Quantifying Pod Detachment Rate of Florunner Peanut[1]

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ABSTRACT

Pod detachment is a problem that affects optimum date to peanut harvest. Thus, it is important to understand and quantify causes for pod detachment. The purpose of this study was to test the hypothesis that detachment is initiated in a cohort of peanut pods when the supply of carbon is reduced or terminated. It was assumed that the supply of carbon to an individual pod is related to pod growth rate; therefore, termination of carbon translocation to a pod was characterized by termination of pod growth. Carbohydrate limitations were imposed on Florunner peanut by leaf spot disease, artificial shade, and water stress. A cohort of pods was manually tagged in each treatment and growth characteristics were measured throughout the season. Cumulative pod detachment was measured for tagged pods and plants in each treatment. Initiation of detachment in tagged pods for a control and manual shade treatment corresponded to the date that tagged pod growth ended. However, detachment was initiated before tagged pod growth ended in water stress and disease treatments. A second hypothesis tested was that once detachment is initiated in a cohort, the detachment rate is related to time after carbohydrate is terminated and is independent of the reason for the carbohydrate limitation. We found that once detachment was initiated in a tagged cohort, cumulative detachment over time was similar in each treatment. An exponential equation was used to relate cumulative percentage pod detachment vs. thermal time after initiation of pod detachment in a cohort of pods.

Key Words: Disease, pod losses, disease-induced pod losses, tagged pod growth characteristics.

Peanut (*Arachis hypogaea* L.) pod detachment late in a growing season can result in major yield losses. Pods detach when the peg deteriorates and breaks before or during the harvest operation. Peg deterioration can result from inadequate nutrition, excess moisture, disease, nematodes, insects, or microorganisms (Bailey and Bear, 1973; Troeger *et al.*, 1976; Bourgeois, 1989). Pod detachment has been found to increase with pod age and maturity (Duke, 1971; Sombatsiri and Nuan-on, 1987; Williams and Drexler, 1981). Troeger *et al.* (1976) found

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that peg strength decreases as pods become older and concluded that peg strength depends upon cultivar, peg moisture content, and peg age. The decreased strength in older pegs was probably caused by peg deterioration resulting from saprophytic microorganisms feeding on the pegs and causing damage that cannot be repaired by maintenance respiration (Knauft *et al.*, 1988; Bourgeois, 1989).

Other studies have shown that pod detachment rates are correlated with defoliation by pests or disease. Pixley *et al.* (1990) measured yield for three harvest dates and found that peanut cultivars susceptible to late leaf spot disease [*Cercosporidium personatum* (Berk. & Curtis) Deighton] had much lower pod mass at harvest as a result of decreased leaf area. They observed a high percentage of detached pods at harvest for severely infected plants. Leaf spot-resistant cultivars had higher partitioning to new leaf growth than did varieties susceptible to leaf spot and maintained a higher leaf area index. This resulted in fewer detached pods, possibly because of higher photosynthesis and carbohydrate availability for peg maintenance and pod growth. Knauft *et al.* (1988) and Bourgeois (1989) observed increased pod detachment at harvest for leaf spot-infected plants. Panchabhavi *et al.* (1986) found that artificial defoliation also increased pod detachment at harvest. Some detachment may have been caused by carbohydrate limitations due to defoliation. However, *C. persunatum* and *Cercospora arachidicola* Hori also can infect pegs and enhance deterioration and subsequent detachment.

There have been no reports quantifying the initiation of pod detachment or the subsequent detachment rate based on the hypothesis that carbohydrate limitations result in peg deterioration and subsequent detachment. Two hypotheses were formulated as a basis for the specific objectives of this research as follows: (a) pod detachment is initiated when carbohydrate supply to a pod is terminated, and (b) pod detachment rates are related to time after carbohydrate is terminated but are independent of the reason for carbohydrate limitation to the pod. The specific objectives are to (a) demonstrate that different carbohydrate stress levels result in different dates for initiation of pod detachment, (b) determine the relationship between initiation of pod detachment and carbohydrate translocation to individual pods, and (c) quantify the detachment rate of pods under different stress environments.

