Soil Temperature in the Peanut Pod Zone with Subsurface Drip Irrigation

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ABSTRACT

Maintaining soil temperatures at specified levels (below 29 C) in peanut (*Arachis hypogaea* L.) is vital to crop growth, development, and pod yield. Subsurface drip irrigation (SDI) systems are not designed to wet the soil surface. Possible lack of moisture in the pod zone could result in elevated soil temperatures that could be detrimental to the peanut crop. The objective of this study was to document the response of pod zone soil temperature when irrigated with a SDI system. Thermocouple sensors were inserted at 5-cm soil depth in the crop row and at specified distances from the crop row in SDI and nonirrigated (NI) treatments. Maximum hourly and daily soil temperature data were measured at three locations, one in Virginia and two in Georgia. The maximum daily soil temperature decreased as plant canopy increased. During the first 50 d after planting (DAP), the average maximum soil temperature was 1 to 2 C cooler for both the SDI and NI treatments than the average maximum air temperature. From 50 DAP to harvest, the average maximum soil temperatures for SDI and NI treatments were 6 C cooler than the average maximum air temperature. During pod filling and maturation, the average maximum soil temperature was about 5 C cooler (27 C) for SDI treatments than the maximum air temperature and 2 C cooler than the recommended 29 C. Soil temperature in the NI treatments did exceed 29 C during periods of drought but decreased to values similar to SDI treatments immediately following a rainfall event. Overall, SDI can maintain maximum soil temperatures below critical values (29 C) during peanut fruit initiation to crop harvest.

Key Words: *Arachis hypogaea*, water stress.

Pod zone soil temperatures are vital to peanut (*Arachis hypogaea* L.) crop growth and development. Keeping pod zone soil temperatures above or below specified levels can reduce the risk of *Aspergillus flavus* (Link) invasion, aflatoxin contamination, insect damage, and drought stress

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(Cole *et al.*, 1985; Mack *et al.*, 1987; Sanders *et al.*, 1993; Davidson *et al.*, 1995). Blankenship *et al.* (1984) showed that aflatoxin incidence increased during the later part of the peanut growth cycle when drought stress occurred and soil temperatures were between 25.7 and 27 C. Davidson *et al.* (1991) showed that maximum yield and quality were produced when soil temperatures in the pod zone (geocarposphere) were maintained between 21 to 29 C during pod filling and maturation. High soil temperatures increase the risk of peanut damage from lesser corn stalk bore (*Elasmopalpus lignosellus*, Zeller) invasion (Mack *et al.*, 1987). Overhead sprinkler irrigation systems wet and cool the soil surface along with the plant foliage. Irrigation water applied to peanut at appropriate times can keep soil temperatures below injurious levels throughout the growing season for maximum yield and crop quality (Davidson *et al.*, 1991).

There are over three million irrigated acres in the Georgia, Florida, and Alabama area. Of that area over 56% is irrigated using overhead irrigation type systems (Anon., 1999). Peanut is raised on about 12% of the irrigated land in the tri-state region. In Georgia, peanut is grown on 23% of the irrigated land. Subsurface drip (SDI) irrigation systems are used on less than 6100 ha in the tri-state area with most of the SDI systems used for vegetable production. It is unknown how many of these systems are used to grow peanut. There is little information concerning the use of SDI on peanut or soil temperature data in the pod zone for peanut irrigated using a SDI system. It is unknown if SDI will maintain pod zone temperatures at levels described by Davidson *et al.* (1991) for desired maximum production. The purpose of this paper is to report the response of soil temperature in the peanut pod zone irrigated using SDI systems in Virginia and Georgia.

Materials and Methods

Virginia

Soil temperature data were collected at the Tidewater Agric. Res. and Ext. Center, Suffolk, VA. The soil was an Uchee loamy sand (loamy, siliceous, thermic Arenic Hapludult) with inclusions of Emporia loamy sand (fine-loamy, siliceous, thermic Typic Hapludult). Experimental plots were planted to peanut following corn in a 2-yr rotation. The experimental design was a randomized complete block replicated four times.

The subsurface drip irrigation system consisted of lateral lines installed 38 cm below the soil surface, parallel to the crop row. Irrigation tubing was Chapin Twin-Wall IV drip irrigation tube 14-mil (0.35 mm) thick plastic with water outlets spaced at 23 cm with a flow rate of 1.13 L hr^{-1} per 30 cm of tubing at 7.0 kPa. Drip lines were placed at 0.91 m (lateral under each row), 1.83 m (lateral under alternate row furrows), and 2.7 m (lateral under every third crop row).

