting growth and development of potato through accumulation of time when temperatures are suitable for growth. This may be thought of as physiological or biological time and is often called thermal time or heat units in agronomic publications. At optimum temperature, accumulation is most rapid, when temperature deviates from optimum, accumulation rate slows or stops.

The SIMPOTATO potato growth simulation model (Hodges et al., 1992) uses a thermal time algorithm modified from that in the CERES-Maize model (Ritchie et al., 1989b) to calculate accumulation of biological time (called daily thermal time or DTT) to simulate the effects of temperature on leaf and tuber growth of potato. Eight interpolated temperatures are calculated that range between the daily maximum and minimum temperatures. Thermal time accumulation for each of the interpolated temperatures is calculated from the SIMPOTATO temperature response curve (Figure 1) and the eight thermal time values are averaged to get daily thermal time (DTT) for the day.

The temperature response curve initially used in SIMPOTATO was estimated from published reports on the growth response of potato to temperature (Figure 1; Hodges et al., 1987), since growth data collected for this purpose were not available. Growth data from Eastern Washington and Colorado have since become available to test and improve the temperature response curve.

This Presentation is part of the Proceedings of the 1992 Washington State Potato Conference & Trade Fair.

The arid regions of the Columbia Basin and the San Luis Valley of Colorado are characterized by high yields of good quality potatoes. Weekly growth data from the Columbia Basin and from the San Luis Valley allowed the temperature response functions in the SIMPOTATO potato growth simulation model to be evaluated under a wide range of temperature conditions but with ample water and nitrogen availability. Some growth data taken in the warm humid conditions of the Philippines were also available. When SIMPOTATO was run for data from Eastern Washington, the cool high altitude San Luis Valley of Southern Colorado, and the Philippines, the model was found to underestimate leaf growth at low temperatures and to overestimate it at high temperatures. Small errors in estimating early season leaf growth will have a large effect on later growth because the plant grows exponentially, that is, with an increasing rate of increase during the first month after emergence.

A new temperature response curve was developed which improved the performance of SIMPOTATO at low and high temperatures without hurting performance at moderate temperatures. The original algorithm is shown in Figure 1, the new algorithm is shown in Figure 2. Figures 3-5 compare measured values and model simulations of leaf area increase, tuber growth, and total plant weight for a commercial field in Eastern Washington in 1989. The solid lines in the figures are the model simulations and the letters are values measured in the field. As seen in Figure 2, thermal time accumulation in the new algorithm is more rapid from 7 C (45 F) to 14 C (57 F) and is reduced more rapidly above 20 C (58 F) than in the original algorithm. A further reduction is calculated on days with maximum temperatures above 32 C (90 F). For moderate temperatures between 14 C (57 F) and 20 C (58 F) there is little difference between the original and new algorithms.

The SIMPOTATO model is a simulator of major plant growth and soil processes for potato (Solanum tuberosum). The model is intended for use as a crop management tool, initially for scheduling applications of water and nitrogen. The basic units of simulation are an average plant in a field and a block of soil (variable with depth, homogeneous horizontally). Processes are simulated in daily increments for up to one year. Input data required by the model include (1) soil profile description, (2) crop management information, (3) cultivar specific genetic coefficients, and (4) daily weather data. The soil profile information includes depth, water holding capacity, bulk density, pH, mineral ammonium and nitrate, organic carbon content, and organic nitrogen for each layer; maximum drainage rate through the entire profile; SCS runoff curve number; soil surface albedo; and amount of stage 1 or energy-limited surface evaporation. Crop management information includes cultivar name, planting date, planting depth, population density, emergence date (optional), dates and amounts of water and nitrogen applications (if not simulated), oven dry weight of seed piece, and length of sprouts on seed piece at planting. Weather variables include daily solar radiation, maximum and minimum temperatures, and rainfall.

The SIMPOTATO model is largely derived from the International Benchmark Sites Network for Technology Transfer or IBSNAT (IBSNAT, 1990A) models.

It uses the IBSNAT input files and generates most of the IBSNAT output files. The crop initialization and soil process simulation modules are identical in function to those in the IBSNAT models (Godwin and Singh, 1989; Hodges et al., 1989; Ritchie et al., 1989a), but are completely restructured and rewritten (Hodges et al., 1992). The model can be run from the decision support package developed by IBSNAT.

The SIMPOTATO model is available to be used by potato growers, researchers, and consultantts. It runs on an IBM-compatible personal computer. To obtain the model send 2 high density floppy diskettes (5 1/4" or 3 1/2" size diskettes) with a stamped-self addressed stiff mailer to:

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A detailed description of variable units and file formats for soil, crop management, and weather variables is available from IBSNAT (IBSNAT, 1990b). An address and telephone number for IBSNAT are included on disk with distribution copies of SIMPOTATO. The genetic coefficients are described in a user's manual also included on disk with the model.

