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Effect of soil temperature and drought on peanut pod and stem temperatures relative to *Aspergillus flavus* invasion and aflatoxin contamination

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Abstract

Peanut stem and pod temperatures of plants growing in irrigated, drought, drought-heated soil, and drought-cooled soil treatments were determined near the end of the growing season. Mean soil temperatures of the treatments during this period were 21.5°, 25.5°, 30° and 20 °C, respectively. Peanut stem temperatures in all drought treatments reached a maximum of ca. 40 °C and for 6–7 h each day were as much as 10 °C warmer than irrigated peanut stems. Pod temperatures in drought-heated soil and drought treatments were ca. 34 °C and 30 °C, respectively, for several hours each day. As pod temperatures approached the optimum for *A. flavus* growth (ca. 35 °C), the proportion of kernels colonized and aflatoxin concentrations increased. Increased plant temperature without accompanying pod temperature increases (drought-cooled soil) resulted in colonization percentages and aflatoxin concentrations only slightly higher than those of the irrigated peanuts.

Introduction

Severe late season drought stress on peanuts generally results in decreased, low quality yields and higher incidences of *Aspergillus flavus* group invasion and aflatoxin (5). Recent studies in soil moisture and temperature control plot facilities at the USDA, ARS, National Peanut Research Laboratory have demonstrated not only the relationship between drought and concurrent elevated soil temperatures but also the necessity of a high threshold soil temperature for significant preharvest invasion of peanuts by *A. flavus* (2, 3, 7, 8). Although this relationship has been established, elucidation of the mechanism of invasion is extremely important. In this regard, studies have been initiated to evaluate temperature as one of possibly several factors that may physiologically predispose the peanut plant or fruit to infection or alter fungal metabolism such that increased invasion occurs. This is a report of studies to determine stem and pod temperatures of peanuts growing in late-season drought conditions with various induced soil temperatures and an evaluation of the possible relationship of these temperatures to colonization, growth and aflatoxin production by *A. flavus* group fungi.

Materials and methods

Florunner peanuts were planted on May 5, 1981 in 91-cm row patterns in plots that have been previously described (1, 8). Automatic mechanized roof systems were used to produce drought conditions and soil temperatures were varied with heating cable or epoxy-coated-copper cooling coils. All plots were maintained under similar conditions until 85 days after planting when irrigated (control), drought, drought-heated soil and drought-cooled soil treatments were imposed. The drought treatments received no water through harvest. Soil temperature and moisture tension in the geocarposphere (at ca. 5 cm below the soil surface) were measured every 2 h throughout the growing season with copper constantan thermocouples and Delmhorst gypsum blocks, respectively.

Pod and stem temperatures were automatically monitored at 2-h intervals during the last week of the growing season. The 24 gauge 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 gauge × 1.27 cm needle) (Omega Engineering, Inc.) were carefully implanted into pods attached nearby on the same branch. Cultural practices, aflatoxin analysis and microbiological methods have been previously described (2, 7).

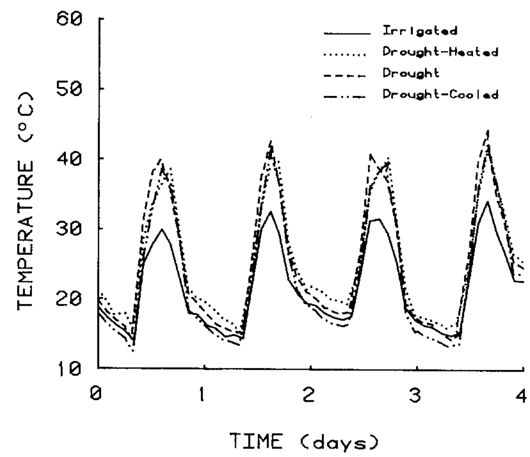

Fig. 2. Peanut stem temperatures in four plot treatments.

Results and discussion

Soil temperature data in Fig. 1 reveal consistently different diurnal variations for the various treatments. In this time period, the single maximum soil temperature of the irrigated plot (23.6 ° C) was approximately the same as the single minimum temperature of the drought plot (23.0 ° C), but the data clearly demonstrate the substantial temperature difference in drought vs. irrigated soil. Daily means for the four plots for this time period were approximately 30°, 25.5°, 21.5°, and 20 °C for the drought-heated soil, drought, irrigated, and drought-cooled soil treatments, respectively. The mean

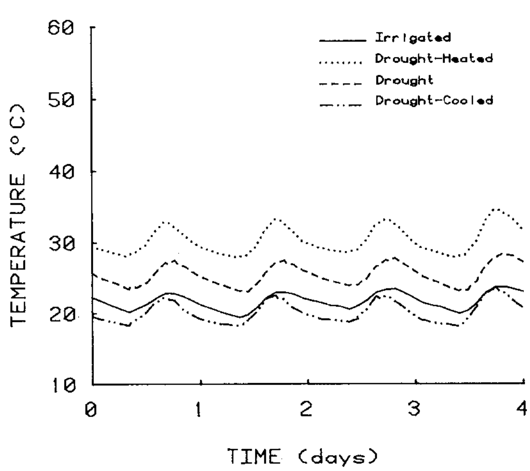

Fig. 1. Soil temperatures in four plot treatments.

drought geocarposphere temperature for the entire treatment period was 25.7 ° C compared to 28.4 ° C for the same treatment in 1980 (7), which was a severe drought year. Mean irrigated geocarposphere temperatures for 1980 and 1981 were 25.1 ° C and 23.8 ° C, respectively. A comparison of the 1981 drought treatment temperature, 25.7 ° C, and the 1980 irrigated treatment temperature, 25.1 ° C, reveals the critical nature of soil moisture in aflatoxin contamination since the irrigated peanuts were not contaminated whereas the drought peanuts contained high levels of aflatoxin although they were grown at almost the same mean temperature (2, 7). Mean soil moisture tensions during the 1981 treatment period in the drought plots ranged from 12.6 to 22.5 bars.