Copper constantan thermocouples were placed in the crop row at 5-cm soil depth for SDI and NI treatments. Thermocouples were placed over the drip tube (1989 to 1991) in the 0.91-lateral spacing only. Thermocouple positions were replicated four times. Data were collected hourly using CR-21X micrologger (Campbell Scientific, Inc., Logan, UT). Maximum, minimum, and average soil temperature values were recorded daily.

Individual plots were six rows spaced 0.91 m by 5.2 m long with a seeding rate of about 143,300 seeds ha^{-1} (Powell and Wright, 1993) of Florigiant (1989) and NC-V11 (1990 and 1991). Crop production practices followed recommendations outlined by Virginia Agric. Ext. Serv. Conventional tillage was performed on all plots and all years.

Georgia

Two subsurface drip irrigation sites were installed in Georgia. The first site was located 11 km west of Dawson, GA called the Payne Farm. The system was installed during the spring 1997. The previous crop was native grass pasture and had not been in crop production for about 20 yr. The soil was a Faceville sandy loam (fine, kaolinitic, thermic Typic Kandiudults) soil with 0-2% slope.

The second site was installed 3 km north of Sasser, GA (Sasser Farm) on a Tifton loamy sand (fine-loamy, kaolinitic, thermic Plinthic Kandiudults) soil with 2-5% slope. This system was installed during the spring of 1998. The previous crop was nonirrigated cotton. The farm had been sold and previous records were unavailable to determine when peanut had last been planted at this site.

At the Payne Farm, thin-wall drip tube (0.66 mm; 13 mil, Python by Netafim Irrigation, Inc., Fresno, CA) was installed with a modified ripper shank. Treatments consisted of a nonirrigated (NI) control, two drip tube lateral spacings, two emitter spacings, and two irrigation levels. Irrigation laterals were spaced at 0.91 and 1.83 m, and emitters were spaced at 0.45 and 0.61 m. Emitter flow rate was 1.51 L hr^{1} for all laterals. The 0.91-m lateral spacing used two emitter spacings and two irrigation levels. The 1.83-m lateral spacing used only one emitter spacing (0.45 m) and two irrigation levels. The 0.91-m drip tube lateral spacing was placed directly underneath the crop row while the 1.83-m drip tube lateral spacing was placed in alternate crop row middles. Each irrigation strip for the 0.91-m lateral spacing was 3.6 m by 67 m. Individual sample size for both the 0.91-m lateral spacing and nonirrigated (NI) control was 1.83 m by 12.2 m. The irrigation strip for the 1.83-m lateral treatment size was 5.5 m by 67 m.

In 1997, two copper-constantan thermocouples were placed underneath the crop row at 5-cm soil depth in each irrigation level and in the NI plots. In 1998, sensors were placed underneath each row, 15, 30, and 46 cm from the crop row. Sensors were replicated twice in each irrigation level and NI treatment. Soil and air temperature data were recorded hourly and daily using a CR-7 micrologger (Campbell Scientific, Inc. Logan, UT).

The Sasser Farm had drip tube (0.51 mm; 10 mil, Super Typhoon by Netafim Irrigation, Inc., Fresno, CA) installed at about 0.3 m deep using a KMC (Kelley Manufacturing Co., Tifton, GA) ripper-spider implement with a modified ripper shank. Drip tube laterals were spaced at the same distances described previously at the Payne Farm. An emitter spacing of 0.45 m was used for all drip tube installed at the Sasser Farm. The emitter flow rate was the same as described for the Payne Farm. Individual plots were 5.5 m wide by 38 m long for the 0.91-m drip tube spacing and 9.1 m wide for the 1.83-m drip tube spacing (Sorensen *et al.*, 2001). Copper-constantan thermocouples were placed at the same soil depth and distance from the crop row previously described for the Payne Farm in 1998. Maximum soil and air temperature data were recorded hourly and daily using a CR-21X micrologger. In 1999, thermocouples were installed underneath each row, 20 and 43 cm from the crop row.

The peanut cultivar Georgia Green was planted at both Georgia sites (both years) with a vacuum-type planter (Monosem planter, ATI., Inc., Lenexa, KS) on a 0.91-m row spacing. In 1997 and 1999, seeding rate was about 143,000 seeds ha^{-1}. In 1998, seeding rate was about 107,600 seeds ha^{1}. Crop production practices followed recommendations outlined by Univ. of Georgia Agric. Ext. Serv.