Materials and Methods

An experiment (referred to as the Drew experiment) was conducted on the R. C. Lowman farm in Levy Co., FL to quantify pod detachment for tagged cohorts of pods. Pods formed on the same day were considered as cohorts. It was assumed that pods in the same cohort had identical growth rates and size characteristics. Florunner peanut was planted on 12 June 1991, at a rate of eight plants m^{-1} row with a row spacing of 0.91 m. After plant emergence, the field was divided to accommodate three treatments representing different conditions that limit carbohydrate to pods: control (Drew control), disease (Drew disease), and shade (Drew shade). Each treatment was divided into 14 plots with four replications 1.0 m long by 0.91 m wide. Field operations were implemented throughout the season to control pests (Table 1). Insecticidal soap was used to slow infestation by white fly. Fungicide applications were used in the control and shade treatments as needed. The fungicide Bravo was initially applied to the disease plots until 31 d after planting (DAP) to control the onset of late leaf spot disease. Triangular shade structures were constructed over the shade treatment plots and shade cloth blocking 95% of all incoming light was attached to the structure 96 DAP.

Table 1. Field operations for Drew control, disease, and shade treatments, 1991.

Date	Operation	Rate
	Control and Shade Treatments	
6/27	10-10-10 fertilizer (banded)	147.0 kg ha^{-1}
	Benlate (sprayed)	7.1 L ha^{-1}
6/28	Nemacure (broadcast)	9.2 g ha^{-1}
	Lorsban (broadcast)	4.6 g ha^{-1}
7/11	Bravo (sprayed)	271.0 g ha^{-1}
7/18	Bravo (sprayed)	271.0 g ha^{-1}
7/29	Bravo (sprayed)	271.0 g ha^{-1}
8/2	Bravo (sprayed)	271.0 g ha^{-1}
	Gypsum (banded)	276.0 kg ha^{-1}
	Lorsban (broadcast)	4.6 kg ha^{-1}
8/8	Bravo (sprayed)	271.0 g ha^{-1}
8/12	Safer Soap	1.2 L ha^{-1}
8/14	Bravo (sprayed)	271.0 g ha^{-1}
8/19	Bravo (sprayed)	271.0 g ha^{-1}
	Safer Soap	1.2 L ha^{-1}
8/26	Bravo (sprayed)	271.0 g ha^{-1}
8/29	Safer Soap	1.2 L ha^{-1}
9/2	Safer Soap	1.2 L ha^{-1}
9/4	Bravo (sprayed)	271.0 g ha^{-1}
9/9	Safer Soap	1.2 L ha^{-1}
9/12	Bravo (sprayed)	271.0 g ha^{-1}
	Disease Treatments	
6/27	10-10-10 fertilizer (banded)	147.0 kg ha^{-1}
	Benlate (sprayed)	7.1 L ha^{-1}
6/28	Nemacure (broadcast)	9.2 kg ha^{-1}
	Lorsban (broadcast)	4.6 kg ha^{-1}
7/11	Brave (sprayed)	271.0 g ha^{-1}
8/2	Gypsum (banded)	276.0 kg ha^{-1}
	Lorsban (broadcast)	4.6 kg ha^{-1}
8/12	Safer Soap	1.2 L ha^{-1}
8/19	Safer Soap	1.2 L ha^{-1}
8/29	Safer Soap	1.2 L ha^{-1}
9/2	Safer Soap	1.2 L ha^{-1}
9/9	Safer Soap	1.2 L ha^{-1}

Another experiment was conducted in a different field on the R. C. Lowman farm (referred to as the Lowman experiment) to quantify pod detachment due to pod aging. This field was managed by the grower and consisted of Florunner peanut planted on 28 April 1991. Fourteen plots with four replications 1.0 m x 0.91 m were selected for biomass sampling several weeks before and after the normal harvest date. Adequate disease and pest control were maintained

by the grower.

Air temperature was measured every 15 min at the Drew site using a Campbell Scientific CR-10 datalogger. It was assumed that temperatures at the Lowman field were the same as Drew field since they were only 1 km apart. Rainfall data were collected at both Drew and Lowman sites using a tipping bucket rain gauge (MicroRain, developed by the Agricultural Engineering Dept. at the Univ. of Florida). The gauge recorded the number and date of each tip (1 mm rainfall).

After pegging began, 10 young pegs in each replication of the Lowman and Drew treatments were tagged by wrapping a 6-cm wire loosely around the peg and stem. The selected pegs were generally located on nodes 1-3 on the lower branches and had just begun to penetrate the soil surface. No peg had penetrated the soil over 1 cm. This procedure insured that all tagged pegs were approximately the same age. It was assumed that all tagged pegs in a treatment were the same physiological age and thus belonged to a cohort. Pods in the Drew disease plots were tagged 51 DAP, while those in the shade and control plots were tagged 52 and 53 DAP, respectively. Pods in the Lowman plots were tagged 51 DAP.

