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Yield and Quality Response of Florunner Peanut to Applied Drought at Several Growth Stages[1]

J. R. Stansell* and J. E. Pallas, Jr.[2]

ABSTRACT

Florunner peanuts (*Arachis hypogaea* L.) were subjected to 35 and 70-day drought periods during several growth stages (days after planting). Drought conditions were maintained by the use of automatic rainout shelters covering groups of drainage lysimeter plots.

Detrimental effects of 35-day drought periods were greatest from 71-105 days after planting, least for 106-140, and intermediate for 36-70 days after planting. Seventy days of drought extending from 36 through 105 days after planting effectively eliminated pod production, whereas 70 days of drought during the period of 71 through 140 days after planting reduced but did not completely eliminate the production of marketable pods.

Key Words: Irrigation, rainfall shelters, available water, drought.

The increasing need for energy and water conservation in irrigation is intensifying the need for crop specific responses to irrigation. In particular, the question of what period of growth is a crop most susceptible to drought stress, and during what stages of growth can irrigation be reduced with a minimum effect on ultimate production and quality. Since peanuts (*Arachis hypogaea* L.) are a major irrigated crop in the Southeast United States, a study was conducted to evaluate their response to moderate and extended periods of drought during flowering, pod set and maturation.

Whit and van Bavel (28) noted that water requirements for peanuts reached a maximum during the flowering and pod development stage. Prevots and Oleagnier (19) reported a study by M.P. Fourrier in Senegal in which he withheld water from peanuts for a two week period during flowering. This resulted in a sharp reduction in the yields of peanuts receiving supplemental N (75 kg/h)but only moderate yield reductions for peanuts without N. Fourrier and Prevot (7) imposed 25-day droughts on peanuts by covering the plots from (a) 35 to 60 days after planting; (b) 60 to 85 days after planting; and (c) 85 to 110 days after planting. Their report indicates that water stress during periods a and b was more damaging than stress during period c. Yield reductions were 29, 18, and 15 percent for periods a, b, and c, respectively.

Ochs and Wormer (14), in greenhouse studies, found the period from onset of flowering throught the 50th day after seeding to be most sensitive to drought, although drought at any period reduced dry matter production. Il'ina (10) stated that soil moisture is most profitably used for crop growth during flower formation and flowering. He also found that water requirements for peanuts changed during the growing season. Billaz and Ochs (2), in pot studies, imposed drought stress on peanuts according to the following schedule: (a) 10 to 30 days after seeding; (b) 30 to 50 days after seeding; (c) 50 to 80 days after seeding; and (d) 80 to 120 days after seeding and obtained pod yields of (a) 78.4; (b) 82.2; (c) 53.6; and (d) 73.2 percent of check for treatments a, b, c, and d, respectively. All stressed treatments yielded significantly less than the no stress check, with treatment c (heavy flowering to fruit formation) yielding significantly less than the

[1]Contribution from University of Georgia, Agricultural Engineering Department, Coastal Plain Experiment Station, Tifton, GA and ARS USDA, Watkinsville, GA. Supported by State, Hatch and Georgia Agricultural Commodity Commission for Peanuts and funds allocated to the University of Georgia College of Agriculture Experiment Stations.

[2]Assistant Professor, University of Georgia, Agricultural Engineering Department, Coastal Plain Experiment Stations, Tifton, GA 31793 and Plant Physiologist, ARS, USDA, Watkinsville, GA 30677.

others. Treatments a,, b, and d were not statistically different. Billaz (3) intercepted rainfall on field plots with portable covers to create drought stress in peanut plots from 40 to 46 days and 51 to 67 days after planting. These periods corresponded to the heavy flowering and pod formation stage, respectively, of the plants and contributed to a 365 kg/ha reduction in pod yield.

Peak flowering (30-60 days after planting) was found to be the most stress sensitive period for a spanish type peanut (cv. Tainan No. 6) with the period 90 days after planting to maturity least sensitive (26). With limited water, a single irrigation of 50 mm 15 days after flowering increased pod yields by 17 percent. Su et al. (27) reported similar results.

Three week drought periods were imposed on Spanish peanuts 30 and 60 days after emergence by Bausch, Hiler, and Tackett (1). They found drought 30 days after emergence was more detrimental to yields than drought starting 60 days after emergence.