Data sets for 15 experiments are included with the model from the U.S. (Washington, Oregon, Hawaii, Michigan, and Idaho), Great Britain, Australia, and The Philippines. The model performs very well on the detailed data sets from Washington and Oregon, but poorly on the Philippine data (probably the growth and partitioning responses to constantly high air and soil temperatures are inaccurate). Only final yield is available for the other locations where predictions range from poor to very good.

Development of SIMPOTATO is continuing due to support for potato cropping system research from the USDA-ARS. Algorithms to simulate number and size distribution of tubers, specific gravity, and some tuber deformities are currently being developed. At least one more year of data collection is planned in Eastern Washington and in Colorado.

ACKNOWLEDGMENTS

Past support from the USDA-ARS for potato model development is gratefully acknowledged as is support from the Washington Potato Commission in 1991.

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Figure 1. Original temperature response curve for the SIMPOTATO model.

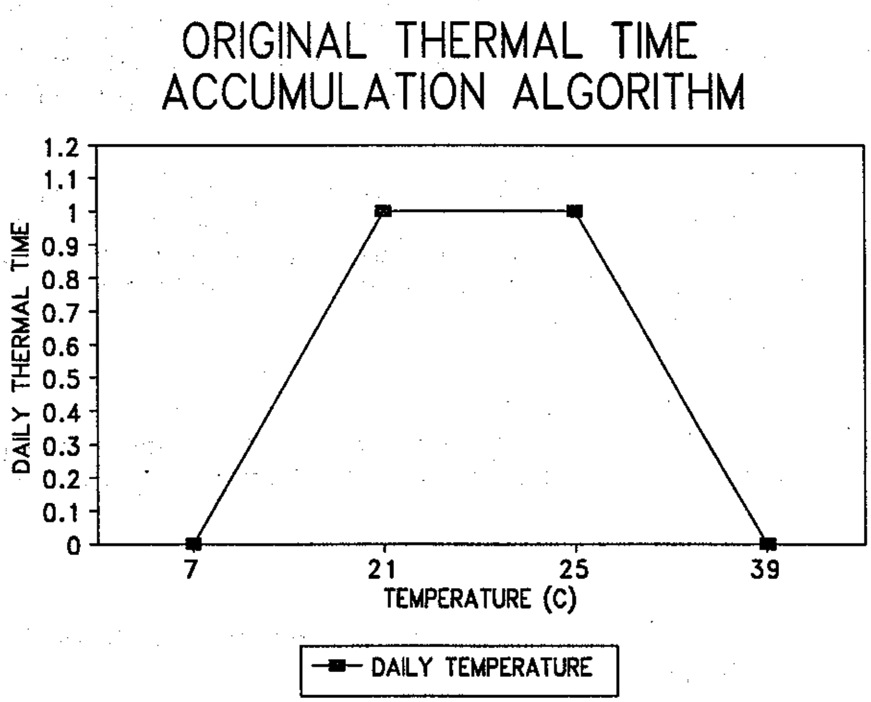

Figure 2. Improved temperature response curve for the SIMPOTATO model.

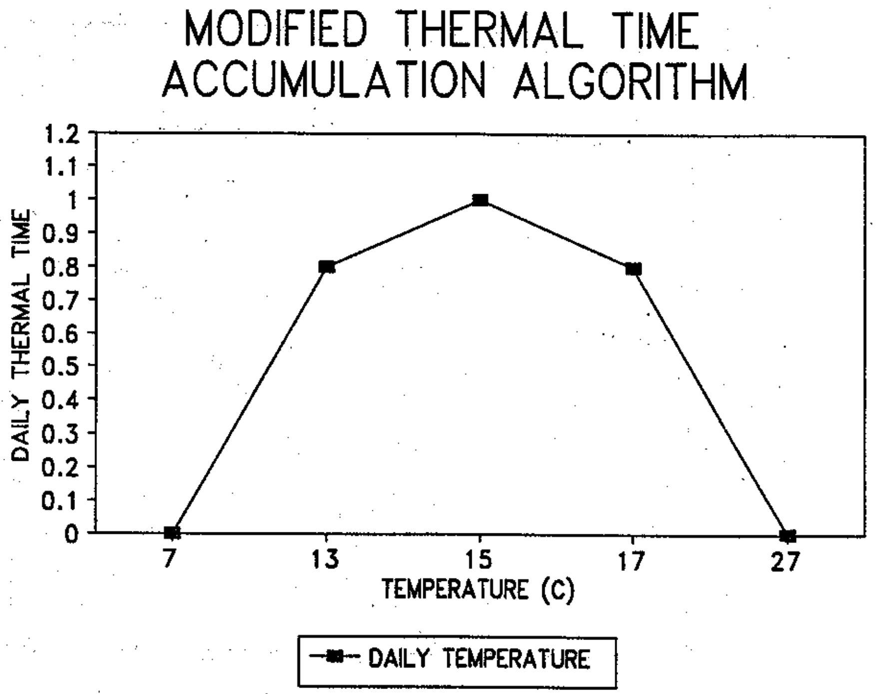

Figure 3. Simulated (solid line) and measured leaf area index (A) values for a commercial potato field in Eastern Washington in 1989.

