Temperature Relationships of Peanut Leaf Canopy, Stem, and Fruit in Soil of Varying Temperature and Moisture

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ABSTRACT

Physiological processes of plants are affected by temperature and temperature variation of individual plant parts has been demonstrated to affect such physiological interactions as source-sink relationships. Determination of plant part temperatures in relation to the surrounding environment, especially during stress, may provide significant information relative to how plants respond to various stress environments. To determine peanut plant part temperatures in various environments, rainfall control research plots equipped either with heating cables or cooling coils were utilized to grow Florunner peanuts and implement treatments of various soil temperatures under water stress and irrigated conditions. Peanut stem and pod temperatures were monitored automatically at 2-hr intervals with attached and implanted thermocouples. Canopy temperatures, determined by infrared thermometry, were related to water stress but were apparently unrelated to varying soil tempertures. Late-season, afternoon (1:00 p.m.) canopy temperature in the irrigated treatment averaged 28.5 C and mean canopy temperatures in all water stressed treatments were 35 ± 1 C. Late-season plant stem temperature/soil temperature means in irrigated, water stressed-heated soil, water stressed, and water stressed-cooled soil treaments were 21.6 C/21.6 C, 25.2 C/30.2 C, 25.0 C/ 25.C, and 23.3 C/ 20.6 C, respectively. Peanut pod temperatures ranged higher and lower than soil temperature in each plot and maximum pod temperatures often occurred earlier than maximum soil temperature. Concurrent pod, stem, and air maximum and minimum temperatures suggest the strong influence of aerial plant-part temperatures on temperatures of the subterranean fruit. The results of this study show the effect of moisture and temperature stress on peanut plant part temperatures and demonstrate the relationships which result from the unique subterranean fruiting habit.

Key Words: *Arachis hypogaea*, drought, irrigation, soil temperature, water stress, groundnut, temperature stress.

Temperature is of extreme importance in all areas of plant growth and development. The effect of temperature on peanuts has received considerable study; however, disagreement as to optimum temperature for various growth phases is often evident in the literature (5,10). In temperature studies air temperatures are most commonly reported, with only a few studies being concerned with or reporting soil temperatures (6,11). Air temperatures do not provide an adequate indication of soil temperature and thus provide little information on pod temperatures. Ono *et al.* (11) demonstrated that soil temperature was independently important to peanut pod development. The subterranean growth habit of peanut fruit results in unusual temperature relationships among soil, air and plant (i.e. fruit and other plant parts) that exist in few crops and these relationships have generally been ignored in temperature studies.

Although temperature has been shown to affect peanut vegetative and reproductive growth, the physiological bases for these responses have not been extensively investigated. The fact that the metabolic activity of a sink region can be modified by adjusting its temperature (15) suggests that knowledge regarding specific temperatures in peanut plants (especially pods) may be useful in understanding the effect of soil temperature on yield factors and/or growth of peanuts (13). Translocation rates of sucrose from source leaves to sink regions are influenced by alterations in the source-sink relationship through modifications of their respective strengths (14).

The objectives of this study were initially to evaluate factors contributing to preharvest invasion of peanuts by *Aspergillus flavus*; however, the plant, soil, and air temperature relationships in irrigated and low-moisture soils were found to have a much wider application useful to growth and development studies of peanuts. Thus, the objective of this report is to present data on temperature relationships found in full season peanuts, under various environments and demonstrate that those relationships vary sufficiently to warrant consideration in studies of growth and yield physiology of peanuts.