Although not associated with growth stages, Pallas, Stansell, and Bruce (16) found that both sound mature kernels (SMK) and germination of the Florigiant variety were significantly reduced by severe drought, while the smaller seeded Florunner and Tiftspan varieties were less sensitive to moisture stress. They proposed that drought adversely affected the calcium metabolism of the peanut seed, and thereby contributed to reduced germination.

Howell *et al.* suggested that if only one irrigation could be applied to spanish peanuts after the blooming stage, it should be during the pegging stage. For Florunner, however, adequate soil moisture in the pod maturation stage was more beneficial. Martin and Cox (12) found the only measurable decrease in pod yield resulted from drought during the period 50-80 days after flowering began, with the most severe yield decreases associated with drought during the latter part of the period. Reddy *et al.* (20) observed that drought during the flowering and pod forming stage of growth adversely affected peanut yields. Boote and Hammond (4) reported that drought during early pegging and pod formation (40-82) days after seeding) reduced vegetative growth by reducing the rate of node formation and by reducing enlongation between nodes, resulting in 51 percent fewer pegs and pods at 77 days after planting. Pod formation resumed after watering but resulted in a 10-11 day harvest delay.

Both Klepper (11) and Boote *et al.* (5) summarized the published research to indicate the period of greatest drought sensitivity is about six to eight weeks after planting, or the pod initiation, pod fill stage.

Drought stress has been implicated as a contributing factor to *A. flavus* infection of peanuts (Pettit *et al.* (18), McDonald and Harkness (13)). Dickens, Satterwhite, and Sneed (6) found that adequate soil moisture during the last two months of the growing season reduced aflatoxin contamination as well as full season irrigation. Sanders *et al.* (21) and Hill *et al.* (8) investigated Florunner response to late season (94 days after planting) modification of soil environment which included soil water and soil temperature variables. They found that drought stress increased the incidence of *A. flavus* whereas irrigation tended to reduce *A. flavus* except when the irrigated soil temperature was artificially elevated. Wilson and Stansell (29) found that soil water stress during the final 40 to 75 days of the season contributed to aflatoxin contamination of SMK three of four years for both the Florunner and Florigiant varieties. Conversely, in no treatment where irrigation was applied during the final 40 days of the season was a significant incidence aflatoxin observed.

Pallas *et al.* (15, 17) reported the response of Florunner peanuts to periods of drought based on the 1976 growing season of the study reported herein, with emphasis on physiological responses to drought imposed at several growth stages. Leaf water potentials of -3000 kPa were measured in several drought stressed plots, while a leaf potential of -4000 kPa was recorded at the end of mid-season, 35 day drought. Leaf water potentials for the full season irrigated treatment were never observed lower than -1200 kPa. Leaf water potential of the driest plots returned essentially to normal within one day following irrigation. Drought extending to harvest, whether of 35 or 70 days duration, significantly reduced the germination percentage of the seed produced. Stansell and Pallas (24) further reported that 35 day drought treatment at 71 to 105 and 106 to 140 days after planting were not significantly different but were significantly poorer than the 35 day drought treatment at 36-70 days after planting. Seventy day drought from 36-105 days after planting significantly reduced yields as compared to 70 day drought from 71-140 days after planting.

Much of the research into the relationship between peanut growth stage and drought tends to define the period of active flowering as most sensitive to drought. Later studies, particularly those including the Florunner variety, seem to indicate the most drought sensitive period is somewhat later, during the pod formation and filling stages. The study reported herein was conducted to more effectively define the periods of greatest drought sensitivity for Florunner peanuts.

Materials and Methods

Florunner peanuts were grown for four years in 1.52 m x 1.83 m drainage type lysimeters which were protected from rainfall by automatic moveable shelters described by Stansell and Sparrow (22), Stansell *et al.* (23) and Stansell and Smittle (25). Moisture barriers between plots and subsurface drains effectively isolated the plots from groundwater and from each other.

The shelters cover 24 water isolated plots, each of which contained six resistance block soil moisture sensors place at depths of 10, 23, 38, 53, 81, and 107 cm. The sensors were hardwired to a computer controlled data collection system. Water status of the soil was determined each morning, and a status report, including irrigation needs for the day, was printed. The data was also permanently stored on comptuer disks for later use.

Weather records at the plot site were maintained and included maximum and minimum air temperature, rainfall, open pan evaportion and wind movement over the pan. A continuous record of air temperature and relative humidity was also maintained.

The soil type was Tifton loamy sand with a top soil depth of 30 cm. The top soil was removed and replaced each year with soil which had been out of peanut culture for at least two years. Water retention curves and water holding parameters for the soil were determined and have been previously reported (23, 25).