Plant biomass samples were taken from each treatment throughout the season. In the Lowman treatment, biomass samples were taken weekly beginning 66 DAP. In the Drew treatments, biomass samples were taken every 3 wk until 71 DAP, after which sampling was increased to weekly intervals until the end of the season. A pitchfork was inserted on either side of the plants to loosen the soil from the pods and roots. An attempt was made to locate each tagged pod and to recover any detached tagged pods before the plants were removed. This was accomplished by digging down beside each tagged peg until either an attached or detached pod was found. In most cases, when a tagged pod was detached, it was not recovered. A pitchfork was used to lift the plants above the ground. The plants were counted and the taproots were discarded. The remaining soil was sifted to recover any detached pods.

A subsample of three representative plants was selected from each plot (1.0 x 0.91 m) when plants were small and the number of pods, pegs, and main stem vegetative nodes were recorded. When plants became larger, one representative plant was selected for detailed growth analysis. Fresh leaves were handpicked from the subsample, and the leaf area index of the subsample was measured using a leaf area meter (LICOR LI-3100). The subsample was then divided into leaf, pod, peg, and stem components. These components were dried at 60 C until no change in mass was observed and the mass of each component was recorded. The remainder of the plants collected from a plot were divided into canopy and pod components, which were then dried and weighed. The fractions of leaf and stem mass were computed for the subsample and used to compute the total leaf and stem masses for the plants harvested from the plot. Pod mass and numbers also were measured for the remainder of the sample.

Each replication contained 10 tagged pegs corresponding to each tagged pod. Each peg containing a wire tag was examined to determine if the associated pod was attached or detached. If a tagged peg had an attached pod, it was placed in an envelope and marked for identification. If a peg was frayed, decayed, or rotted, it was recorded as a detached pod. If a peg had fresh, white frayed endings, it was assumed that the missing pod was detached due to harvesting or transporting the samples and the peg was ignored. Percent detachment was computed as the ratio of detached pods to the sum of attached and detached tagged pods. Each recovered tagged pod was placed in an envelope and dried at 60 C until no change in mass was observed. The average mass per pod, seed mass per pod, shell mass per pod, seed per pod, and shelling percent were then measured.

Direct measurements of carbon translocation to pods were not made, due to the difficulty in performing such measurements on a farm site. In this study, we assumed that carbon limitations to a pod corresponded to the pod growth rate. Thus, when seed mass stopped increasing, it was assumed that carbon was no longer translocated into that pod.

Tagged pod cohort data were analyzed to determine when seed and pod growth were initiated. After all tagged pod data were collected, growth curves defined by mass per pod and seed mass per pod were plotted against days after planting. A regression analysis was performed on the linear portion of each growth curve to estimate the average seed and pod growth rates, respectively. The linear portion of each growth curve was extrapolated to zero to estimate the dates of seed and pod initiation. Seed filling duration was computed by dividing the maximum tagged cohort seed mass by the average seed growth rate. Pod filling duration was computed in a similar manner.

Finally, thermal time occurring on a particular day (TT) was computed hourly and averaged over the day using a normalized triangular function with a base temperature of 11 C that corresponded to zero thermal days, an optimum temperature of 28 C that corresponded to one thermal day, and an upper temperature of 55 C, beyond which no thermal time was accumulated. Equation 1 shows the daily computation of thermal time, where $T_{a,i}$ is the average temperature for hour i during the day.

$$\begin{aligned} TT &= 0 && \text{if} \quad T_{a,i} < 11C \text{ or } T_{a,i} > 55C \\ TT &= \sum_{i=1}^{24} \frac{1}{24} * \left(\frac{T_{a,i}-11}{17}\right) && \text{if} \quad 11C \le T_{a,i} < 28C \\ TT &= \sum_{i=1}^{24} \frac{1}{24} * \left(1-\frac{T_{a,i}-28}{27}\right) && \text{if} \quad 28C \le T_{a,i} \le 55C \end{aligned} \qquad \text{[Eq. 1]}$$

