The Effect of Dry Pegging Zone Soil on Pod Formation of Florunner Peanut[1]

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ABSTRACT

Peanut (*Arachis hypogaea* L.) fruit growth is sensitive to surface soil (0-5 cm) conditions due to its subterranean fruiting habit. This study was conducted to determine the effect of soil water content in the pegging zone (0-5 cm) on peanut pod growth rate and development. A pegging-pan-root-tube apparatus was used to separately control soil water content in the pegging and root zone for greenhouse trials. A field study also was conducted using portable rainout shelters to create a soil water deficit. Pod phenology, pod and seed growth rates, and final pod and seed dry weights were determined. In greenhouse studies, dry pegging zone soil delayed pod and seed development. In the field, soil water deficits in the pegging and root zone decreased pod and seed growth rates by approximately 30% and decreased weight per seed from 563 to 428 mg. Pegs initiating growth during drought stress demonstrated an ability to suspend development during the period of soil water deficit and to re-initiate pod development after the drought stress was relieved.

Key words: Peanut, *Arachis hypogaea*, drought, pod growth rate, seed growth rate.

The subterranean fruiting habit of peanut (*Arachis hypogaea* L.) makes its reproductive development more sensitive to the environment in the surface soil (i.e., the pegging zone at approximately 0 to 5 cm depth) as compared with crops having above-ground reproductive structures. Low soil water content of the pegging zone has been associated with an increased failure rate of pegs developing into pods (Skelton and Shear, 1971; Underwood *et al.*, 1971; Ono *et al.*, 1974; Patel *et al.*, 1983; Wright, 1989). This inhibition of pod development has been attributed to the greater physical resistance of dry surface soil to peg penetration (Underwood *et al.*, 1971; Patel *et al.*, 1983) and to reduced availability of calcium in dry soil (Skelton and Shear, 1971; Wright, 1989). Although several investigators have measured peanut pod or seed growth rates under conditions where water was not limiting (Cox, 1979; Dreyer *et al.*, 1981; Sung and Chen, 1990), information on rate of pod and seed development as affected by pegging zone soil water content is limited.

Isolation of the pegging zone from the root zone is necessary to study the effect of dry pegging zone soil independently of root zone soil moisture. Most previous studies involving the measurement of dry pegging zone soil on peanut pod development have utilized small pots or containers that have limited pegging and rooting volumes. However, to properly investigate the effect of pegging zone soil moisture on pod and seed growth rates, the area of the soil available for peg penetration should not be a limitation on the rate of pod addition (i.e., branches should not hang over the edge of the pot so that

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pod addition is limited because some pegs do not have any soil under them). If the number of pods added per plant were limited by a restricted pegging zone surface area, then the pod and seed growth rates and final seed size would be overestimated (relative to field environments) due to the increase in assimilate supply associated with limited pod set (Egli *et al.*, 1985; Egli *et al.*, 1989; Sung and Chen, 1990). Further, limited rooting-zone volume often results in rapid imposition of severe plant water deficits restricting the ability to control water availability similar to that occurring in field environments.

Field and greenhouse experiments were conducted at Gainesville, FL to determine the effects of soil water in the pegging zone and root zone on the rates of peanut pod and seed development and final seed size. Water deficits were imposed by use of rainout shelters in a field study, while greenhouse studies were conducted using an apparatus designed to reduce limitations on pegging and rooting zones (Bennett *et al.*, 1990).

Materials and Methods

Greenhouse Studies. Peanut plants of the cv. Florunner component line F430-16-10-3 were established in a root-tube-pegging-pan apparatus as described by Bennett *et al.* (1990). Briefly, the apparatus consisted of a root tube (1.6 m long, 0.15 m diameter) with a pegging pan (0.50 m length, 0.20 m width, 0.20 m deep) fitted around the upper portion of the tube. The top of the root tube was capped with a convex PVC cap, into which a 0.05-m hole was drilled. A PVC spacer (25 mm long) was glued in the cap and provided the opening through which the peanut roots entered the rooting-zone. The root tube and the pegging pan were filled with air-dry Kendrick fine sand topsoil (loamy, siliceous, hyperthermic, Arenic Paleudult). As pegs developed, they entered the soil in the pegging pan and were isolated from the root zone soil. This system allowed soil water in the root and pegging zones to be controlled separately.