Calibration curves were developed in the laboratory relating the gypsum block electrical resistance to soil water suction. These data were incorporated into a computer program which translates moisture block resistance into equivalent volumetric soil water content. To compute soil water deficits for irrigation purposes, the maximum water holding capacity (FC) of the soil was determined to correspond to a soil water suction of approximately 8 kPa. It was also assumed that a soil water suction of 1.5 mPa corresponed to the dry limit of plant usable water. The available water (AW) references in this paper refer to soil water stored between these limits.

The plots were hand tilled, fertilized, and treated with herbicides according to recommended cultural practices. Plots were seeded to four 1.5 m rows spaced 38 cm apart. Seeding rate was to give a plant density of 187,000 plants per hectare. Planting dates varied from April 22 to May 12 and age at harvest varied from 135 to 148 days (Table 1.)

Table 1. Planting and harvest dates for Florunner peanuts.

Crop Year	Planting Date	Harvest Date	Age (days) at Harvest
1974	May 5	September 23	145
1975	May 12	September 30	141
1976	April 22	September 17	148
1977	May 6	September 23	135

Six treatments (Table 2) with four replications were arranged in a randomized block design. Plots were irrigated for three weeks based on visual observation for plant establishment and to allow time for significant rooting to develop. Three weeks after seeding, plots were watered as indicated by sensor response.

Table 2. Soil water regimes for drought study, 1974-1977.

Treatment Number	Irrigation Code	Age of Peanuts (Days)			
		1-35	36-70	71-105	106-140
1	WWWW	Wet[1]	Wet	Wet	Wet
2	WDWW	Wet	Dry	Wet	Wet
3	WWDW	Wet	Wet	Dry	Wet
4	WWWD	Wet	Wet	Wet	Dry
5	WDDW	Wet	Dry	Dry	Wet
6	WWDD	Wet	Wet	Dry	Dry

[1]Wet = Water applied to refill soil profile to a depth of 60 cm when average soil water suction in top 30 cm reached 20 kPa.

Dry = No water applied for 35 day period.

Plots not in scheduled drought periods were watered to refill the upper 60 cm of the soil profile to FC when the average soil water suction in the surface 30 cm of soil reached 20 kPa.

Peanuts were harvested at approximately 140 days after planting. All treatments were harvested at the same time without regard for possible maturity differences between treatments, as plot size precluded sampling for maturity determinations. Plots were hand harvested, placed in burlap bags, and dried at 30C. Pods left in the soil were recovered by screening and are included in the yields presented herein.

Table 3. Pod yields and quality[1] of Florunner peanuts subjected to drought at several stages of growth.

Treatment Code	Irrigation Code	Total Pods (kg/ha)	Grade Categories in Percent				
			SMK[2]	SS[3]	OK[4]	OK[5]	Hulls
			1974				
1	WWWW	7589a[6]	78.3a	1.6ab	3.0bc	0.6bc	18.0c
2	WDWW	5554c	73.7a	1.2b	4.2bc	0.5c	21.7b
3	WWDW	5336c	72.3a	1.0b	5.9b	1.4bc	20.2bc
4	WWWD	6298b	78.3a	2.6a	2.2c	1.3bc	18.2c
5	WDDW	1892e	42.6b	0.9b	21.1a	2.0ab	34.3a
6	WWDD	3693d	74.6a	1.9ab	2.8c	3.1a	19.4bc
Means		5060A[7]	70.0B	1.5B	6.6C	1.5B	22.0B
			1975				
1	WWWW	4573a	78.2a	3.6a	5.1b	0.0b	17.2b
2	WDWW	3671b	75.0a	4.6a	4.9b	0.5b	19.2b
3	WWDW	3432bc	74.5a	3.4a	4.4b	3.3a	17.9b
4	WWWD	4340a	81.4a	3.5a	1.6b	0.2b	16.8b
5	WDDW	553d	16.8b	0.1b	37.1a	0.0b	45.4a
6	WWDD	3026c	79.0a	2.8a	2.7b	0.5b	18.0b
Means		3265C	67.5C	3.0A	9.3B	0.7A	22.4B
			1976				
1	WWWW	5464a	79.3ab	2.4a	2.8bc	1.2b	16.2cd
2	WDWW	4599b	79.2ab	2.4a	2.0cd	1.3b	16.6cd
3	WWDW	3418c	76.1b	2.7a	3.7b	2.8b	17.1bc
4	WWWD	3666c	81.0a	2.3a	0.9d	1.9b	15.6d
5	WDDW	2539d	59.8d	1.5a	10.3a	4.3ab	25.2a
6	WWDD	1932e	69.5c	1.4a	3.7b	8.3a	18.2b
Means		3605B	74.1A	2.1B	3.9D	3.3B	18.1C
			1977				
1	WWWW	3032b	70.3ab	3.5a	6.8de	1.9a	20.4de
2	WDWW	2393c	65.8b	2.6ab	9.9cd	0.9ab	22.7d
3	WWDW	2146c	56.1c	0.8c	13.1b	2.3a	27.5c
4	WWWD	3776a	74.9a	3.8a	4.3e	1.6a	18.5e
5	WDDW	564e	13.3d	0.4c	42.4a	0.0b	43.6a
6	WWDD	1715d	55.2c	1.6bc	10.8bc	2.3a	31.2b
Means		2271D	55.9D	2.1B	14.5A	1.5B	27.3A
			Combined Analysis				
1	WWWW	5165a	76.5a	2.8a	4.4c	0.9c	18.0d
2	WDWW	4055c	73.4b	2.7a	5.2c	0.8c	20.0c
3	WWDW	3584d	69.7c	2.0b	6.8b	2.5ab	20.7bc
4	WWWD	4521b	78.9a	3.0a	2.2d	1.2c	17.3d
5	WDDW	1387f	33.1d	0.7c	27.7a	1.6bc	31.1a
6	WWDD	2592e	69.6c	1.9b	5.0c	3.6a	21.7b

