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EVALUATION OF GOSSYM/COMAX FOR SCHEDULING MICROIRRIGATION IN THE SOUTHEASTERN COASTAL PLAIN

by

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Summary:

The cotton growth model, GOSSYM was used to schedule microirrigation for cotton and to simulate daily soil water potential values during 1991-1994. Simulated soil water potential values in the root zone were compared to measured values based on tensiometer data. Simulated values were generally lower (drier soil) than measured values. This information can be used to improve the soil water portion of the GOSSYM.

Keywords:

Microirrigation, Simulation, Tensiometers, Cotton, Soil water potential

INTRODUCTION

Microirrigation offers several advantages over sprinkler irrigation, including lower application rates, more precise water and nutrient placement, lower water pressure, and lower operational costs. Many irrigation scheduling methods, especially crop growth models and computer-based water balances, do not consider the special case of subsurface microirrigation. Subsurface microirrigation could become more practical for cotton because the irrigation system can be used for multiple years and nutrient amounts might be reduced.

GOSSYM-COMAX (GC), a cotton growth model coupled with an expert system decision aid, has been used by producers for over ten years. The model has been updated and modified frequently to provide new features and to accommodate special applications. GC generally treats all irrigation as rainfall, applying it uniformly over the soil surface. This is a reasonable technique for sprinkler irrigation but does not provide a realistic simulation for furrow irrigation and various forms of microirrigation, especially for subsurface microirrigation. In the latter case, the application is non-uniform (line or point sources of water) and is not on the soil surface. Because the soil surface may not be wetted with subsurface placement, less evaporation would be expected and other soil water processes would be altered. A special release of GOSSYM (GOS) that provided the option to simulate subsurface drip irrigation when placed under each row, but not under alternate furrows was developed by Crop Simulation Research, USDA-ARS, Starkville, Mississippi. The special release of GOS could not be operated with the expert system decision aid, hence GOS had to be used alone.

GOS consists of two major parts, the above ground and the below ground processes. In the below ground section, the subroutine SOIL (Boone, et al., 1992), better known as RHIZOS (Baker et al. 1983), addresses several processes, including nitrogen and organic matter, water and nitrogen movement, rain and irrigation runoff, evapotranspiration, water uptake in rooted cells, and other plant physiological processes. The water stress indices computed by GOS are often used to aid in scheduling irrigation. The objective of this paper is to evaluate the effectiveness of GOSSYM for irrigation scheduling in the southeastern Coastal Plain and, specifically, to compare soil matric potential values simulated by GC with those measured via tensiometers.

PROCEDURE

The field study was conducted on a 1.2-ha site of Eunola loamy sand (Typic Paleudult) near Florence, South Carolina. The experimental design was a randomized complete block in a split-plot arrangement with four replications. Each replication was divided into two equal areas; one was planted with cotton cultivar 'PD3'[1] in 1991-1994, and the

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[1]Mention of trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the U. S. Dept. of Agr. and does not imply its approval to the exclusion of other products or vendors that may also be suitable.

other was planted with peanuts in 1991 and 1993, and with cotton in 1992 and 1994. Each of these plots was 15 m long and 8 m wide, and contained eight rows spaced 0.96 m apart (Figure 1). Irrigation tubing (GEOFLOW ROOTGUARD®) had in-line, turbulent-flow emitters spaced 0.6 m apart each delivering 1.9 L/h at 140 kPa pressure. The irrigation treatments were every-row (ER), alternate furrow (AF), and non-irrigated (NI). The irrigation tubing was buried at a depth at 30 cm below the soil surface, directly under each row for ER and midway between alternate rows for AF. The irrigation tubing was connected to polyvinylchloride (PVC) pipe manifolds, both supply and flushing, for each plot. Water was supplied from a well and was filtered using a 100-mesh cartridge filter. Water distribution through the irrigation system was controlled with a micro-processor controller and solenoid valves. Sidedress nitrogen was applied via