Irrigation Technique

In Virginia, irrigation water was applied following the procedure outlined by Powell and Wright (1993). In Georgia, all sites were irrigated based on replacement of crop water use for peanut described by Stansell *et al.* (1976). Air temperature (maximum, minimum, and average) and total solar radiation were recorded daily at each site. Specified plots were then irrigated at 100, 75, and 50% of estimated water use. Irrigation events were scheduled daily except when precipitation exceeded estimated water use.

Soil Temperature Analysis

Thermocouples and microloggers were used to measure and record soil and air temperature data as described previously. Davidson *et al.* (1991) showed that crop yield correlated best with maximum soil temperature; therefore, microloggers were programmed to output hourly averages and daily maximum and minimum soil and air temperatures. At about 40 to 50 d after planting (DAP), the plant canopy was large enough to completely shade sensors beneath the crop row. Therefore, two time periods were established to average the maximum daily soil temperatures. These time periods were from date of planting to 50 DAP and from 50 DAP to harvest. Average maximum soil temperature values were compared to the average maximum air temperature for the same time period and to the critical value of 29 C value described by Davidson *et al.* (1991). Maximum daily air temperature was used to compare with the maximum daily soil temperature. Maximum air temperature would indicate the highest level of energy available to heat the soil. Temperature sensors between the crop rows were analyzed following the same procedure described above. The standard error about the mean (SE) was determined to describe the variability of the maximum soil and air temperatures within each time period.

Results and Discussion

The average planting date for the Virginia and Georgia sites was 12 May with the average harvest date of 2 Oct. resulting in an average 142 d from planting to harvest. The results from each state will be discussed independently.

Virginia

Bosch *et al.* (1998) reported the total rainfall for the growing season (May through September) for 1989 to 1991. These data show that 1990 was dryer than the other 2 yr requiring an increased need for total irrigation water applied (Powell and Gray, 1990, 1991, 1992). More than twice the depth of irrigation water was applied in 1990 (122 mm) compared with 1991 (50 mm) but only 18% more than was applied in 1989 (99 mm). Irrigation amounts were less than 20% of the total water (precipitation plus irrigation) applied to the crop. The small percentage of irrigation water applied did not significantly affect yield (Bosch *et al.*, 1998).

Figure 1 shows the maximum daily soil and air temperature for years 1989, 1990, and 1991. After planting, maximum daily soil temperature exceeded maximum air temperature. During the first few weeks of crop growth, the plant is smaller and more erect allowing solar radiation to strike the soil surface throughout the day resulting in increased soil temperature. As the plant canopy expands, the plant covers more area with plant stalks and leaves actually laying on the soil surface. The result is less solar radiation striking the soil surface and the soil

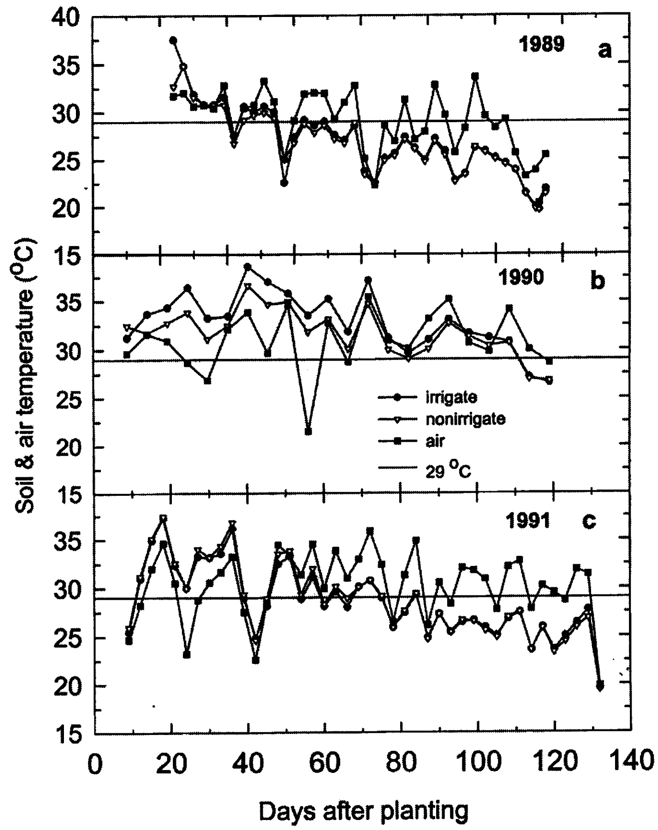

Fig. 1. Maximum daily soil and air temperatures collected at Suffolk, VA for years 1989 to 1991. Soil temperatures collected at 5-cm soil depth and underneath the crop row (only every 3rd d shown).

temperature beneath the crop should decrease. By 70 DAP the maximum soil temperature diverged from the maximum air temperature (Fig. 1a,c). Soil temperature decreased as the peanut plant increased in size and shaded more of the soil surface (70 DAP).