Results and Discussion

Seasonal Trends in Vegetative Components. The different methods of imposing carbohydrate limitations to pegs and pods created differences in vegetative growth. Leaf area index (LAI) for the experiments are shown in Fig. 1. Defoliation from leaf spot disease was expected to induce carbohydrate limitations to pods. Significant differences ($\alpha/2 \le 0.05$) in the means of LAI and leaf mass between the Drew control and disease treatments occurred approximately 71 DAP (t test). Defoliation in the Drew disease treatment began approximately 46 DAP, when necrotic lesions caused by leaf spot were first observed, and increased until total defoliation was reached on 106 DAP. The shade structure, which blocked 95% of incoming light, was used to induce carbohydrate limitations on pods 96 DAP. Significant differences ($\alpha/2 \le 0.05$) in LAI for the control and shade treatments occurred approximately 124 DAP. Defoliation occurred due to plant death beginning 124 DAP. The Lowman experiment was planted 55 d before the Drew control

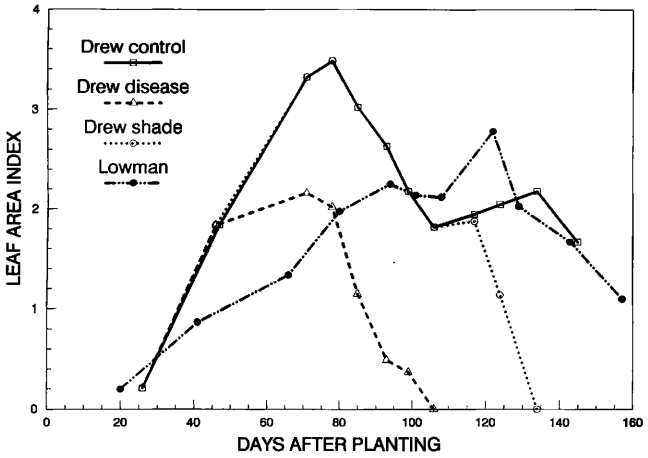

Fig. 1. Leaf area index for Drew control, disease, shade, and Lowman treatments.

experiment, which resulted in a lower maximum LAI (Fig. 1).

Seasonal Trends in Reproductive Biomass. Overall pod detachment in each treatment responded to the different levels of stresses. Attached and detached pod mass and pod numbers for the Drew treatments are shown in Figs. 2-4. In the control treatment, carbohydrate limitations occurred during a period of severe water stress. Some pods detached beginning 106 DAP, which corresponded to the end of rapid defoliation due to water stress. These pods probably detached because the photosynthetic capacity of the plants was reduced and all of the pods could not be sustained by the plants. However, leaf area index remained sufficiently high to support most of the pods until 168 DAP when mature pods began to detach. In general, as the number of attached pods decreased, the number of detached pods increased. However, there was a net loss of pods from the plants that were not recovered in the soil screening method.

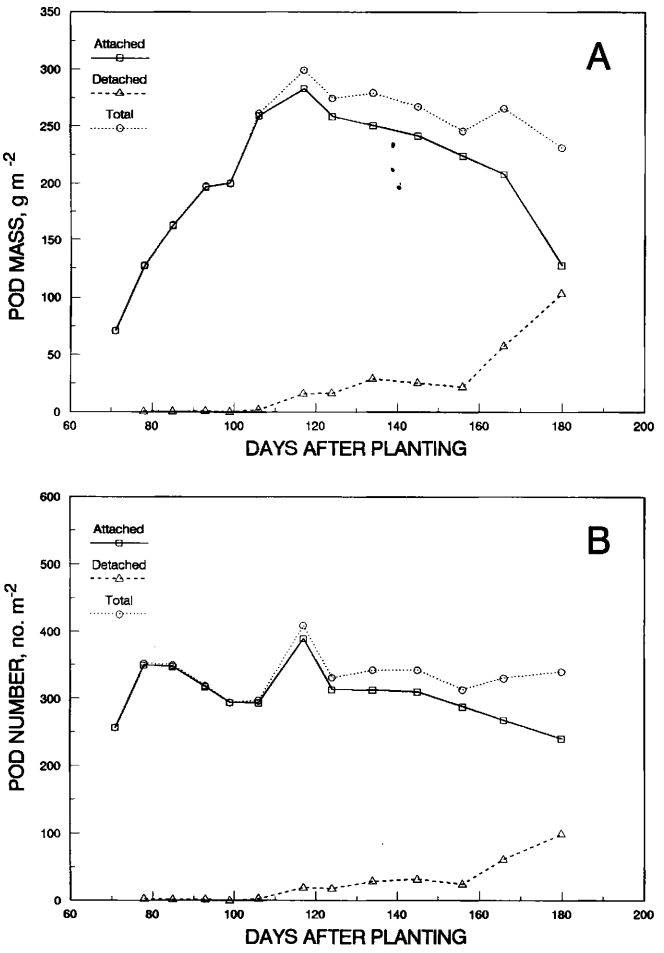

Fig. 2. Pod mass (A) and number (B) for the Drew control treatment.