Greenhouse Trials—Wet vs. Dry Pegging Zone. Seeds were sown into germination flats containing coarse sand on 10 Feb. 1989. Four days later, when radicles were approximately 2.5 mm in length, two germinated seedlings were transplanted into each root tube. Seedlings were thinned to one per root tube on 24 Feb., and inoculum of the peanut rhizobia *Bradyrhizobium* spp. (*Arachis*) was added through a watering access tube inserted at the top of the root tube.

Soil in the root tube was kept moist throughout the study with additions of 1 or 2 L of water given at 2- to 3-d intervals. Quantity and frequency of watering depended on environmental conditions and stage of plant development, but frequent watering eliminated plant water deficits.

Wet and dry pegging zone treatments were imposed as soon as pegs began to develop. In one trial, the pegging zones around each of four plants were divided into two equal sections by a plastic barrier. Half of each pegging pan contained air-dry soil (≤ 0.5% gravimetric water content) while soil in the other half was kept moist (between 7 and 12% gravimetric water content). This is referred to as the 'split plant' trial. In another trial conducted concurrently, the entire pegging zones of 10 plants were assigned either a wet or a dry treatment (five plants for each treatment). This is referred to as the 'whole plant' trial. Beginning 24 March, new pegs in each treatment were tagged with color-coded, 18-mm wound clips as they entered the soil of the pegging zone. Clips were color-coded by date so that at final harvest age of pods could be determined.

All plants were harvested during the week of 24 May 1989. All pods were characterized according to reproductive stage (Boote, 1982) and hull and seed dry weights were measured after oven-drying.

Apparent pod and seed growth rates were calculated by regressing their weight against pod age during the linear growth phase using the General Linear Model procedure of the SAS statistical package (SAS, 1982). The term "apparent growth rate" describes growth rate as estimated from pods initiated on different dates and harvested on the same date. This approach assumes that both the duration of the lag phase and the rate of linear growth were not affected by the time of pod initiation relative to the life cycle of the plant. In the field trial (see below) pegs tagged 16 d apart did not show significant differences in pod or seed growth rates; however, the affect on duration of the lag phase is less clear. Pod stage distributions of the wet and dry pegging zone treatments were compared using the Chi-square test.

Field Trial. The field experiment used a randomized complete block design with four replications at the irrigation park adjacent to the University of Florida campus. In each replication, treatments were imposed within a 14 × 14-m area, with the rain exclusion treatment being randomly assigned to either the east or west portion of the area and with the remainder being the control. Florunner seeds were sown in all plots on 6 April 1989 at a population of 16 plants m^2 with a row spacing of 0.914 m. Insects and diseases were controlled with appropriate agrochemicals applied at recommended rates. All plots were irrigated using a sprinkler irrigation system as needed to prevent soil water deficits until treatments were imposed. The soil was a Millhopper fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult).

Within each plot a 4.3 × 4.9-m area was identified for placement of a portable rainout shelter. The width of the shelter allowed it to cover four rows, the middle two rows of which were used for sampling. In previous experiments with similar rainout shelters used on the same sandy soil utilized here, there was little evidence of lateral flow of water. Beginning 15 June [71 d after planting (DAP)], rainout shelters, constructed of translucent plastic sheeting placed over frames of PVC pipe, were employed to impose soil water deficits on plants within the designated rainout shelter area. The rainout shelters were manually put in place during the night and whenever rain appeared imminent until 10 July (96 DAP). Air temperature under the rainout shelters was greater than ambient, especially in the daytime, so placement of shelters was limited to times when rainfall appeared imminent. The imposed soil water deficit was relieved by a 50-mm irrigation given on the morning of 11 July. The area outside that covered by the rainout shelter was maintained, well-watered, and comprised the control treatment.