Materials and Methods

On May 5, 1981 Florunner peanuts were planted in a 91-cm row pattern in rainfall control plots containing Tifton sandy loam soil (3,4). The plots were 5.5 x 12.3 m and had been constructed to prevent lateral moisture movement into the plots from surrounding soil. Mechanized rain activated roofs prevented rainfall from entering the plots. All plots were maintained the same until 85 days after planting (DAP), when irrigated (I), water stressed (WS), water stressed-heated soil (WSH), and water stressed-cooled soil (WSC) treatments were initiated. Water was provided in the I treatment when 30 cm depth tensiometers in the plots indicated -0.3 bars tension. The water stressed treatments (WS, WSH and WSC) received no water after 85 DAP. Soil temperature was elevated in one water stressed treatment and lowered in another. To accomplish soil temperature elevation, nine General Electric 73.2 m long, 240 V, 1600 W heating cables were installed back and forth across the plot with adjacent runs approximately 10 cm apart and 12.7 cm deep. The entire cross-sectional area of the plot was covered with the cable pattern. An on-off heating thermostat was used to regulate the operation of the cables and maintain the temperature of the soil in the plot above a minimum prescribed limit. Water at approximately 20 C was circulated through parallel 0.6 cm diameter, rigid copper pipes spaced 10.2 cm apart and 10.2 cm deep to provide cooling to the other soil temperature-regulated plot. The pipes were coated with a chemically-resistant, epoxy paint to prevent elevation of cupreous compounds in the soil and possible occurrence of copper toxicity in peanuts grown in the plot. The copper pipes were attached just outside each end of the plot to a 2.54 cm insulated manifold. Pressurized water from a 32 m deep drilled well was passed through the pipes once and then exhausted by a solenoid valve in the exhaust piping regulated by a cycle timer. The water was evacuated from the system once every 2 min. Soil temperature and moisture tension ca. 5 cm and 30 cm below the soil surface were measured at 2 hr intervals with 12 copper constantan thermocouples and 12 Delmhorst gypsum blocks. The sensors were spaced 90 cm apart on two lines 6.1 m apart running across the width of the plots. Half the sensors were located under rows and half were between rows. All data were recorded automatically on cassette tape.

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Leaf canopy temperatures were measured with a Telatemp Model AG-42 infrared thermometer at 1:00 p.m. from 115 DAP through 135 DAP. The 4° field of view instrument viewed the canopy at an eastward glancing angle (ca. 16° below horizontal) 2.7 m from the target that allowed only plant material to be viewed. The instrument internally determined the difference between ambient air and leaf canopy. Stem and pod temperatures of three plants in each plot were automatically monitored at 2 hr intervals from 143 DAP through 146 DAP. The 24 gage copper constantan thermocouples used for stem temperature measurements were placed against the stem and held firmly in place by taping a split, indented, 3.8 cm square styrofoam block around the stem and thermocouple. Stem thermocouples were placed on lateral branches and hypodermic probes containing copper constantan thermocouples (30 gage x 1.27 cm needle) (Omega Engineering, Inc.) were carefully implanted into pods attached nearby on the same branch. Pods 2.54-5.08 cm below the soil surface were uncovered, the probes were inserted and pods were covered with soil to the original depth. Air temperatures in the I and WS treatment plots were measured with a shaded thermocouple mounted 30.5 cm above the soil surface.

Results and Discussion

Geocarposphere temperatures in the four plot treatments are shown in Fig. 1 for the dates and time of day corresponding to canopy temperature determinations. The data demonstrate not only the increase in soil temperature due to water stress conditions but also the relatively constant plot to plot temperature relationship produced by the soil heating and cooling systems. Diurnal variation in soil temperature is shown later in figures reporting data collected at 2 hr intervals. Mean soil temperatures for the entire treatment period (data collected at 2 hr intervals from 85-146 DAP) were 30.5, 25.7, 23.8, and 19.8 C for the WSH, WS, I and WSC treatments, respectively.

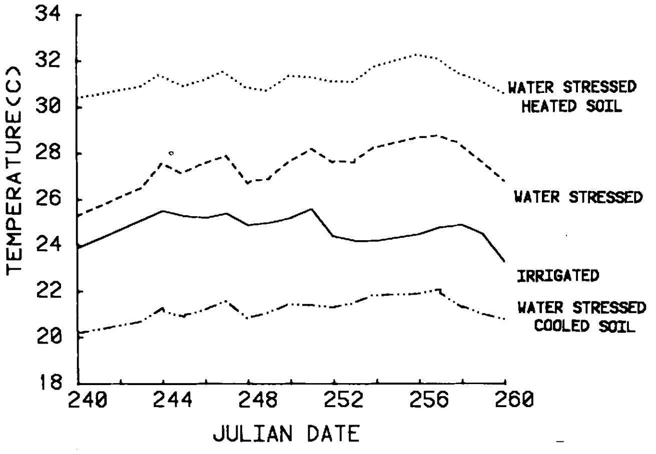

Fig. 1. Geocarposphere (5 cm) temperature of irrigated, water stressed, water stressed-heated soil, and water stressed-cooled soil at 1:00 p.m. from 115-135 days after planting Florunner peanuts.