The average maximum soil temperature for the first 50 DAP is shown in Table 1 for both the SDI and NI treatments. At 50 DAP, pegs are in the soil, pods are forming, and the leaf area index (LAI) is about 3 to 3.5 according to Boote and Ketring (1990). During this same time period, the average maximum soil temperature for both SDI and NI treatments was equal to or slightly greater than the maximum ambient air temperature. Since the plants have not completely covered the soil

Table 1. Average daily maximum soil and air temperatures with standard error values for subsurface drip (SDI) and nonirrigated (NI) treatments in Virginia and Georgia.

Year	Irrigation level	Air	Irrigated distance from crop row (cm) 0	15	30	46	Nonirrigated distance from crop row (cm) 0	15	30	46
	%		--Soil temp (C)--				--Soil temp (C)--			
					0 to 50 DAP					
Virginia										
1989		30.0±0.4	31.0±0.4				30.3±0.4			
1990		29.9±0.5	34.3±0.4				32.6±0.4			
1991		30.2±0.5	32.2±0.5				32.7±0.5			
Payne Farm, GA										
1997[a]										
1998		36.2±0.4	32.1±1.1	33.4±1.1	36.6±1.0	36.7±0.7	33.4±0.6			34.8±1.1
Sasser Farm, GA										
1998	100	35.1±0.4	33.8±0.4	32.6±0.4	34.0±0.4	33.3±0.4	28.0±0.4	29.5±0.5	32.8±0.5	32.6±0.4
1999	100	31.1±0.3	30.1±0.7	32.1±0.7		34.1±0.6	30.5±0.1	32.6±0.1		36.1±0.1
1999	75		29.8±0.6	32.3±0.6		33.1±0.5				
1999	50		30.6±0.5	32.9±0.5		33.5±0.5				
					50 DAP to Harvest					
Virginia										
1989		29.5±0.6	26.9±0.3				26.6±0.3			
1990		31.5±0.4	31.1±0.4				30.4±0.4			
1991		30.6±0.4	27.3±0.3				27.5±0.3			
Payne Farm, GA										
1997		32.2±0.3	25.6±0.2				30.3±0.2			
1998		34.3±0.4	27.6±0.2	27.3±0.2	27.6±0.2	27.8±0.2	27.8±0.2			29.1±0.2
Sasser Farm, GA										
1998	100	33.1±0.3	26.2±0.2	26.2±0.2	26.3±0.2	26.0±0.2	24.1±0.2	24.3±0.2	25.2±0.2	25.1±0.3
1999	100	34.1±0.4	26.5±0.1	27.0±0.2		28.5±0.2				
1999	75		27.3±0.5	27.3±0.6		28.3±1.1	30.1±0.2	30.3±0.3		31.2±0.2
1999	50		28.2±0.1	29.5±0.2		31.3±0.2				

[a]Sensors not installed during this time period.

surface, solar radiation would continue to strike the soil surface between crop rows warming the soil surface. Therefore, the maximum soil temperature was only a couple of degrees warmer than the average maximum air temperature. In 1990, the average maximum soil temperature was 3 to 4 C warmer than the average maximum air temperature. In 1989 and 1991, the average maximum soil temperature was within 1 to 2 C of the average maximum air temperature. The SE was essentially the same between SDI and NI within year as well as across years.

By 90 DAP the area between the rows (furrows) were completely covered by the crop canopy. According to Boote and Ketring (1990), by harvest the LAI doubled to a value of 5 to 6. After the crop canopy has covered the soil surface, solar radiation striking the soil surface would be minimized resulting in a lower soil temperature. The average maximum soil temperature between the time period of 50 DAP to harvest was 1 to 3 C cooler than maximum air temperature. The maximum daily soil temperatures were cooler in both the SDI and NI treatments when compared with maximum daily air temperature (Fig. 1) during this time period. The average maximum soil temperatures for SDI and NI were essentially the same (Table 1). After about 60 DAP (1989 and 1991), the maximum soil temperature was below the 29 C value described by Davidson *et al.* (1991).