[1]Seed quality as determined by Federal-State Inspection Service procedures.

[2]SMK = Sound mature kernels. Includes sound splits (SS).

[3]SS = Sound splits.

[4]OK = Other kernels - includes immature and shriveled kernels.

[5]DK = Damaged kernels - includes moldy or decayed kernels and those with concealed damage.

[6]Mean separation by Duncan/Waller test. Means in columns within a year followed by same letter are not different at the 5% level.

[7]Mean separation by Duncan Waller test. Annual column means followed by same capital letter are not different at 5% level.

Results and Discussion

Yield and Quality

Table 3 summarizes the yield and grade response of the Florunner peanuts to imposed drought periods and Table 4 lists the application amounts and water distribution by treatments and year.

The peanuts were grown in the same plots for the four year study, and although the surface 30 cm of top soil was replaced each year, there was a significant year effect, with reductions in yield following 1974, with no apparent disease buildup. However, the yield and quality of the 1976 crop was better than that of the 1975 crop.

The combined four year analysis shows that continuous irrigation (Table 2) contributed to significantly higher yields when compared to droughted treatments. However, in 1975 treatment 1 was not significantly better than treatment 4, and in 1977, treatment 4 yielded significantly higher than treatment 1.

The data, averaged over four years, show that among the 35 day drought periods, Florunners are most sensitive during the period 71-105 days after planting (Tr. 3). This corresponds to the beginning seed to beginning maturity period as defined by Boote *et. al.* (5). Both yield and SMK were reduced. Next in severity was the day 36-70 drought (Tr.2) during flower initiation to beginning seed stage.

Drought imposed from 106 days after planting through harvest (Tr. 4) was least damaging to the peanuts, with a yield reduction of 640 kg/ha. The peanut quality for this treatment, as indicated by the percent sound mature kernels (SMK), was equal or superior to the non-droughted plots.

Treatment 6, which had no water added after 70 days of age, produced a surprising mean of 2600 kg/ha for the four years. We feel that at 70 days of age, the peanut roots were reaching the deeper profile depth, and at irrigation cutoff there was about 10 cm of profile water available which was sufficient to mature about one-half of the crop. Treatment 5, which had no irrigation during the midseason period from 36-105 days of age, suffered severe vegetative damage, including some plant mortality. The water in the profile at irrigation cutoff was insufficient to sustain vegetiative and pod development needs, resulting in severe yield and quality depression.

Table 4. Water applied for each 35 day period.