Peanuts had been exposed to water stress and variable temperatures approximately 30 days when canopy temperature determinations were initiated. Canopy temperatures of peanuts in the four treatments were influenced more by water stress than by soil temperature (Fig. 2). The mean canopy temperature of peanuts in the I treatment for this time period was 29.2 C compared to 36.6, 36.3, and 35.5 C for the WS, WSH and WSC soil treatment plants, respectively. Dates on which all water stressed canopy temperatures approached those of I treatment canopy temperatures were characterized, without exception, by cloudy conditions. On these dates, I treatment canopy temperatures decreased slightly while large (10 C) decreases occurred in stress treatment canopies. With limiting water supply, canopy temperatures of stressed plants are similar to or greater than air temperatures during the middle of the day, while canopy temperatures of well watered plants are usually 2-7 C below air temperatures (8,9,16). During this time period the mean moisture tensions at 5 cm and 30 cm below the soil surface were -0.6 and -2.53 bars, respectively, in the I treatment and -19.1 and -19.6 bars in the stressed treatments. The mean differences between ambient air and canopy temperature in the I, WSH, WS, and WSC plots were 0.76, 7.5, 6.9 and 5.8 C, respectively. The 0.76 C mean difference in canopy and air temperatures in the I treat indicates that the water applied did not constitute "well watered conditions" as defined in other studies (8,9,16); however, the difference between the I and water stressed plots is apparent.

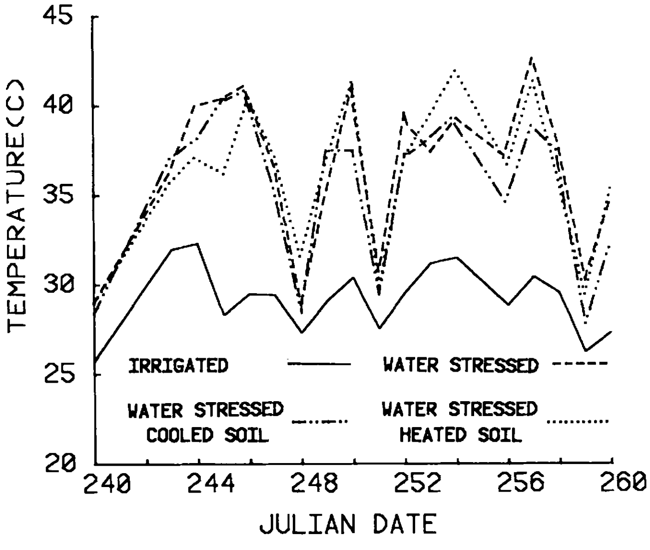

Fig. 2. Peanut canopy temperature of plants in irrigated, water stressed, water stressed-heated soil, and water stressed-cooled soil at 1:00 p.m. from 115-135 days after planting.

The daily relationship of stem, pod, soil, and air temperatures (143-146 DAP) in I treatment peanuts is presented in Fig. 3. Minimum temperatures during this time period were 34.4 C and 34.9 C, respectively. Rates of temperature increase and decrease were similar.

Pod temperatures in the I treatment ranged ca. 1.6 C higher and lower than soil temperatures at the maximum and minimum during the daily cycle and the mean temperatures (based on 2 hr interval data) were 21.6 and 21.3 C for soil and pods, respectively. The temperature differences in soil and pods were more obvious in other treatments and discussion of the phenomenon is provided later.

Temperatures of plants in the WS treatment in Figure 4 contrast in many ways with the data from I plants. Maximum stem temperatures were 40-45 C, approximately 10 C higher than irrigated peanuts, while minimum temperatures were only 1-2 degrees different

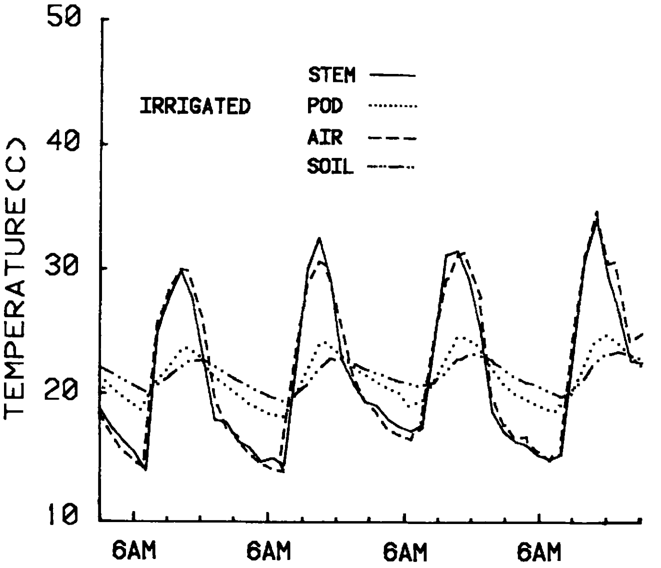

Fig. 3. Diurnal temperatures of peanut stems, pods, air, and soil in irrigated soil conditions (143-146 days after planting).