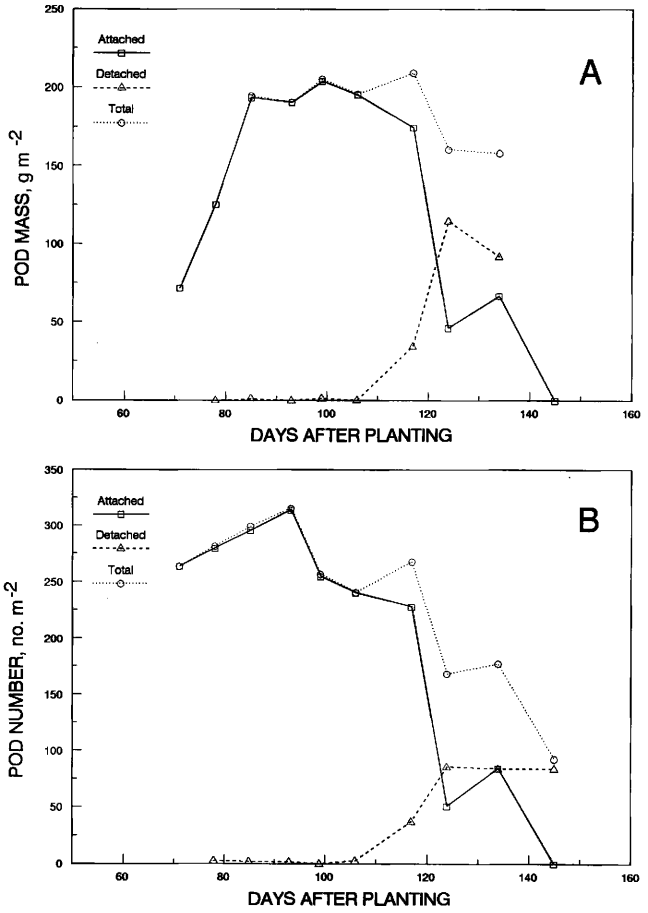

Fig. 3. Pod mass (A) and number (B) for the Drew disease treatment.

In the disease treatment (Fig. 3), carbohydrate limitations probably began during rapid defoliation caused by leaf spot disease. Rapid pod detachment began 106 DAP when total defoliation occurred. Significant differences between control and disease attached pod mass and number ($\alpha/2 \leq 0.05$) occurred 106 DAP. Total pod number decreased after the peak (*ca.* 90 DAP), which was likely due to sampling error involved in recovering pods from the soil. In the shade treatment (Fig. 4), carbohydrate limitations resulted when the shade cloth