Treatment Number	Irrigation Code	Water Added (cm)				
		0-35	36-70	71-105	106-harvest	Total
			—1974—			
1	WWWW	12.23	15.88	20.00	9.09	57.20
2	WDWW	11.27	0.00	22.26	13.61	47.14
3	WWDW	10.73	16.45	0.00	11.70	38.88
4	WWWD	11.67	15.20	21.37	0.00	48.24
5	WDDW	11.14	0.00	0.00	11.02	22.16
6	WWDD	11.86	15.46	0.00	0.00	27.32
			—1975—			
1	WWWW	8.69	16.45	13.58	8.31	47.03
2	WDWW	9.01	0.00	16.70	8.44	34.21
3	WWDW	9.71	16.70	3.12[1]	9.53	39.06
4	WWWD	8.64	13.71	10.34	1.50[2]	34.19
5	WDDW	8.66	0.00	0.00	13.06	21.72
6	WWDD	8.27	13.30	0.00	1.50[2]	23.07
			—1976—			
1	WWWW	7.34	11.14	16.24	16.07	50.79
2	WDWW	7.22	4.85[3]	11.66	14.40	38.13
3	WWDW	7.22	11.91	6.00[4]	8.70	33.83
4	WWWD	7.22	11.25	14.61	0.00	33.08
5	WDDW	6.53	0.51[5]	5.90[6]	19.70	32.64
6	WWDD	6.53	9.89	1.30[7]	0.00	17.72
			—1977—			
1	WWWW	9.08	17.92	11.80	6.92	45.72
2	WDWW	8.15	0.00	13.46	5.29	26.90
3	WWDW	8.15	14.68	0.00	7.19	30.02
4	WWWD	8.00	14.40	17.36	0.00	39.76
5	WDDW	8.00	0.00	0.00	9.63	17.63
6	WWDD	8.28	14.25	0.00	0.00	22.53
			—Combined 1974-1977—			
1	WWWW	9.34	15.35	15.40	10.10	50.19
2	WDWW	8.93	1.21	16.02	10.43	36.59
3	WWDW	8.95	14.93	2.28	9.28	35.44
4	WWWD	8.88	13.64	15.92	0.40	38.84
5	WDDW	8.58	0.13	1.48	13.35	23.54
6	WWDD	8.74	13.22	0.32	0.40	22.66

[1]Watered day 105 for post drought leaf potential recovery measurements.

[2]Equipment failure - rain on day 121.

3Watered day 69 for post drought leaf potential recovery measurements.

[4]Rain day 74 (1.3 cm) + irrigation (4.7 cm) on day 104.

[5]Rain day 70 (0.51 cm)

[6]Rain day 74 (1.3 cm) + irrigation (4.6 cm) on day 104.

[7]Rain day 74 (1.3 cm).

Soil Water Status

In general more water was applied during 1974 than subsequent years (Table 4) and may have contributed to the higher yields obtained. However, we feel that adequate water was available to all treatments during non-droughted periods and the high water use of 1974 was the result of plant needs associated with the vigor and growth of the first year peanuts. Although we have no physiological data to verify this assumption, the plot of soil water content for treatment 1, 1974 is so similar to treatment 1, 1976 presented here (Fig. 2) that soil water regimes were obviously not the cause of observed yield differences.

The accumulated pan evaporation for the four years is presented in Fig. 1. The curves indicated similar evaporative demands over the study, and also does not explain the differences in annual yield response as a function of weather stress.

Figures 2 through 5 present the irrigations and soil water responses for the 1976 crop, which is fairly representative of the other years.

Data for the curves were generated by summing the soil water content in 15 cm profile increments for the 0-60 cm curves, and summing the water in the 60-90 cm and 90-120 cm depth for the 60-120 cm curve. Soil water retention curves and parameters for field capacity and wilting point are the same as given by Stansell et al. (23).

Treatment 1 was irrigated throughout the growing period and produced the highest yield of high quality pods. The available soil water status for both the 0-60 and 60-120 cm profile is illustrated in Fig. 2 and illustrates