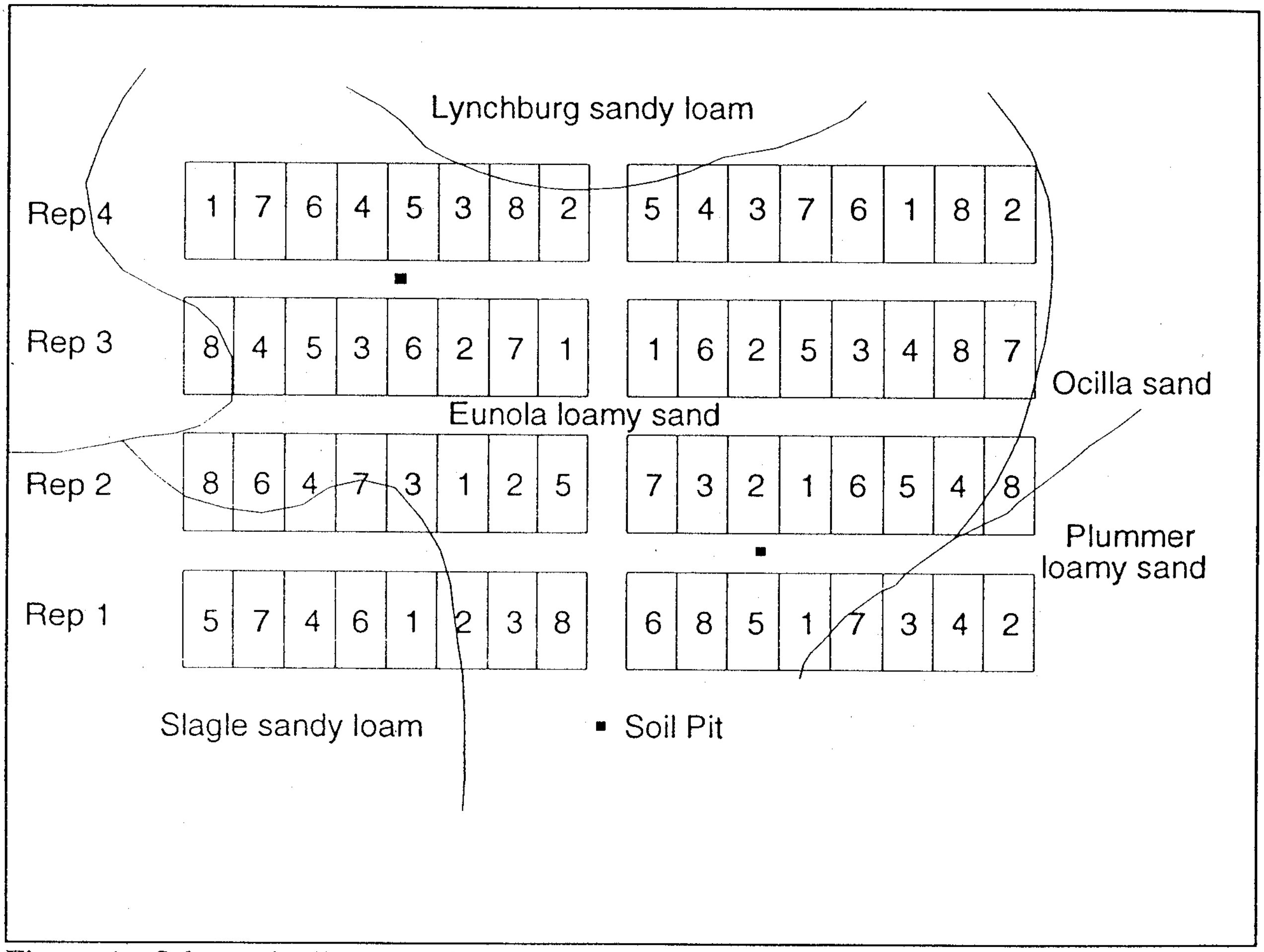

Figure 1. Schematic diagram of experimental layout showing locations of plots, soil boundaries, and soil sample sites.

the irrigation system. Tensiometer data were collected from all ER treatments but only those from locations planted to cotton in the predominant soil, Eunola ls, were included in this evaluation. Tensiometers were installed at depths of 0.3 m, 0.6 m, and 0.9 m in the row in both the ER and AF treatments. Tensiometer readings were recorded three times each week and serviced once each week. Rainfall, temperature (maximum and minimum), wind run, and solar radiation were measured with a Campbell Scientific, Inc. weather station especially equipped for collecting weather data needed for GC. Daily evaporation data were collected from a National Weather Service Class A pan located on site.