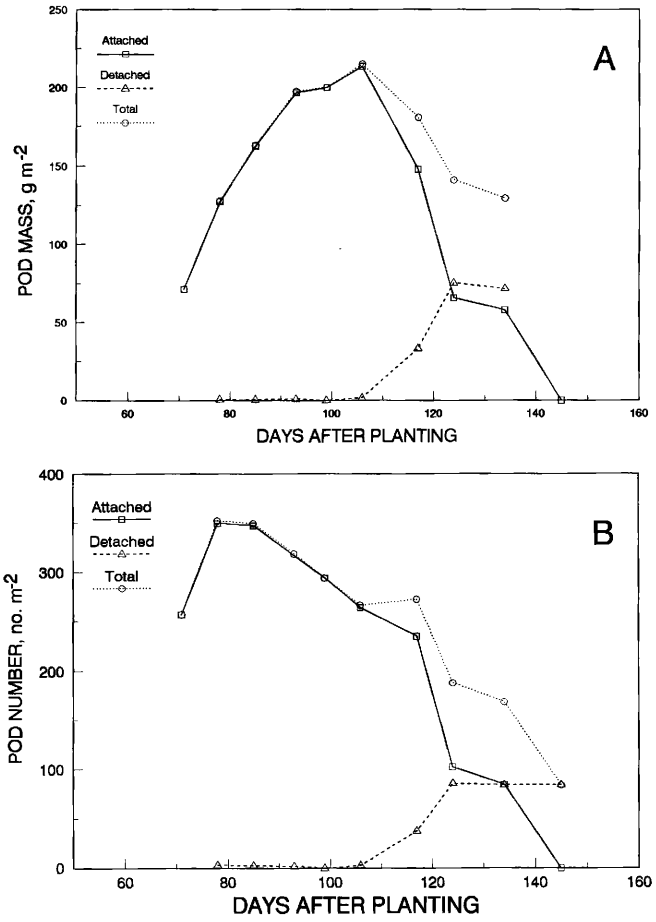

Fig. 4. Pod mass (A) and number (B) for the Drew shade treatment.

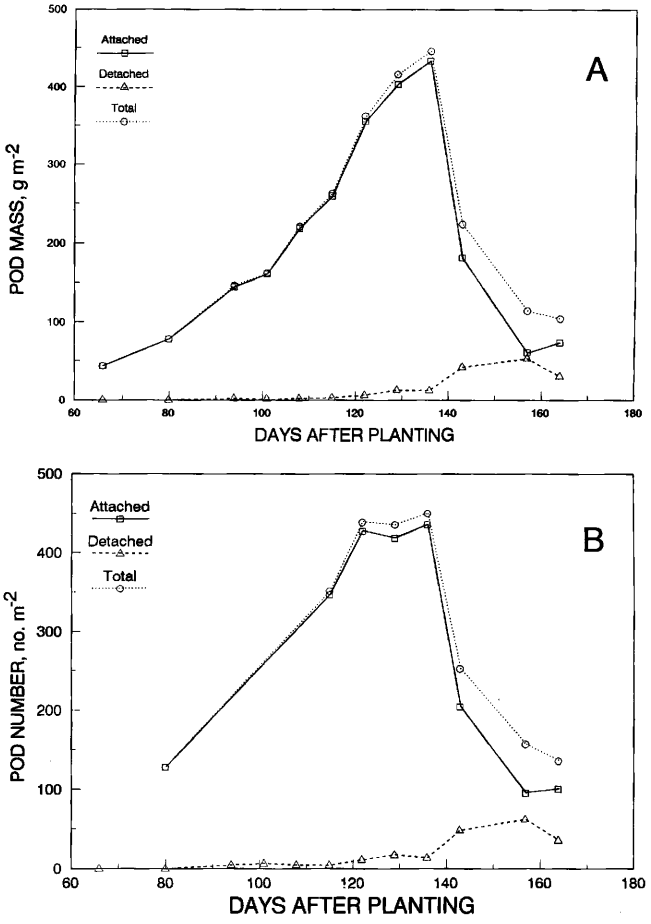

Fig. 5. Pod mass (A) and number (B) for the Lowman experiment.

was applied, blocking 95% of incoming light beginning 96 DAP. Rapid detachment also began 106 DAP. Significant differences between control and shade attached pod mass and number ($\alpha/2 \leq 0.10$) occurred 117 DAP, 21 d after the shade was applied.

There were no visible signs of carbohydrate limitations from disease or water stress in the Lowman experiment. Some pods began to detach 117 DAP (Fig. 5). This probably resulted from normal pod maturation and subsequent detachment due to termination of carbohydrate translocation to mature pods. Severe raccoon damage occurred beginning 140 DAP, thus data collected after this time were ignored.

Seasonal Trends in Tagged Pods. Growth characteristics of tagged pods for Drew control, disease, shade, and Lowman treatments are shown in Figs. 6-9. The patterns of seed growth in tagged pods were similar to those for pod growth. Both pod and seed growth rates were approximately constant until the maximum mass per pod or seed was reached. A linear regression was developed for both pod and seed growth for each treatment during the linear period in order to estimate the times of pod and seed initiation (Table 2). This method does not account for the slow growth phase during the first several days of pod and seed initiation. However, useful estimates for pod and seed initiation dates were obtained. Table 2 shows seed and pod growth rates and filling durations for each treatment on a calendar and thermal day basis. Pod and seed filling durations for the shade treatment were 7 d shorter than the control treatment because the shade limited photosynthesis production beginning 96 DAP. Some seed growth after shading probably occurred due to carbohydrate and amino acid translocation from vegetative tissue. The limitation of