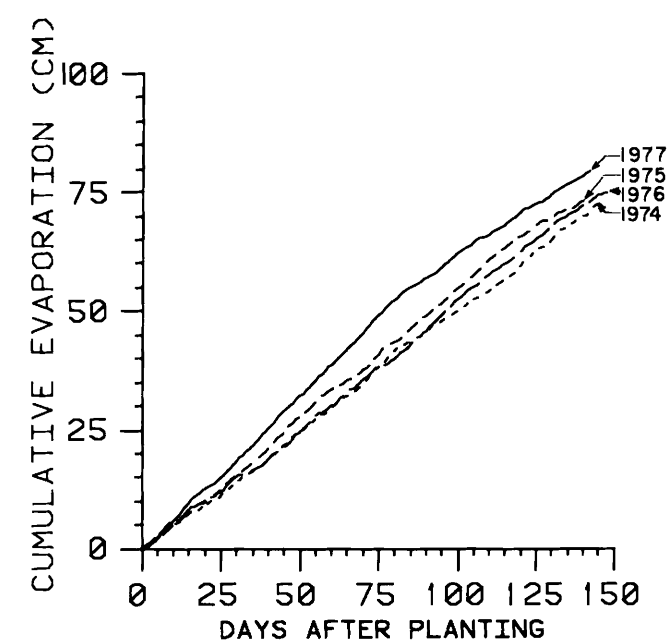

Fig. 1. Cumulative open pan evaporation for peanut crops, 1974-1977.

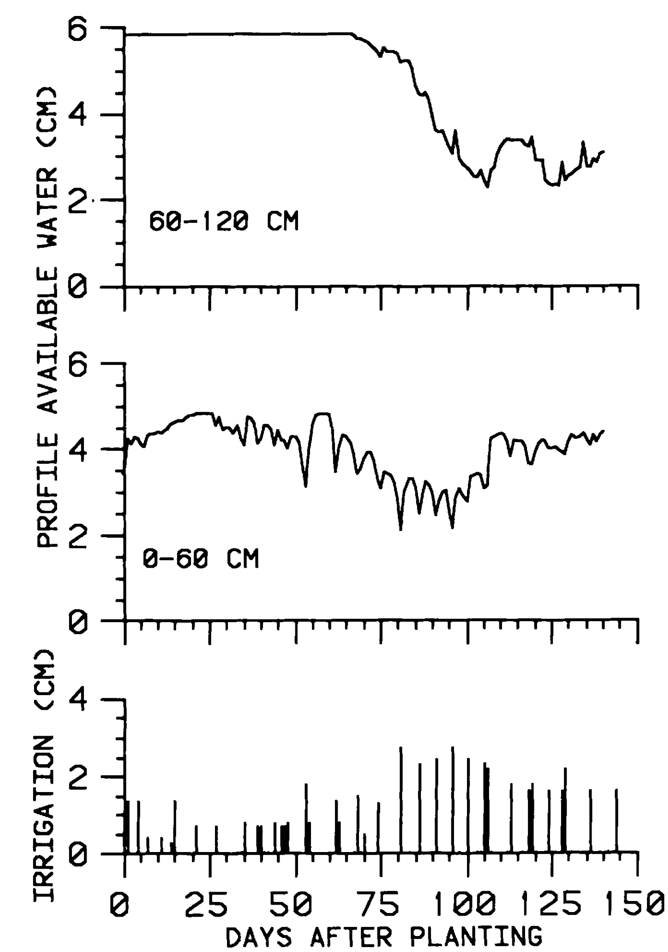

Fig. 2. Irrigaiton applications and available soil water for Treatment 1 (WWWW), 1976.

a typical water extraction pattern for Florunner peanuts. With irrigation applications designed to maintain the soil water regime in the upper 60 cm profile, root penetration, and water use from the deeper profile is evident from the general decline in the available water (AW) of the 60-120 cm depth beginning at about day 70.

Drought during the period 36-70 days after planting (Tr. 2) corresponds to the period from flower initiation to beginning seed stage (5). Drought during this period was observed to markedly reduce vegetative growth although the plants did not die and with resumption of irrigation, the plants recovered to the point that drought effects were not visually apparent. Although we were unable to include late harvest variables in this study, it is possible that delayed harvest would have markedly reduced the drought effects of this treatment.

The soil water regime for Tr. 2 is given in Fig. 3. Note that essentially all water use was from the 0-60 cm depth until about day 60 even though irrigation was discontinued after day 27. After the roots grew into the deeper subsoil, considerable water was extracted from the 60-120 cm zone.