The special release of GOS that was used to manage irrigation and nitrogen in this experiment had been modified by Crop Simulation Research personnel to accommodate drip irrigation (line source) under the row at any depth in the soil profile. Recently, the model was further modified to provide model-generated, daily soil matric potential values at depths corresponding to those for tensiometers. In GOS, the soil profile is 20 cells wide and 40 cells deep; each cell is 5 cm wide, 5 cm deep, and 1 cm thick. The maximum soil profile depth is 2 m. The simulated soil matric potentials values were determined for a block of cells surrounding the tensiometer depths; 0.3, 0.6, and 0.9 m. Each block included 2 cells horizontally on all sides and 3 cells vertically, both above and below each depth. After soil matric potential was simulated for each cell, the model calculated the mean soil matric potential for soil depths of 0.3, 0.6, and 0.9 m.

A soil hydrology file was developed for the predominant soil, Eunola ls. Soil cores were collected from pits at two locations within the experimental site and a soil water characteristic curve was developed from soil water retention data obtained in the laboratory. The hydrology file was developed by the Crop Simulation unit using the soil water contents at wilting (1.5 MPa), field capacity, saturation, and air dry, and other measured soil parameters. The same volumetric water content-soil matric potential relationship was used both for normal GOS operations and for producing the soil matric potential output in the special release used for the evaluation reported in this paper.

At the beginning of each growing season measured soil water, nitrogen, and organic matter contents were used to initialize the soil portion of the model. Soil water content was determined from random samples collected at five locations in the Eunola ls and at 15-cm depth increments between the surface and 0.9 m. Simulated soil matric potential values were determined for two initial soil conditions; one using measured soil water content values and one with the soil profile assumed at field capacity.

RESULTS AND DISCUSSION

Volumetric soil water values measured each year before planting were used to initialize the soil profile for each simulation. These measured values did not always appear to be reasonable when converted to soil water potential using the soil water characteristic curve. Also, these values did not produce realistic simulated soil matric potential values when compared with measured soil matric potentials. Consequently, most of the simulated soil matric potential values reported were obtained using the assumption that the initial soil profile was at field capacity although this was not known to be true for some years.

Simulated soil matric potential values at the 0.3-m depth for the 1991 growing season had trends similar to the measured values, but were more erratic and generally indicated drier soil conditions (Figure 2). Simulated values from days 180 to 210 at the 0.3-m depth were less (lower matric potential) than the measured values but had similar trends. The simulated and measured values are similar between days 210 and 238. From day 238 to about day 250 (next irrigation), the simulated potential values decreased rapidly, almost exponentially, in comparison with measured values. After several irrigation events (days 250-260), the soil profile re-wetted and the simulated values were similar to measured values for a short period, but quickly decreased relative to measured values in the absence of rainfall or irrigation.

Simulated values for the 0.6-m depth were more erratic than those for the 0.3-m depth and generally reflected a much drier soil. Simulated values for the 0.6-m depth decreased exponentially from -5 kPa on day 170 and extended off scale (indicated by broken line), while the measured values were -10 to -15 kPa. The simulated values increased with large rainfall events on days 212 and 222, but quickly decreased to values < -80 kPa while the measured values remained around -10 kPa. A similar relationship existed for the 0.9-m depth, but the difference between simulated and measured values was much less.

The relationship between simulated and measured soil matric potential values for the 1992 and 1993 growing seasons was very similar to that for 1991 except that simulated values were greater than measured values on two occasions for the 0.3-m depth (Fig. 3 and 4). Simulated values from days 210 to 226 in 1992 were about -5 kPa while measured values ranged from -20 to -50 kPa. Simulated values ranged from -5 to -15 kPa between days 202 and 220 in 1993 while measured values ranged from -20 to -40 kPa. Both of these time periods coincided with or followed significant irrigation events.

Simulated values at the 0.6- and 0.9-m depths in 1992 and 1993 are similar to the 1991 values at these depths, and simulated soil matric potentials values were lower than measured values except for initial values and those immediately following heavy rainfall. Simulated values for both depths were much less than measured potentials and were less than -80 kPa (off scale) some of the growing season.