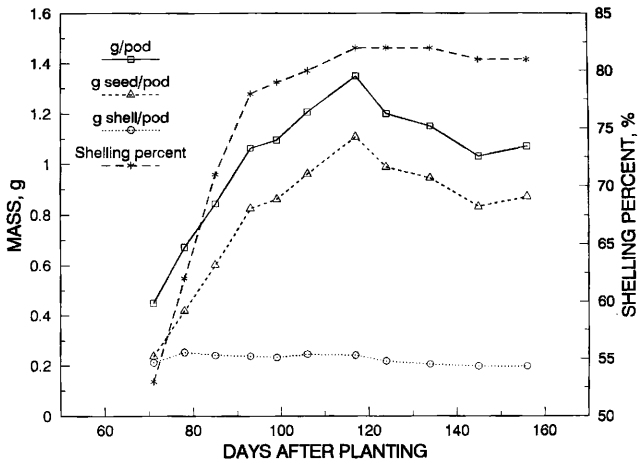

Fig. 6. Tagged pod characteristics for Drew control treatment.

Table 2. A summary of tagged pod growth rates and filling durations for pods and seed in both calendar and thermal days. Thermal days (in parenthesis) were computed using a normalized triangular function with a base temperature of 11 C that corresponded to 0 thermal d, an optimum temperature of 28 C that corresponded to 1 thermal d, and an upper temperature of 55 C, beyond which no thermal time was accumulated (average of 1.63 seed per pod).

Treatment	Growth rates (per pod basis)		Filling duration		Initiation	
	Pod	Seed	Pod	Seed	Pod	Seed
	– – mg d^{-1} – –		– – – thermal d – – –		d after planting	
Drew control	21.5	21.1	63 (50.5)	53 (41.9)	47	58
Drew disease	23.4	23.3	52 (42.5)	42 (33.9)	51	60
Drew shade	20.9	21.0	56 (45.9)	45 (36.5)	47	58
Lowman	19.6	17.6	63 (51.9)	59 (48.5)	59	68

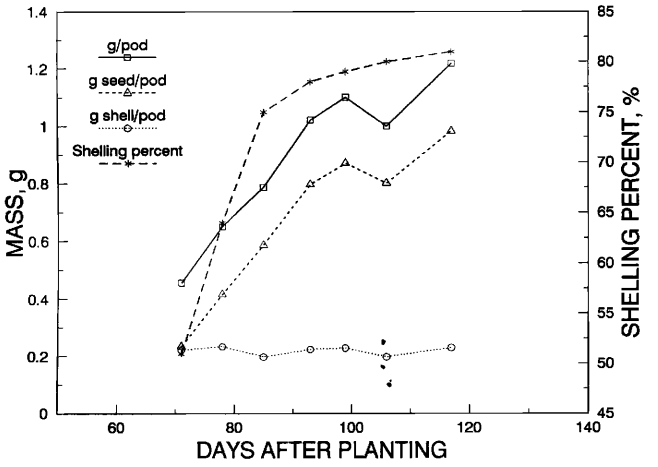

Fig. 7. Tagged pod characteristics for Drew disease treatment.

assimilate imposed by leaf spot disease in the diseased treatment did not affect the growth rates of pod and seed in the disease treatment. Since the tagged pod cohort was one of the first cohorts on the plant, it is possible that it had first priority for any available assimilate.

There was no significant difference ($\alpha/2 \leq 0.10$) in the maximum tagged mass per pod or seed for Drew control, Drew disease, or Lowman (Figs. 6-9). However, there were significant differences in both maximum mass per pod and mass per seed between Drew control and shade treatments. This occurred because pod growth in the shade treatment did not continue after the shade was applied 96 DAP.

Initiation of Detachment in Tagged Pods. The hypothesis that pod detachment is initiated when carbohydrate translocation to a pod is terminated was tested using the tagged pod cohort detachment data from the Lowman and Drew experiments. It was assumed that when a tagged cohort of pods reached its maximum mass per pod, no more assimilate was allocated to those pods. In the Lowman experiment, detachment of the tagged cohort began approximately 122 DAP (Fig. 10), which