We expected the maximum soil temperatures in the NI treatments to be higher than the soil temperatures in the SDI treatments. However, SDI and NI soil temperatures followed the same pattern throughout the growing season (Fig. 1). This can be explained by precipitation events which occurred frequently during the growing season. Daily precipitation data showed that, during the growing season for all 3 yr, the longest time period between precipitation events was 13 d. The longest time period between precipitation events which totaled 5 mm was only 15 d. Precipitation events this frequent are similar to overhead sprinkler irrigation events which apply water to the soil surface resulting in soil cooling due to evaporation. This would explain why SDI and NI plots show the same maximum soil temperatures.

The SE was lower for the soil temperatures than the air temperature (Table 1). As the crop canopy expanded, less solar energy would strike the soil surface during daylight hours resulting in lower soil temperatures. At night the crop canopy would act as an insulating barrier keeping the soil temperature from cooling as much as the air. Therefore, the range between the maximum and minimum soil temperatures would be modified.

Georgia

Total precipitation amounts from planting to harvest were lower than ET_0 estimated for this same time period for all 3 yr. The average ET_0 for the growing season was estimated at 751 mm while precipitation was measured at 601, 718, and 492 mm for 1997, 1998, and 1999, respectively. These precipitation data suggest that little irrigation was needed in 1997 or 1998; however, 1999 was drier than normal (see Table 2). The average monthly precipitation also suggests that little irrigation water was required. Some months had daily precipitation events which measured over 100 mm d^{-1} with longer time periods between precipitation events. Thus, irrigation water was supplied between irrigation events, especially during the fall of 1997 and the summer of 1999.

Payne Farm, 1997 and 1998. Soil temperature data at the Payne Farm are shown in Figures 2 and 3 for 1997 and 1998, respectively. Figure 2 shows that from about 108 DAP to harvest the soil temperature in the nonirrigated treatment

Table 2. Precipitation data (percentage of normal) for the growing season (April through October) for 1997, 1998, and 1999 for Payne and Sasser Farm locations in Georgia.

Month	1997	1998	1999	Normal
	% of normal			mm
April	156	140	15	94
May	78	113	56	101
June	102	22	128	125
July	68	116	120	145
Aug.	180	90	42	113
Sep.	110	364	64	84
Oct.	181	10	44	56

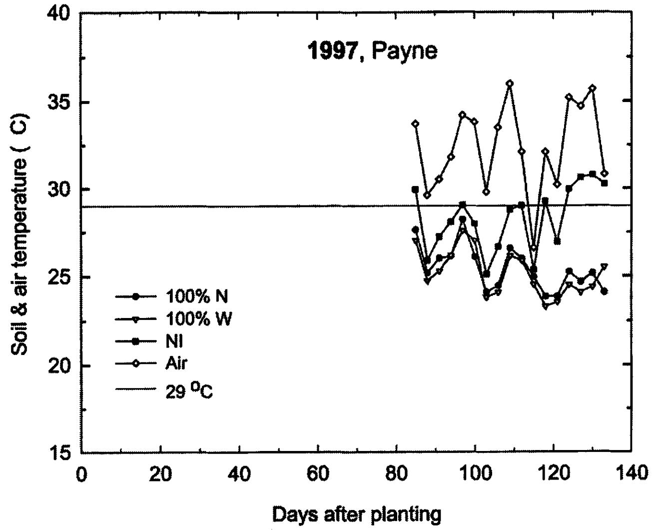

Fig. 2. Maximum daily soil and air temperatures collected at the Payne Farm for 1997 (only every 3rd d shown). Soil temperatures collected at 5-cm soil depth and underneath the crop row. Drip tube laterals spaced underneath each crop row (N; 0.91 m) and alternate middles (W; 1.83 m) irrigated at 100%.