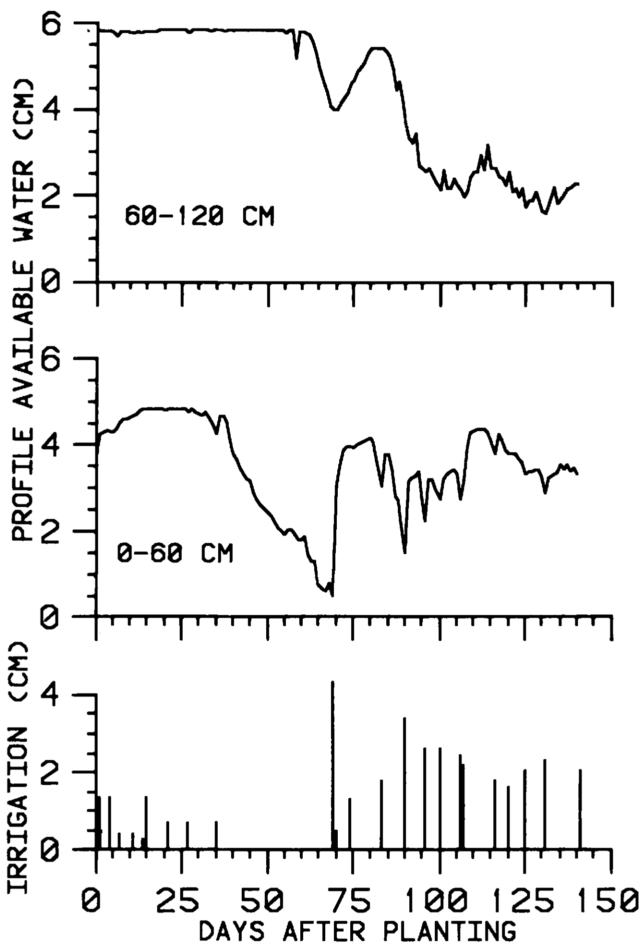

Fig. 3. Irrigation applications and available soil water for Treatment 2 (WDWW), 1976.

The most damaging 35-day drought was during the period from 71-105 days after planting (Tr. 3). This period coresponds to the beginning seed and into the beginnning maturity stages as defined by Boote et al. (5). Florunner at 70 days after planting are fully leafed and approaching their maximum evapotranspiration demand period. As a result, initiation of a drought period at 71 days after planting resulted in a rapid depletion of soil water (Fig. 4) accompanied by severe wilting, and ultimately, mortality of some plants. The soil water status illustrated in Fig. 4 illustrates what happened. Within 15 days after drought inception, the AW in the 0-60 cm profile was essentially gone. Within 25 days, the AW was also exhausted from the 60-120 cm profile depth, leaving essentially no water available to the peanuts for the final 10-15 days of the period. Although most plants survived, and responded rapidly to the resumption of irrigation, they were unable to fully recover by harvest.

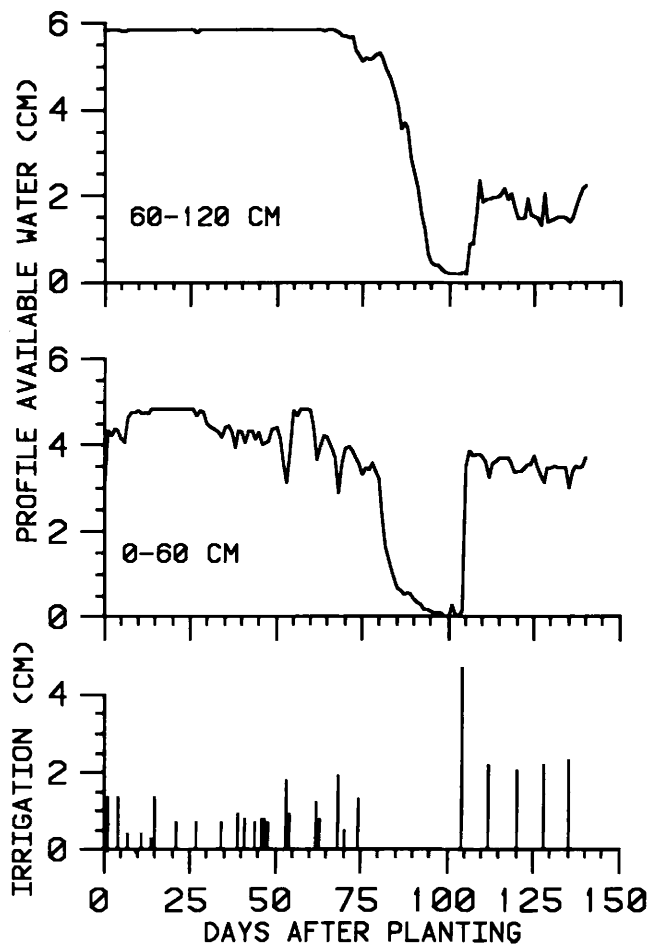

Fig. 4. Irrigation applications and available soil water for Treatment 3 (WWDW), 1976.