On 5 June, 10 d before the imposed drought began, 45 new pegs were tagged in each replicate of each treatment with 18-mm wound clips. New pegs were defined as those not having swollen and not having penetrated the soil by more than 5 mm. Tagged pods were subsequently sampled (*ca.* seven pods replication^{-1}) at 15, 26, 40, and 49 d after tagging. On 21 and 22 June (6 and 7 d after imposition of treatments), a second set of new pegs were tagged in a

similar manner as the first set. Those pods were sampled (*ca.* nine pods per replication) at 15, 26, 38, and 47 d after tagging. Individual sampled pods were categorized according to growth stage (Boote, 1982), oven-dried, and hull and seed weights were recorded. On 19 June, one replication of the rain-exclusion treatment accidently received rainfall. Data from that replication were not included in the analyses. Plots were harvested on 30 Aug. (147 DAP). All remaining tagged pods were recovered at this time and their growth stage and dry weight were determined.

Pod and seed growth rates of the early and late tagged pods were calculated by regressing mean weight per pod and mean weight per seed for each plot against days after tagging during the linear portion of their growth phase. The General Linear Model procedure of the SAS statistical package (SAS, 1982) was used for calculation of pod and seed growth rates. Pods with fewer than two seeds or which had not progressed past the R4 stage by 35 d after tagging were excluded from the analyses of pod and seed growth rates. Treatment effects on pod stage distribution were tested by Chi-square. For determination of gravimetric soil water, fresh weight of soil was measured from samples transported in plastic bags, and dry weight was measured after drying the samples to a constant weight at 70 C.

Results and Discussion

Greenhouse Experiments—Wet vs. Dry Pegging Zone. Initiation of pod and seed development from new pegs was delayed by a dry pegging zone environment. Shelling percentage of pods initiated in the dry pegging zone lagged behind that of pods initiated in the wet pegging zone (Fig. 1). Pod stage distributions from the wet and dry pegging zones also reflected a delay in pod development associated with the dry pegging zone soil (Table 1). These data suggest that the transition from R2 and R3 stages to R4 may be inhibited or slowed by about 5 or 6 d in a dry pegging zone soil (Fig. 1) even though roots are well supplied with water.

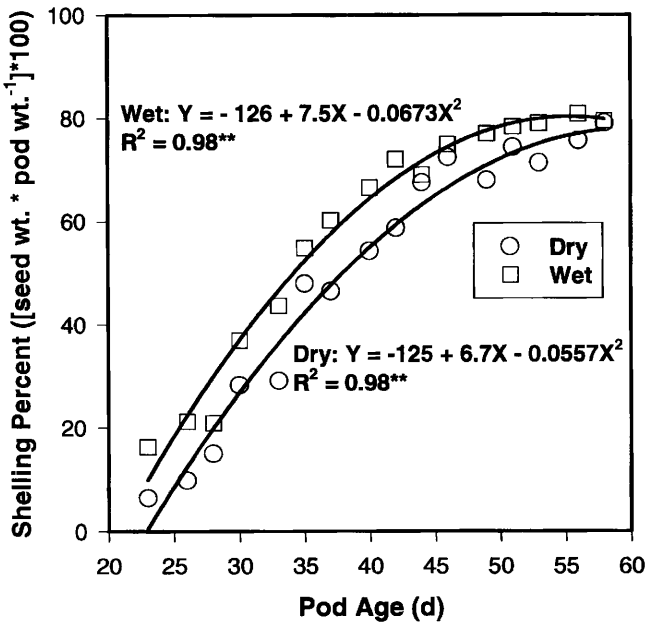

Fig. 1. Shelling percentage versus pod age for the wet and dry pegging zone treatments in the split plant greenhouse trial. Shelling percentage obtained from the whole and split plant experiments showed a similar response to pegging zone soil water; therefore, only results from the split plant trial are shown.

Table 1. Pod stage distributions from the wet and dry pegging zone treatments at harvest in the whole plant and split plant greenhouse trials.