Because of generally adequate rainfall, only four irrigation events (25-mm total) were required in 1994. At the 0.3-m depth, the simulated soil matric potential values were very similar to measured values for much of the growing season. Simulated values were less than -80 kPa on only two occasions early in the growing season, but the values quickly increased to values similar to measured values because of either rainfall or irrigation. Except for two periods about days 238 and 258, simulated values were very similar to measured values for the remainder of the growing season. The agreement between simulated and measured values for the 0.3-m depth was much better in 1994 than in any other year. The frequency and quantity of rainfall frequently re-initialized the model and kept the soil profile moderately wet, where differences between simulated and measured values are minimum. Likewise, the agreement between simulated and measured values for the 0.6- and 0.9-m depths was better in 1994 than in any other year, although the differences for the 0.6-m depth were greater than for the 0.3-m depth.

Lower simulated values could have been caused by the method in which irrigation water is added in the model. Irrigation water is added to the cell where the irrigation lateral is located (0.3 m deep and directly under the row), which is one of the areas for which the model simulates soil matric potential. Assuming that the irrigation water volume added to the cell is based on a uniform distribution along the row, the simulated soil matric potential values should be uniform along the row. Emitters are spaced 0.6 m apart along the lateral (row). Therefore, soil matric potentials will vary considerably along the lateral immediately after irrigation but differences should decrease with time because of water redistribution within the soil profile. This effect could cause differences between simulated and measured soil matric potential values because tensiometers were located randomly both along the row and relative to the emitters.

For all soil depths and years, except for the two periods in 1992 and 1993 at the 0.3-m depth, simulated soil matric potential values were less than the measured values, generally reflecting a much drier soil profile than actually occurred. This difference was especially true as the soil profile became drier or as time after a fully-recharged soil profile increased. Several factors could cause or influence this discrepancy. Based on these results, it appears that GOS would benefit from periodic re-initialization of the soil water balance during the growing season using measured soil water values, perhaps soil matric potential values based on tensiometer data. Water storage capacity for the Eunola ls soil may be greater than is reflected by the soil characteristic curve and/or hydrology file used in the model. Also, GC may be removing more water from the soil profile than is actually required by or being removed by the crop. It is also possible that water is being supplied to the soil profile from an unknown source such as a water table. Previous research at this site (Camp et al., 1994) indicated the water table during the growing season is normally > 2 m deep, and has little effect on soil water content in the crop root zone. The discrepancy between simulated and measured soil matric potential values cannot be fully explained at this time. However, during the four years of this field experiment, GOS predicted water stress levels that could not be verified by visual inspection or by leaf water potential measurements. Similarly, when used for managing irrigation, GOS indicated the need for irrigation earlier than when using tensiometer data or visual crop stress. If these simulated soil matric potential values reflect those throughout the soil profile, GOS simulations of other processes may be affected. Generally, GOS predicted lower lint yields than were measured during this experiment. It is hoped that additional analyses of these data and future collaboration with the Crop Simulation Research unit regarding the SOIL subroutine will result in model and/or input data improvements. This should allow GOSSYM/COMAX to evolve and improve with respect to management of subsurface microirrigation for cotton for the southeastern Coastal Plain.

CONCLUSIONS

The cotton growth model, GOSSYM (GOS) was used to assist in the management of subsurface microirrigation for cotton. Soil matric potentials simulated after the growing season by a special release of the model were compared to measured values based on tensiometer data. Simulated values were consistently lower (drier soil profile) than measured values and would require more irrigation water during the growing season. Visual observations and limited plant water potential measurements of the crop support the measured values (tensiometer data). During the growing season, both GOS and tensiometers were used for scheduling the amount and frequency of irrigation during the growing season; however, GOS consistently indicated the need for irrigation earlier than did tensiometers. If GOS had been used alone, a larger volume of irrigation water would have been required to maintain simulated water stress at a desirable level. Although GOSSYM/COMAX appears to perform satisfactorily in simulating the cotton growth process, it cannot be recommended for irrigation scheduling for the conditions of this study without the use of other information, e.g. tensiometer data. We recommend that GOS be modified to allow re-initialization of the soil water balance during the growing season based on measured data. This would reduce cumulative errors in the simulation and, based on these results, would greatly improve the simulated soil matric potential values. Modification of GOS and/or soil hydrology data will probably be required to improve precision of the simulated soil matric potential.