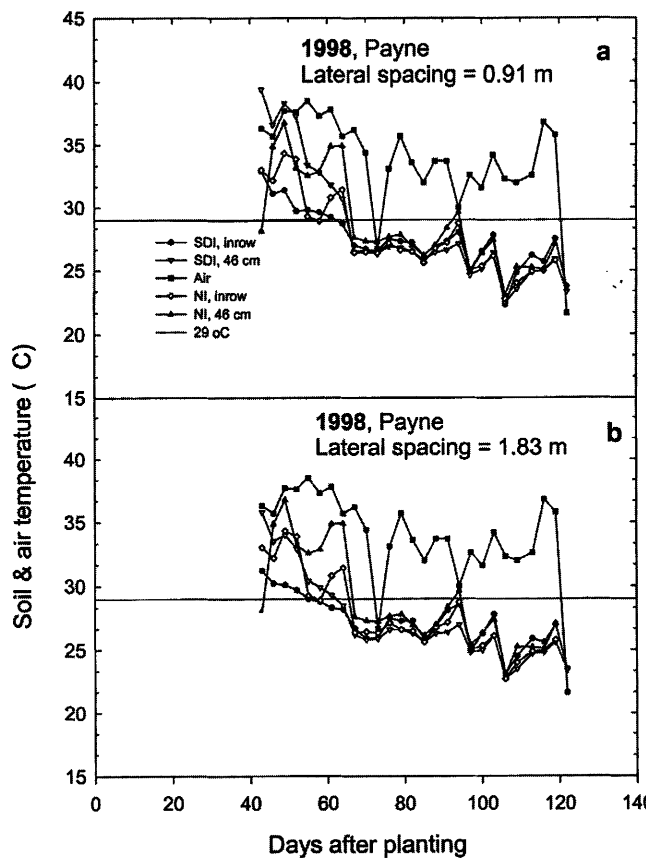

Fig. 3. Maximum daily soil (SDI and NI) and air temperatures collected on the Payne Farm for 1998 (only every 3rd d shown). Drip tube laterals spaced at 0.91 m (3a) and 1.83 m (3b). Soil temperature sensors located at 5-cm soil depth and underneath the crop row (in-row) and in crop row middles (46 cm).

was much warmer than the soil temperature in either the 0.91-m or the 1.83-m drip tube lateral spacing. There was a divergence of temperature between the NI and SDI treatments which continued through the latter part of the growing season except when a large rainfall event occurred (115 DAP). On average, the NI soil temperature was about 3 C warmer than the SDI soil temperature and about 4 C cooler than the air temperature (Table 1). From day 105 DAP until harvest, the NI treatments were drought stressed with plants showing severe drought stress symptoms—i.e., leaf folding, loss of plant turgor, etc.

Figure 3a and b showed the maximum soil and air temperatures during the 1998 growing season for the narrow (0.91 m) and wide (1.83 m) lateral spacings, respectively. After planting, the soil temperature underneath the plant (in-row) cooled down earlier during the season than the soil temperature between crop rows due to crop canopy growth and shading of the soil surface. By 80 to 90 DAP, the crop canopy covered the middle of the rows and the maximum soil temperature in these areas were similar to soil temperatures underneath the crop row. This was true for both the narrow and wide drip tube lateral spacings. Conversely, the NI in-row and row middles showed slightly warmer soil temperatures that lagged a few days behind the irrigated treatments implying slower plant growth and possible leaf folding due to slight water stress. The 1998 growing season rainfall total was close to normal such that the NI treatments did not show severe drought stress symptoms like those describe for the 1997 growing season.

During the first 50 DAP, the crop canopy increased along with fruit initiation and pod set. During this time period, the average maximum soil temperature for the SDI treatments under the plant row was about 3 C below air temperature. The average maximum soil temperature in the row middles was 2 C higher than the maximum air temperatures. From 50 DAP to harvest the maximum soil temperature in both treatments were about the same at 27 C while the air temperature averaged 34 C (Table 1).

Sasser Farm, 1998 and 1999. Figure 4 shows the maximum daily soil and air temperature during the 1998 growing season at 15 cm distance from the crop row. This figure shows that SDI and NI treatments had the same general trend described previously of high soil temperatures early in the growing season and decreased soil temperature later in the growing season as plant canopy increased. During the first 40 DAP, the average maximum soil temperature was the same as the average maximum air temperature, 34 C. During the next 10 d, the plant canopy was large enough to cover the soil surface such that by 50 DAP the SDI soil temperature averaged about 2 C cooler than the air temperature. During the rest of the year, rainfall events were often enough that plant stress for the NI treatments was minimal. Soil temperature in both the SDI and NI treatments were 6 to 7 C below air temperature for this same time period (Table 1). At about 105 DAP, the NI treatment soil temperature did start to increase due to the lack of precipitation. The NI soil temperature decreased rapidly at 117 DAP due to a precipitation event.