Pegging zone treatment	Pod stage categories[a]				Chi-square value
	R2	R3	R4/5	R6/7	
	----- % of total sites -----				
Whole plant trial[b]					
Wet	16	8	16	60	30.94**
Dry	29	11	13	46	
Split plant trial[c]					
Wet	25	8	27	40	11.13*
Dry	26	17	31	26	

[a] Pod stages were characterized according to Boote (1982).

[b]There were a total of 476 and 537 reproductive sites (pegs and pods) in the wet and dry treatments, respectively, of the whole plant trial.

[c]There were a total of 178 and 199 reproductive sites in the wet and dry treatments, respectively, of the split plant trial.

*,**Indicates that the pod stage distributions for the two treatments are significantly different at $P \leq 0.05$ and 0.01, respectively, according to the Chi-square test.

Wright (1989) observed a lower fraction of conversion of pegs into pods for the cultivar Robut 33-1 with a dry pegging zone soil. It is not clear from our data if a dry pegging zone soil would decrease pod number per plant. Even though the percentage of pegs that formed fully expanded pods was lower in the dry pegging zone soil (Table 1), plants with a dry pegging zone soil showed a trend to produce more pegs (107 pegs plant^{-1} for the dry treatment versus 95 pegs plant^{-1} for the wet treatment in the whole plant trial). This tendency could help to compensate for a lower rate of pod formation from pegs and probably reflects increased assimilate supply available when fewer rapidly growing pods are present. Also, the data do not allow differentiation between small pods (<R4) which have stopped growth entirely and those which have merely been delayed and will later form full size pods.

Weight per pod, weight per seed, and shelling percentage at 100 DAP were all significantly smaller ($P \leq 0.05$) in the dry pegging zone soil of the split plant experiment (Table 2). Results were similar in the whole plant trial (data not shown). Pod and seed weights were relatively low because the plants were harvested before seed maturity. In the split plant trial, dry soil had no discernable effect on pod or seed growth rates (Table 2); whereas, in the whole plant trial, dry pegging zone soil decreased seed growth rate from 22 to 18 mg seed^{-1} d^{-1}. The reason for this discrepancy is unknown. The similar

Table 2. Apparent pod and seed growth rates, individual pod and seed weights, and shelling percentage for the wet and dry pegging zone treatments in the split plant greenhouse trial.

Pegging zone treatments	Apparent growth rate		Individual wt		Shelling percentage
	Pod	Seed	Pod	Seed	
	– – mg d^{-1} – –		– – – mg – – –		%
Wet	46	22	653	226	49.0
Dry	40	23	464	162	35.3
F-test	NS	NS	**	**	**
CV (%)	37	30	46	49	40

**Indicates a significant F-test for treatment effect at $P \leq 0.01$.

growth rates in the split plant trial would suggest that the lower pod and seed weights observed in dry soil may be due to a delayed start of pod development rather than to a slower rate of growth. Subsequent work (J.M. Bennett, unpubl. data) showed no deleterious effect of a dry pegging zone soil on final weight per seed if the seeds were allowed to fully mature before harvest. This is consistent with the work of Wright (1989) who also found that a dry pegging zone soil did not decrease final individual pod or seed weights of fully mature plants (harvested at 124 DAP).

Since the soil used in the greenhouse experiments was a fine sand and remained loose throughout the experiment, we assumed that little physical resistance to peg penetration existed, even when the soil was dry. This was not the case in several previous studies with heavier soils, where low soil moisture in the pegging zone was associated with increased mechanical impedance to peg penetration (Underwood *et al.*, 1971; Patel *et al.*, 1983).

Field Experiment. This experiment was conducted to observe the effect of soil water deficit on pod and seed growth from plants grown to full maturity in the field. New pegs were tagged at 10 d prior to, and 7 d after exclusion of rainfall and irrigation. Pegs tagged prior to imposition of soil water deficits developed in a dry pegging zone with soil initially moist in the root zone (until the deeper soil water was depleted). This is similar to the dry pegging zone/wet root zone treatment in the greenhouse experiments. Pegs tagged after exclusion of rainfall and irrigation were exposed to soil water deficits in both the pegging and root zones.