Treatment 4 was not watered from 106 days after planting through harvest (Fig. 5). As shown in Table 2, this was the least damaging 35-day drought. We assume that the pods were essentially filled at 105 days after planning and water reserves in the soil profile were sufficient to carry a major part of the crop to maturity.

The AW curves of Fig. 5 also illustrate soil water extraction from the deep profile after day 70. Although the water regime of the 0-60 cm depth was maintained at the treatment designated level, water extraction from the 60-120 cm depth was observed beginning at about day 70.

The peanuts of Tr. 4 reacted similarly to those of Tr. 3 when irrigation was interrupted. They rapidly went into a permanent wilt state and did not recover overnight. There were a small number of plants which did not survive until the 140 days harvest date.

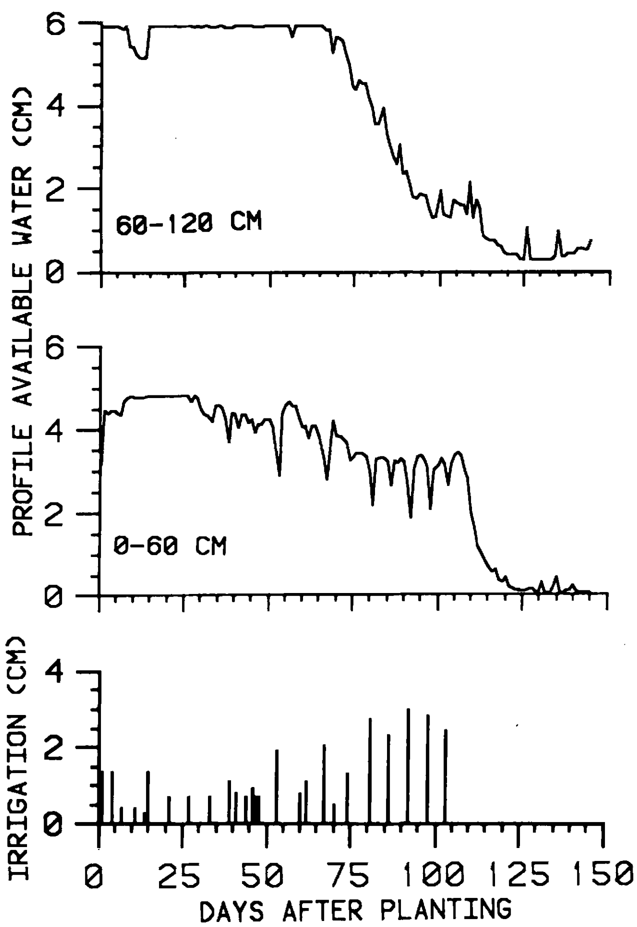

Fig. 5. Irrigation applications and available soil water for Treatment 4 (WWWD), 1976.

During the four year test, there were three occasions when soil water incursions from beneath the plots were recorded. In 1974, following 11 cm of rain on days 128 and 129, an increase in water in the 60-120 cm profile was observed. However, it did not affect the 0-60 cm profile water content. An 8.8 cm storm in 1975 (day 110, 111) and a 15 cm storm on days 104 and 105, 1977, also caused an increase in the deep profile water. Although the effects of these three uncontrolled variables are uncertain, the yield data do not reflect any unusual responses to the extra subsoil water.

Summary

Drought periods of 35 and 70 days were imposed on Florunner peanuts in a replicated, 4 year experiment. Results from the study indicate that among 35 day droughts, the drought extending from 70 to 105 days after planting was most damaging, followed by the 35 to 70 day drought, with drought from 105 to 140 days least damaging.

A drought of 70 days duration, extending from 35 to 105 days after planting drastically reduced pod productions, and drought from 71 to 140 days after planting reduced yield by 50 percent and lowered SMK significantly; but marketable peanuts were produced in both cases.

The data from this study indicate that water stress during any growth period is detrimental to Florunner peanuts, and that midseason drought of 35 days duration is more damaging than either early or late season droughts of the same duration. Seventy day droughts severely depressed pod production and quality, although the 70-day late season drought was less damaging than the 70-day midseason drought.

We have also shown that irrigated peanuts will utilize soil water from depths greater than 60 cm, even when the upper 60 cm of the soil profile is adequately supplied with water. A part of the peanut's known drought resistance is undoubtly associated with its ability to utilize soil water stored at depths of at least 120 cm.

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