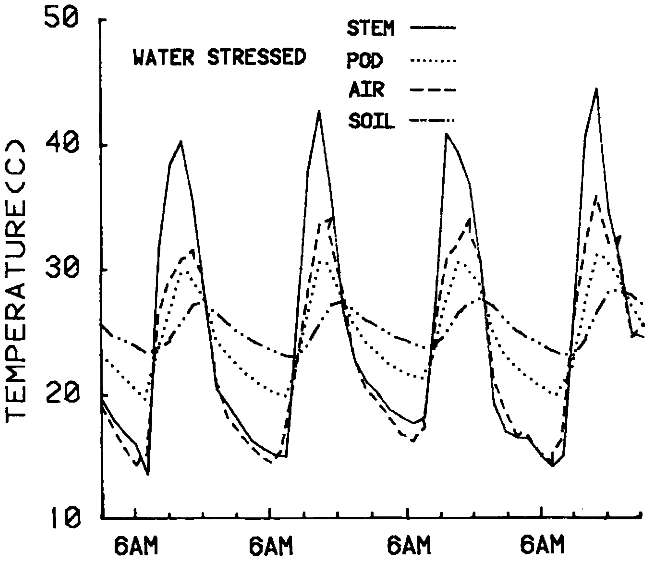

Fig. 4. Diurnal temperatures of peanut stems, pods, air, and soil in water stressed conditions (143-146 days after planting).

in the two treatments. Stem temperatures are closely related to canopy temperatures and as leaf temperatures approach 30 C, apparent photosynthesis reaches maximum (1). At 40 C, apparent photosysthesis decreases, approximately 25% (1). High leaf temperatures coupled with water stress induced photosynthesis decreases, as described by Bhagsari *et al.* (2), probably reduced photosynthate supply to an extremely low level. The relationship between air and stem temperatures in the WS treatment was different than that in I conditions. Stem temperatures in the WS treatment were 6-10 C higher than air temperature. These data verify the leaf canopy temperature data presented in Fig. 2 in that leaf temperatures approached 40 C and the WS treatment resulted in overall higher temperatures. As peanuts are subjected to continued water stress they become prostrate and stems are exposed to some direct solar radiation.

Soil and pod temperatures in WS were higher overall than those in irrigated conditions. Soil temperatures in WS ranged from 23-28.5 C over the four day period while a wider range (19.5-31.3 C) occurred in the pods. Pod temperatures not only reached maxima greater than soil temperatures (ca. 3 C), but those temperatures often occurred earlier in the pods than in the soil. This phenomenon was observed at least once in each plot except WSC and a shorter interval between temperature readings would have been useful to determine if it always occurred. Conduction of heat from the stem-canopy complex to the peanuts in the soil is probably responsible for this phenomenon. Pod temperatures are influenced by the surrounding soil but the fact that pods begin to heat and cool in concert with stems and air suggests a close relationship among the three. Further, data from all treatments which shows that pods cool below soil temperatures, when air and stem temperature are lowest, strengthens the case for a conduction-type relationship.

Temperatures in the WSH treatment closely resemble those encountered in natural, widespread droughts. In 1980, a year in which a severe natural drought occurred, the mean soil temperature of a WS treatment during the entire treatment period (2 hr interval data mid-August through September) was 28.4 C (7,12) compared to a mean of 30.2 C for the four days shown in Fig. 5. Pod temperature maxima in the WSH treatment were near the air temperature maxima recorded in the WS treatment. Stem temperatures in the WSH treatment were very similar to temperatures in the WS plot. Mean stem temperature (2 hr interval data) in the WS treatment was 24.9 C compared to a mean of 25.2 C in the WSH treatment. In both treatments, stem temperatures were approximately the same as canopy temperatures determined by infrared thermometry.