Gravimeteric soil water in the pegging zone (0-5 cm) was already near 1% when the rainout shelters were first employed. Gravimetric soil water in the pegging zone remained below 1% throughout the duration of the rain-exclusion treatment (25 d), while in the irrigated plots soil water in the pegging zone fluctuated between 2 and 8%. By 86 DAP, all soil horizons monitored (0-120 cm) were at or below 2% gravimetric soil water in the rain-exclusion treatment (Fig. 2). Water stress decreased number of seed pod^{-1}, weight per pod and seed, shelling percentage, and total pod yield (Table 3).

Among tagged pods, both time of tagging and irrigation treatment had significant effects on pod distribution

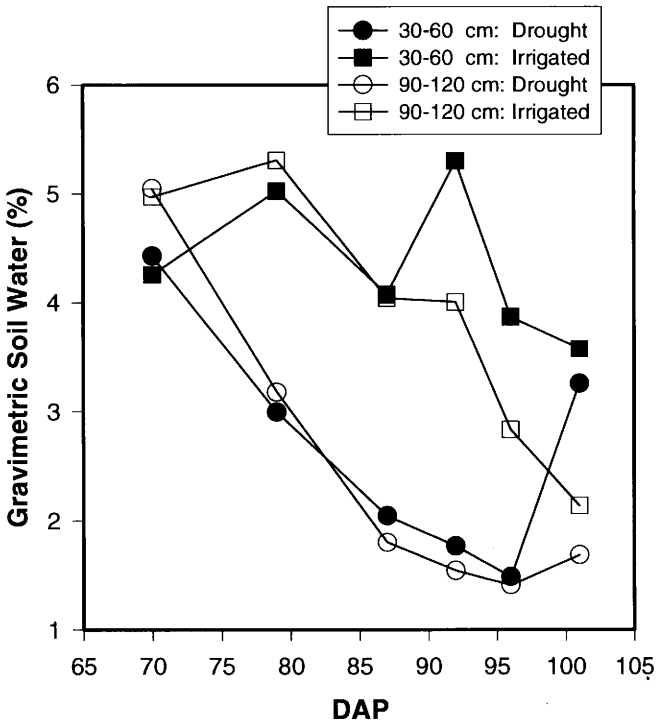

Fig. 2. Gravimetric soil water at depths of 30 to 60, and 90 to 120 cm, versus days after planting (DAP) during the period of imposed drought stress. The drought was relieved by a 50 mm irrigation given on 96 DAP.

Table 3. The effects of irrigated and rain-sheltered treatments imposed in the 1989 field experiment on pod and seed characteristics harvested at 147 DAP.

Variable	Irrigated	Rain exclusion	CV
			%
Pods (≥R5) m^{-2} (no.)	441	373	10
Seeds pod^{-1} (no.)	1.45*	1.24	2
Weight pod^{-1} (mg)	1220*	960	1
Weight $seed^{-1}$ (mg)	630*	520	3
Shelling %	79.2*	73.9	1
Pod yield (kg ha^{-1})	5370*	3570	11

*Treatment effect was significant at $P \leq 0.05$ according to F-test.

(Table 4). Fewer than 10% of the late tagged pegs in the rain-exclusion treatment had formed fully expanded pods by 26 d after tagging; however, the majority of these pegs did form full-size pods by 47 d after tagging (28 d after drought was relieved) (Table 4). This suggests that there is some plasticity in pod phenology that allows them to delay development in order to avoid stress. Nevertheless, the percentage of pegs that progressed to form pods (≥ R4 stage) by 47 to 49 d after tagging was reduced from a combined average of 81% in irrigated treatments to 57% in stressed treatments (Table 4). Rajendrudu and Williams (1987) also reported that drought reduced the percentage of pegs that developed into pods.

Table 4. Pod stage distributions at 15, 26, and 47 (or 49) d after tagging for early and late tagged pods in the field trial.