Figure 5 shows the maximum soil and air temperatures during the 1999 growing season for the 0.91-m drip tube lateral spacing. Soil temperatures for the 1.83-m drip tube lateral spacings were similar to those for the 0.91-m lateral spacing and are not shown. Soil temperatures during the first part of the growing season were equal to or greater than the air temperature. The average maximum soil temperature at 20 cm distance from the crop row for the first 40 DAP was only 1 C warmer than air temperature. The average maximum soil temperature in the area between the crop rows was 2 to 4 C warmer than the average maximum air temperature. Underneath the crop row, the average maximum soil temperature was equal to air temperature (Table 1).

From about 50 DAP to harvest, maximum soil temperatures were consistently lower than the daily maximum air temperature. Soil temperature for irrigation

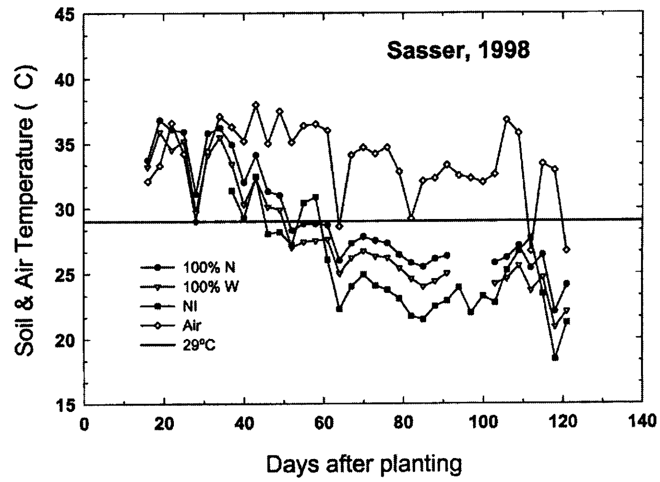

Fig. 4. Maximum daily soil and air temperatures collected at the Sasser Farm. Soil temperatures collected at 5-cm soil depth and at 15 cm from the crop row (only every 3rd d shown). Treatments include 100% irrigation using SDI and NI. SDI drip tube laterals were spaced under every crop row (N; 0.91 m) and alternate row middles (W; 1.83 m).

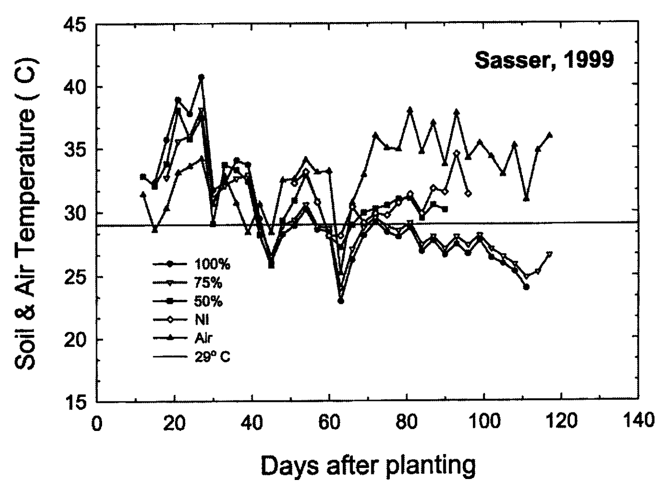

Fig. 5. Maximum daily soil and air temperatures collected on the Sasser Farm for 1999 (only every 3rd d shown). Treatments include 100, 75, and 50 for SDI and NI control. Data shown for the narrow (0.91 m) SDI lateral spacing. Soil temperatures were collected at 5-cm soil depth and at 15 cm from the crop row.

levels of 100 and 75% were essentially the same. However, soil temperatures for the 50% irrigation level and the NI treatments were greater than soil temperatures in the 100 and 75% irrigation levels. Rodent damage to thermocouple sensors stopped data collection just after 90 DAP for both the 50% and NI treatments. Soil temperatures in the 50% and NI treatments were 2 to 3 C warmer than the other irrigation levels and about 4 C cooler than air temperature.

Table 1 shows that the SE was higher for 0 to 50 DAP vs. 50 DAP to harvest. As described earlier, temperature variability decreased as soil temperatures are modified by the crop canopy.