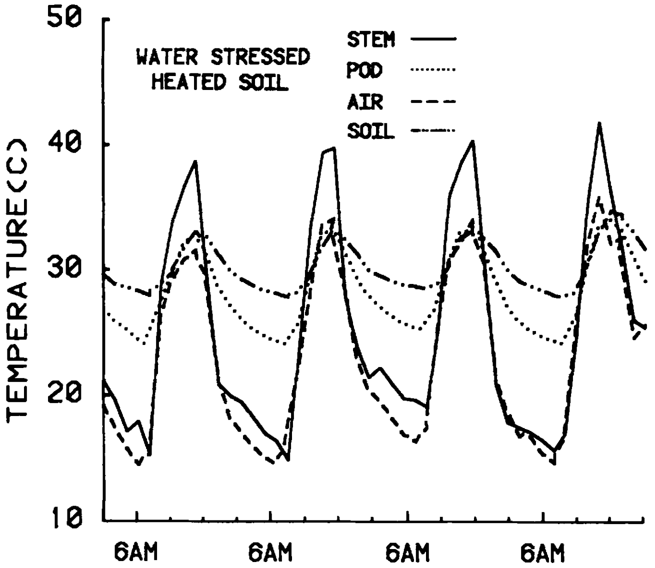

Fig. 5. Diurnal temperatures of peanut stems, pods, and soil in water stressed-heated soil conditions (143-146 days after planting). Air temperatures shown are from water stressed soil conditions.

Of the various treatments, the WSC treatment is the least typical of conditions that might occur naturally, since water stress and high soil temperatures usually occur simultaneously. Stem temperatures in this treatment were similar to other low moisture treatments (Fig. 6) and with data from the WSH treatment demonstrate the singular effect of water stress alone on foliage temperature.

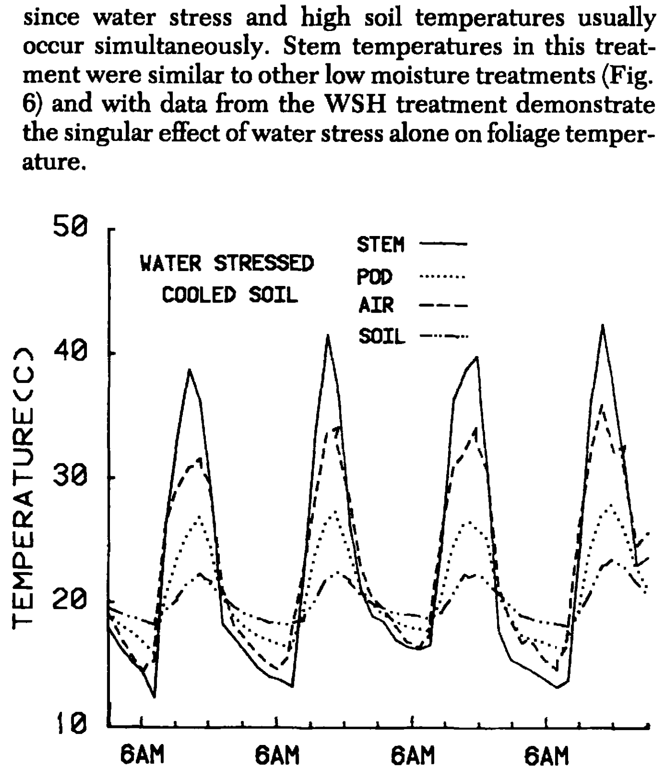

Fig. 6. Diurnal temperatures of peanut stems, pods, and soil in water stressed-cooled soil conditions (143-146 days after planting). Air temperatures shown are from water stressed soil conditions.

Mean pod temperature (2 hr interval data) in the WSC treatment was 20.9 C and was most closely related to the mean in the I treatment (21.4 C). Pod temperatures in the WSC treatment, however, ranged several degrees higher and lower than pod temperatures in the I treatment. Pods in the WSC soil treatment ranged higher (ca. 4.5 C) above the soil temperature than in any other treatment and demonstrate the apparent effect of stem temperature to raise, in this case, or lower pod temperature relative to the surrounding soil.

The comparisons made in and among the various treatments provide a unique insight into the temperature relationships that may exist under different environmental parameters occurring in various crop years. The data demonstrate that soil temperature measurements alone do not always provide an accurate assessment of the environment of developing/maturing peanut fruit. The extremes of soil, plant, and fruit temperatures noted in water stress conditions suggest that the negative effects of natural drought may not result from plant water stress alone but must in part be attributed to interrelated temperature stress, at least for some time periods.

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