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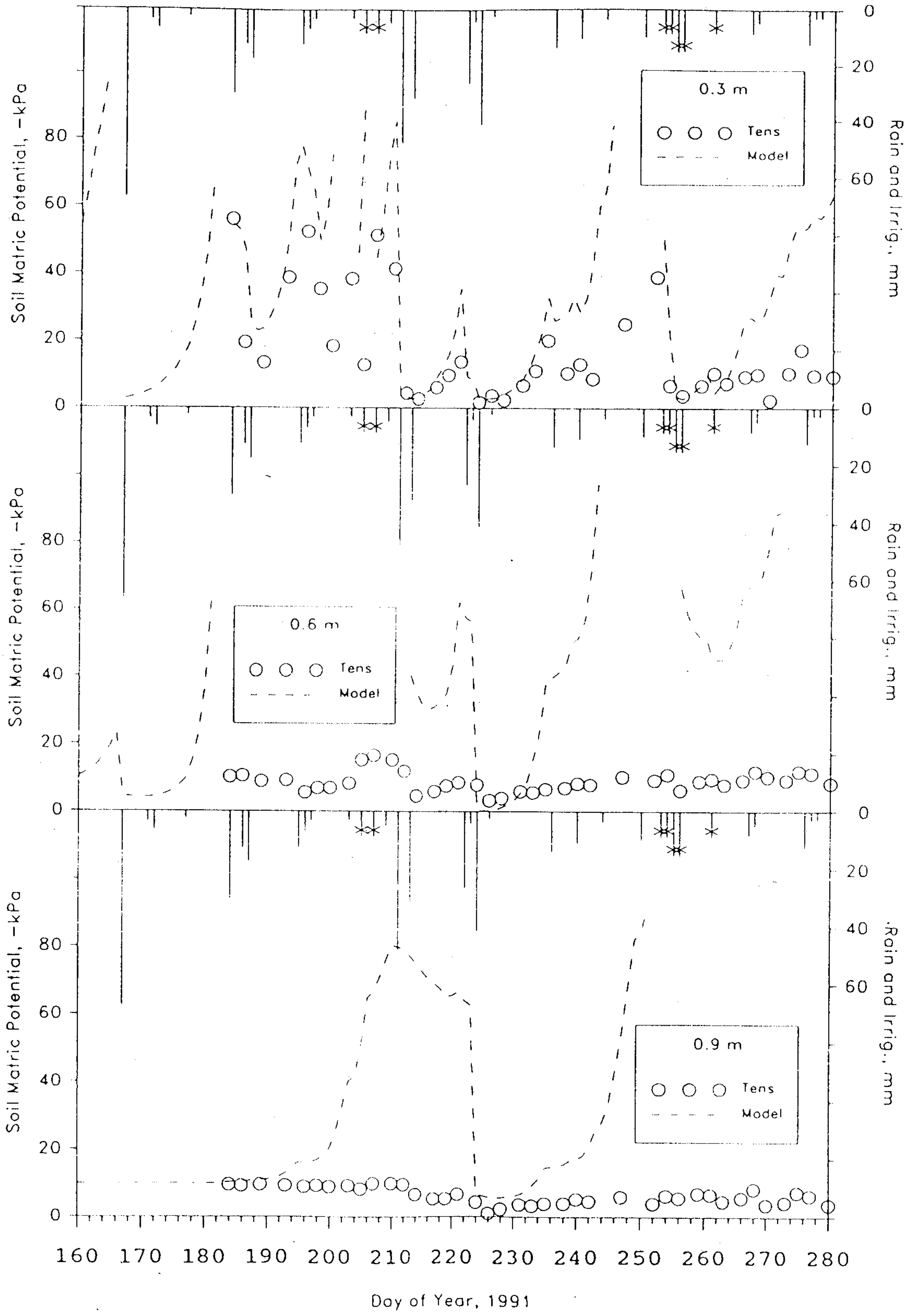

Figure 2. Daily rainfall and irrigation amounts, and simulated and measured soil matric potential values at 0.3-, 0.6-, and 0.9-m depths in a cotton experiment during 1991. Stars indicate irrigation events.