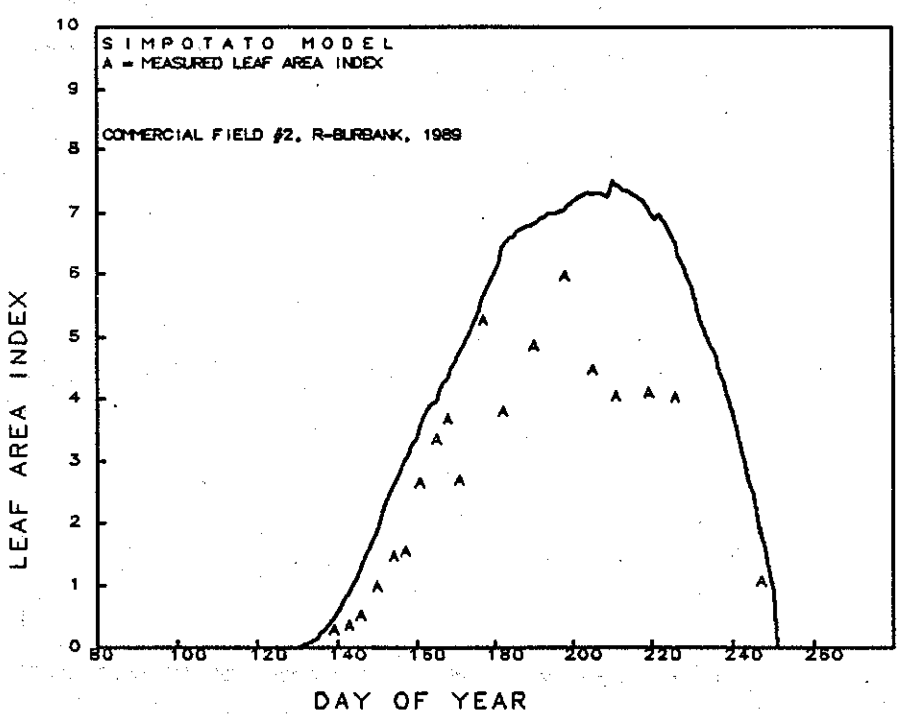

Figure 4. Simulated (solid line) and measured whole plant dry weight (A) values for a commercial potato field in Eastern Washington in 1989.

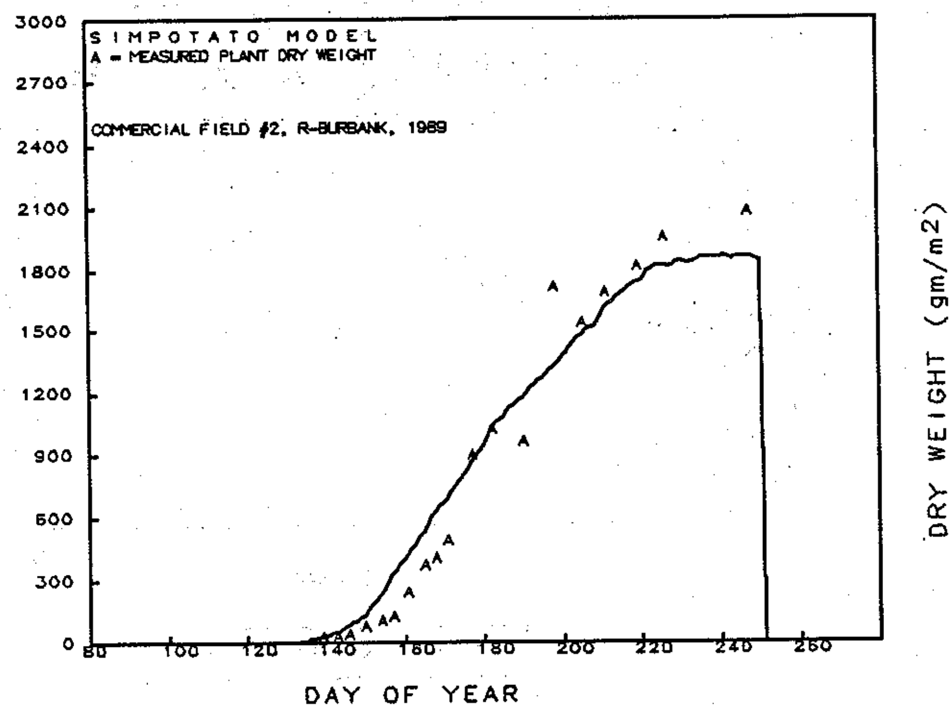

Figure 5. Simulated (solid line) and measured tuber dry weight (A) values for a commercial potato field in Eastern Washington in 1989.