Peg group/ treatment	15 DAT[a]		26 DAT			47/49[b] DAT		
	R2	R3/4/5	R2/3	R4/5	R6/7	R2/3	R4/5	R6/7/8
	--- % ---		---- % ----			---- % ----		
Early tagged:								
Irrigated	18	82	19	62	19	12	6	82
Stressed	23	77	45	45	9	43	0	57
Late tagged:								
Irrigated	35	65	56	15	30	26	11	63
Stressed	63	37	92	8	0	44	19	37
Chi-square test								
Treatment effect	***		***			*		
Early vs. late (A)	***		***			*		
Irrigated vs. stressed (B)	NS		***			**		
A × B	NS		NS			NS		

[a]Days after tagging. Approximately 21 pods were sampled on each date for each treatment. Reproductive stages were characterized according to Boote (1982).

[b]Early tagged pegs were sampled on 49 DAT. Late tagged pegs were sampled on 47 DAT.

*, **,***Indicate statistical significance at $P \leq 0.10, 0.05$, and 0.01, respectively.

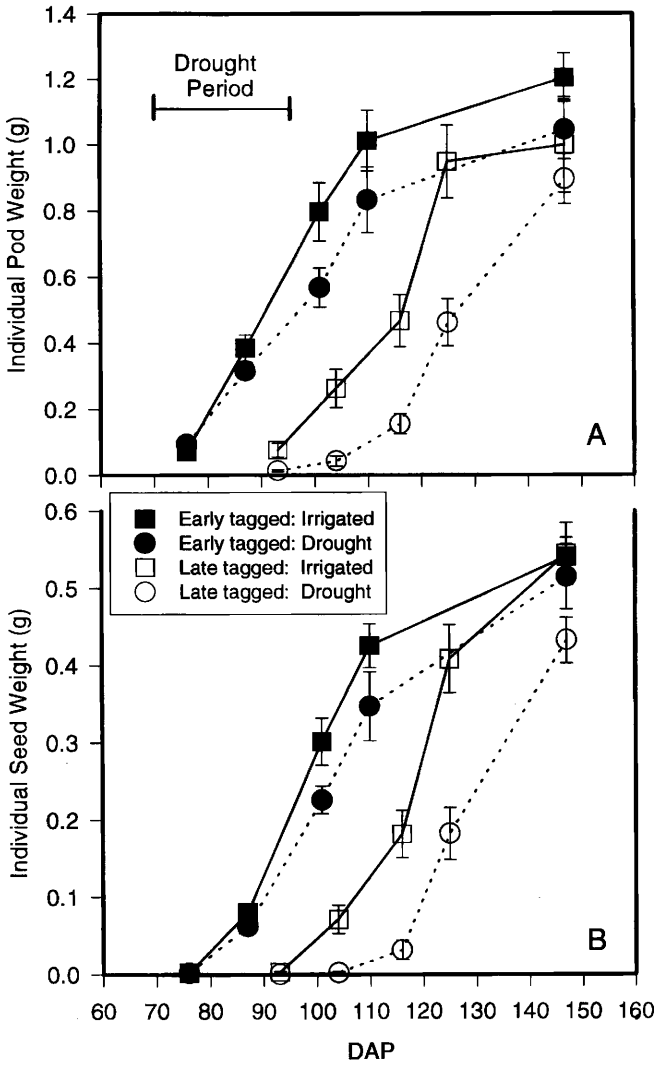

Fig. 3. Mean weight per pod (A) and mean weight per seed (B) versus days after planting (DAP) for the early and late tagged pods in the irrigated and drought-stressed treatments of the field trial. Pods greater than 35 d of age which had fewer than two seeds or which had not progressed past the R3 stage were excluded from the analyses. New pegs were tagged at 61 ("Early tagged") and at 77 ("Late tagged") DAP. The imposed drought period (71 to 96 DAP) is indicated by a horizontal bar. Bars represent plus/minus one standard error of the mean.