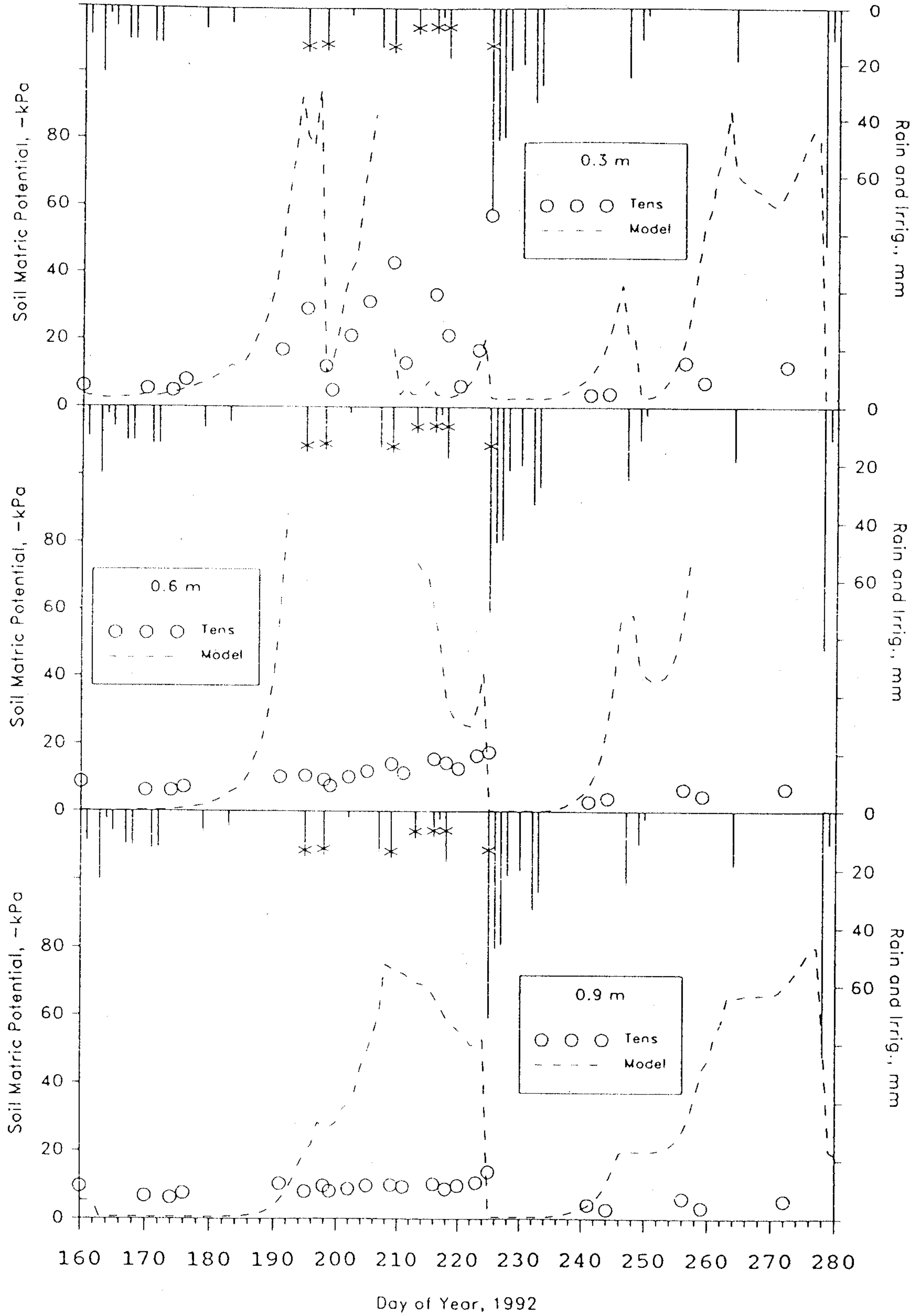

Figure 3. Daily rainfall and irrigation amounts, and simulated and measured soil matric potential values at 0.3-, 0.6-, and 0.9-m depths in a cotton experiment during 1992. Stars indicate irrigation events.