Stem temperature measurements on four consecutive representative days near harvest are presented in Fig. 2. In each 24-h period, temperature variations of approximately 30 ° C were common in the drought treatments while stems in the irrigated plots varied only about 15 ° C. The net result was that drought stressed plant stem temperatures were higher than those of irrigated plants for 6–7 h each day and the maximum temperature differences were about 10 ° C. Lowest temperatures in all treatments were approximately 15 ° C. When these data (Fig. 2) were averaged to provide daily means, the drought-cooled soil treatment stem temperatures were approximately 2 ° C cooler than the other drought treatments and 2 ° C warmer than the irrigated treatment stems. There is some evidence

(6, 9) that peanut flowers are invaded by *A. flavus* and this may account, in part, for the high infection rate of peanut pegs and very immature fruit we reported earlier (8). Flower temperatures, which should relate closely to stem temperatures, probably influence germination of *A. flavus* spores and/or subsequent physiology and growth of the fungus in the flower. We have observed (unpublished) that plants growing in warmed soil bloom earlier in the morning than plants in normal or cooled soil. This physiological response may predispose the flower to infection since early morning dew would provide moisture conditions more conducive to spore germination than later in the morning when flowers appeared on plants in normal and cooled soil.

Table 1. Effect of four soil treatments on aflatoxin concentration and percentage of peanut kernels colonized by *Aspergillus* group fungi.

Treatment	Irrigated	Drought-heated	Drought	Drought-cooled
Aflatoxin concentration, total, (ppb)				
Edible categories	0	417	19	0
Oil categories	0	10516	2553	66
Percent kernels colonized				
Edible categories	14.3	95.7	72.7	27.7
Oil categories	36.3	97.6	79.3	49.9

Although stem temperatures in all drought treatments were similar, data in Table 1 show that peanuts from the drought-cooled soil treatment had relatively low infection percentages and little aflatoxin. This indicates that although stem and flower temperature may influence invasion, additional factors are significant in contamination of preharvest peanuts.

Peanut pods were buried in the soil at approximately the same depth at which soil temperature was measured, but pod temperatures (Fig. 3) varied considerably more than soil temperatures. The data thus suggest that pod temperature was influenced by more than the bulk of surrounding soil. Both drought and drought-heated soil treatment pod temperatures were consistently higher than those in the irrigated treatment. The temperature of pods in the drought-cooled soil overlapped those in the irrigated treatment by several degrees. The difference between drought and irrigated treatment pod temperatures ranged from approximately 2–8 °C. In addition to the fact that drought treatment pods were always warmer than those in the irrigated treatment, for about 10.5 h each day the drought treatment pods were warmer than the maximum temperatures (24–25 °C) attained in the irrigated treatment pods. The relative constancy of soil temperatures throughout the treatment period (data not shown) suggests a high probability that these temperature relationships had existed for some time. Earlier (7), we suggested that when water activity approaches the minimum for *A. flavus* growth, such growth is only possible with temperatures at or close to the optimum of ca. 35 °C. It is unlikely the water activity becomes limiting inside the pod and as temperatures approach the optimum for *A. flavus,* more growth should occur. Pod temperatures in the drought treatment reached 30 °C for several hours each day and pod temperatures in the drought-heated treatment reached temperatures of 33–34 °C for several hours. The data in Table 1 indicate that pods at temperatures nearer the *A. flavus* optimum had higher colonization percentages and aflatoxin concentrations. Somewhat contrary to the previous flower invasion discussion, this may indicate that invasion occurs in the pod when temperatures are elevated above a certain threshold. However, it is obvious that certain temperature conditions inside the peanut pod are necessary for growth and aflatoxin production by *A. flavus* regardless of the invasion mechanism. These temperature conditions are predicated by soil temperature relationships previously established

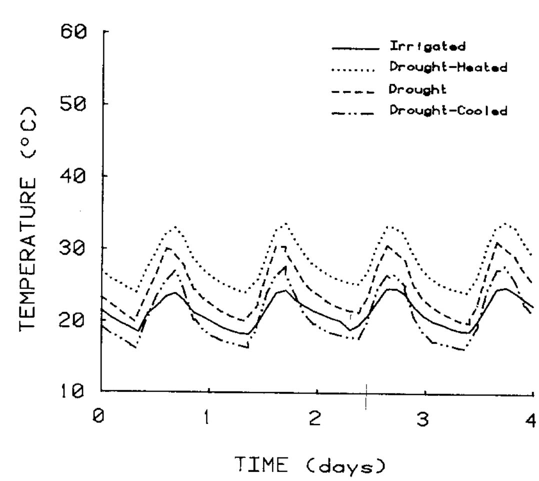

Fig. 3. Peanut pod temperatures in four plot treatments.

(7, 8), but appear to be influenced by other factors. Whether or not the increased temperatures predispose pods/kernels to increased invasion or enhance proliferation of *A. flavus* already present, remains to be determined.

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