Drought stress reduced the pod growth rates of both the pods tagged before and after the rain-exclusion treatment was initiated (Fig. 3a and Table 5). Seed growth rates from pods in the stressed treatment also tended to be lower than those in the irrigated treatment (Fig. 3b and Table 5). Drought stress appeared to delay initiation of pod and seed growth of late tagged pods (Fig. 3a,b). The x-intercept for pod and seed growth rates (an indicator of the initiation of the linear growth phase) for the late tagged pods occurred 10 d later in the stressed, versus the irrigated treatment (Table 5). In the stressed treatment, the x-intercept of 26 d after tagging corresponds to 104 DAP, or 8 d after the drought ended.

Consistent with the phenological data discussed above, this further indicates that pegs initiated during drought stress delayed initiation of pod development until the stress was relieved, and implies that the peanut plant is able to slow or stop the early phases of seed development and later assume normal rates in order to avoid stress. Stirling *et al.* (1989) observed whole plant data (not individual pegs as in this paper) and found that drought did not delay peg initiation, but it did delay the beginning of pod development. The peanut plant's ability to delay growth of individual pods in order to avoid drought may be unique, since previous work with pea (*Pisum sativum* L.) suggests that stress applied before cotyledon cell division is complete would lead to increased rate of seed abortion (Ney *et al.*, 1993) but would have no affect on time to initiation of seed filling (Ney *et al.*, 1994).

It is interesting to note that, during the same period when the growth of late tagged pods was delayed in this study, already established pods were still growing in the drought stress treatment (Fig. 3a). This suggests that previously established reproductive sites had priority over new reproductive sites for the plant's resources.

Final mature pod and seed weights among the tagged pods were lowest for the late tagged pods in the rain-exclusion treatment (Table 5), despite the fact that most of their growth occurred after the stress was relieved (Fig. 3a,b). This suggests that drought stress during early pod development limited capacity for growth later on, even after the drought was relieved. Perhaps drought may have caused a decline in the rate of cell division during early pod and seed development, and thus reduced final seed size as well as pod-growth rate—as observed for soybean [*Glycine max* (L.) Merr.] (Egli *et*

Table 5. Pod and seed growth rates, individual pod and seed weights, seeds per pod, and shelling percentage for early and late tagged pods of the irrigated and drought-stressed treatments in the field trial.

Peg group/ treatment	Growth rate		×-intercept		Individual weight[a]		Shelling percentage
	Pod	Seed	Pod	Seed	Pod	Seed	
	---- mg d^{-1} ----		---- d ----		----- mg -----		%
Early tagged:							
Irrigated	32 ab[b]	15 ab	13	20	1350 a	539 a	79.7 ab
Stressed	24 c	11 b	12	22	1160 ab	438 b	75.3 b
Late tagged:							
Irrigated	37 a	20 a	16	23	1460 a	607 a	83.1 a
Stressed	26 bc	13 b	26	36	1040 b	418 b	79.7 ab
CV (%)	20	19	-	-	23	24	4

[a]Analysis includes only pods that were fully mature (R8) and contained two seeds at final harvest.

[b]Means within columns not followed by the same letter are significantly different at $P \leq 0.05$. Growth rates were compared by contrasting all possible pairs. Pod weight, seed weight, and shelling percentage were compared using LSD.

al., 1989). The lower pod growth rate for the early tagged pods in the rain-exclusion treatment may have been a result of reduced assimilate supply on both cell expansion and growth (Egli *et al.*, 1985; Sung and Chen, 1990).

Conclusions

Dry pegging zone soil delayed pod development and maturation in Florunner peanut. Because of this delay in pod development, plants harvested before maturity (100 DAP) showed smaller individual pod and seed weights in response to dry pegging zone soil. However, seed growth rate was not consistently decreased by a dry pegging zone soil, and there were indications that, given time, pods and seeds in the dry pegging zone soil would acquire the same weight as those in the control treatment.

Drought stress was imposed from 71 to 96 DAP in a field trial with rainout shelters. Drought stress in the root zone decreased individual pod and seed growth rates by about 30% and also decreased mature weight per seed. Individual pegs demonstrated a drought avoidance mechanism of being able to delay initiation of pod growth about 10 d until drought stress was relieved. This gives peanut, or at least the Florunner cultivar, increased plasticity in recovering pod growth and yield after drought is relieved.

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