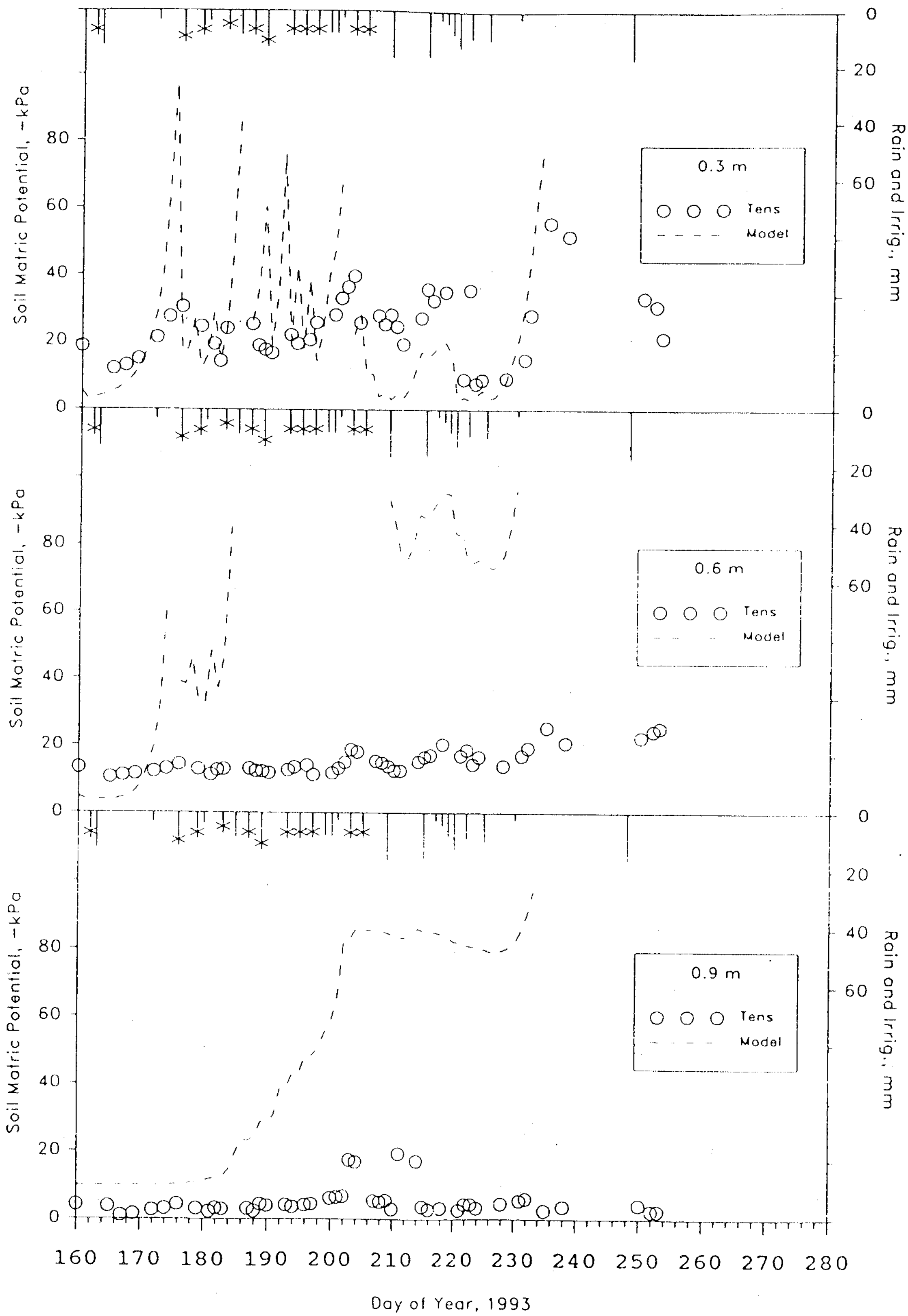

Figure 4. Daily rainfall and irrigation amounts, and simulated and measured soil matric potential values at 0.3-, 0.6-, and 0.9-m depths in a cotton experiment during 1993. Stars indicate irrigation events.