The overall soil temperature trends for both Georgia sites and for all years (1997 to 1999) show that soil temperature decreased as crop canopy increased. Figure 6 shows a 10-d average of the maximum soil (20 cm from crop row) and air temperatures through the 1999 growing season. These data show that maximum daily soil temperatures decreased rapidly (40 to 50 DAP) once the crop canopy covered the soil surface. Once full crop

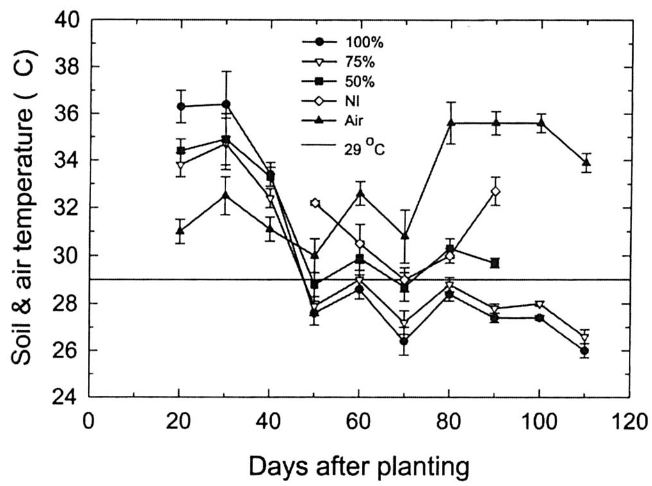

Fig. 6. Average 10 d maximum soil and air temperatures for the Sasser Farm during the 1999 growing season. Irrigation treatments include 100, 75, and 50 irrigation using SDI and a NI treatment. Data shown for the narrow (0.91 m) SDI lateral spacing. Soil temperatures were collected at 5-cm soil depth and at 15 cm from the crop row. Bars show the standard error (n = 10).

canopy was achieved, the maximum average soil temperature in all areas underneath the crop canopy was about 6 to 8 C below the average maximum air temperature. During low rainfall years and minimum irrigation, the maximum average soil temperature in NI and 50% irrigated peanut increased and began to converge with the average maximum air temperature. Figure 6 also illustrates the standard error (SE) for each 10-d average value. These data show that the average maximum air temperature was more variable about the mean than the average maximum soil temperature. Soil temperatures show a greater SE at the first of the season than at the end. This can be explained by the crop canopy. Once the crop canopy covered both row and furrow, soil temperature fluctuations were modified resulting in lower SE. The NI treatment showed a higher SE between 80 to 90 DAP caused by drought conditions. The peanut leaves would wilt and fold allowing more solar radiation to strike the soil surface resulting in an increased maximum daily soil temperature.

Davidson *et al.* (1991) showed that maximum yield and quality would be produced when the maximum soil temperature was between 20 to 29 C during early fruiting through pod maturation. Fruit initiation begins at about 40 to 50 DAP (Boote and Ketring, 1990). Virginia soil temperature data decreased below the 29 C level at different times during the year. The 1989 and 1991 soil temperature data showed temperatures below 29 C by 60 DAP.

Soil temperature data for all Georgia locations showed that, by 50 DAP, the in-row soil temperature was equal to or below 29 C. Soil temperature sensors located between crop rows showed that soil temperatures drop below the 29 C soon thereafter, depending on crop growth or canopy coverage. Soil temperatures after 50 DAP to harvest were always at or below 29 C.

Conclusions

Maximum soil temperatures during the first part of the growing season were about the same or slightly cooler than the maximum air temperature depending crop growth. This was true for both SDI and NI crop treatments. The maximum soil temperature underneath the crop row slowly decreased as the crop canopy increased to completely shade the under-row sensor. Sensors installed between crop row middles maintained high soil temperatures until crop growth covered these sensors, then within a few days, the soil temperature was essentially the same as that recorded underneath the crop row. Crop growth in the NI treatments were dependant on rainfall events. When rainfall was adequate, there was essentially no difference in soil temperatures between SDI and NI treatments. However, after long periods of drought, the plants in the NI treatment tended to show signs of water stress which include leaf curling. This leaf curling allowed solar radiation to strike the soil surface resulting in increased soil temperature. When a rainfall event occurred, the NI treatment plant regained turgidity, return to normal leaf orientation, shaded the soil surface, and soil temperatures quickly returned to values similar to SDI treatments. Overall, SDI systems located in these two areas, can keep pod zone soil temperatures at or below the critical 29 C temperature threshold during pod filling for maximum pod production as suggested by Davidson *et al.* (1991).

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