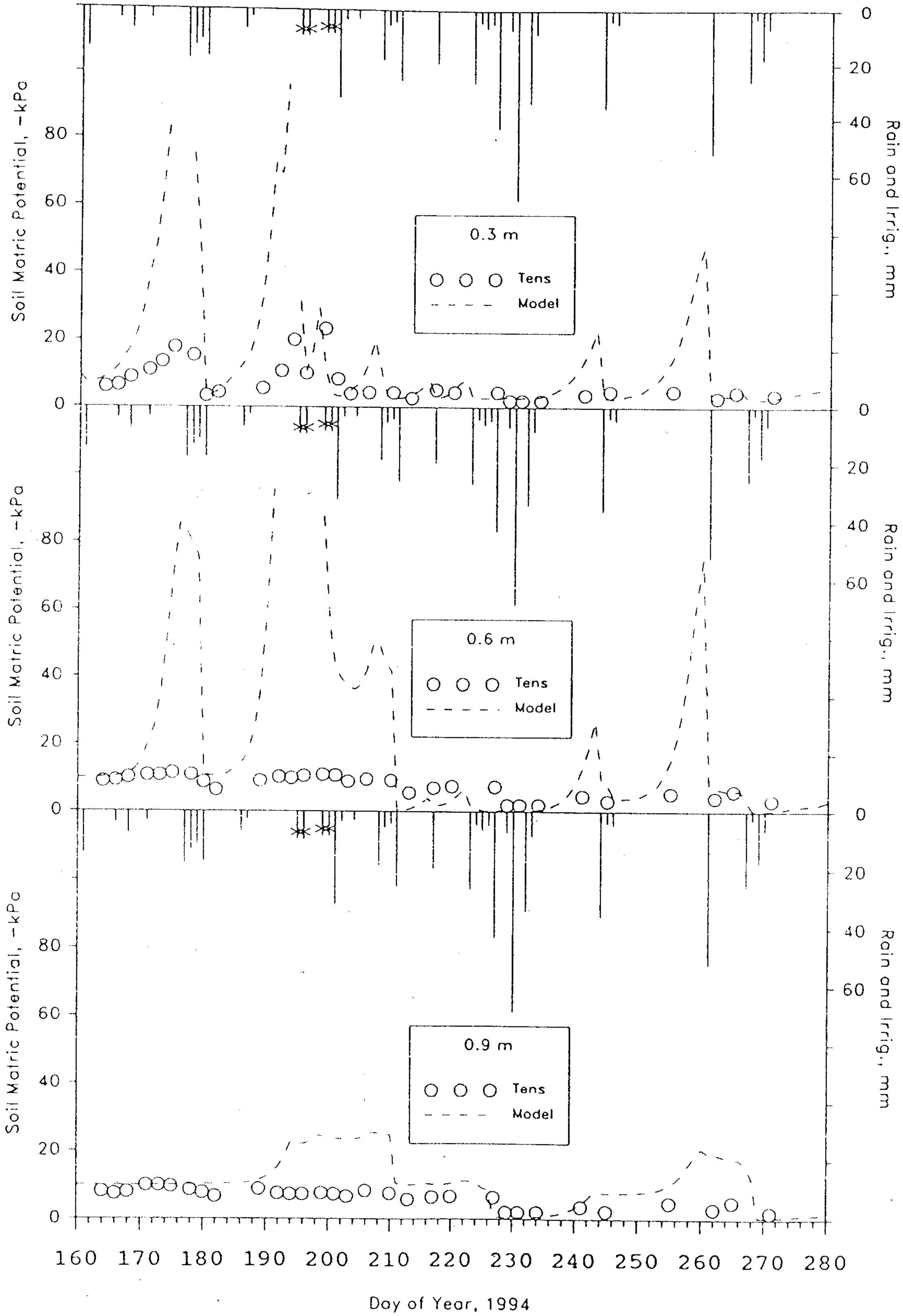

Figure 5. Daily rainfall and irrigation amounts, and simulated and measured soil matric potential values at 0.3-, 0.6-, and 0.9-m depths in a cotton experiment during 1994. Stars indicate irrigation events.