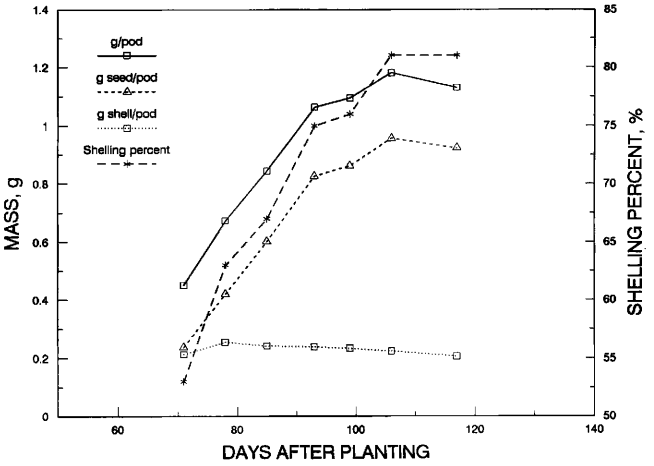

Fig. 8. Tagged pod characteristics for Drew shade treatment.

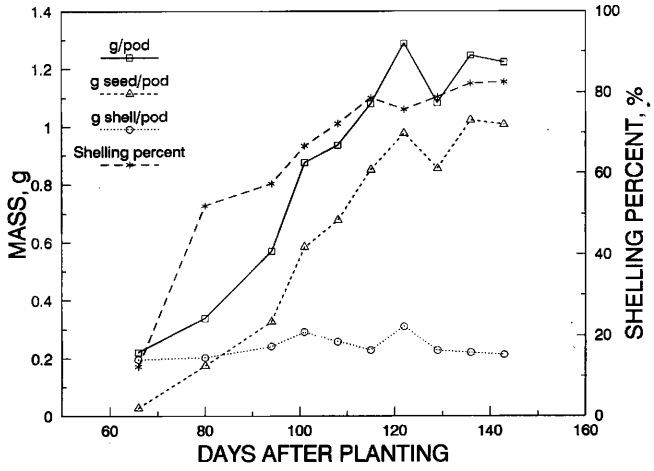

Fig. 9. Tagged pod characteristics for Lowman experiment.

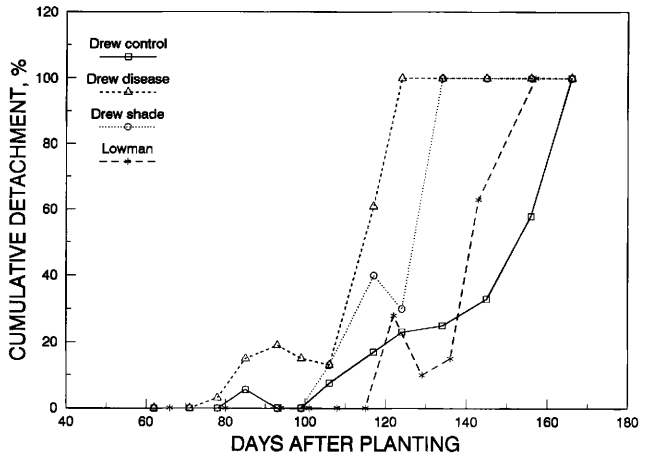

Fig. 10. Cumulative percent detachment of tagged pod cohorts for Drew control, disease, and shade, and Lowman treatments.

corresponded to the maximum mass per pod (Fig. 9). Thus, initiation of detachment corresponded to the end of pod growth. In the Drew shade treatment, 95% of

incoming light was blocked by a shade cloth applied 96 DAP and tagged pod detachment began 99 DAP (Fig. 10). The mass per pod increased slightly for the tagged pods after shade was applied (Fig. 8); there was, however, no significant difference between measured mass per pod at 99 and 106 DAP. Detachment was initiated in these experiments just after growth ceased, presumably when assimilate supply was terminated to the cohort of tagged pods. Since detachment was initiated just after cohort growth ceased, it can be concluded that initiation of detachment corresponds to termination of assimilate allocation to a pod.

Initiation of tagged pod detachment in the Drew control treatment began 99 DAP (Fig. 10), which did not correspond to maximum mass per pod (Fig. 6) that occurred on 117 DAP. Initiation of detachment did, however, correspond to the end of a severe drought that caused the plants to defoliate from a maximum LAI of 3.5 to 1.8. Initiation of tagged pod detachment in the Drew disease treatment began approximately 71 DAP (Fig. 10) and also did not correspond to maximum mass per pod for the tagged pods that occurred on 99 DAP (Fig. 7). Initiation of detachment did, however, correspond to rapid defoliation and plant deterioration due to onset of leaf spot disease (Fig. 1). The results from these two treatments suggest that detachment also can be initiated when the plant experiences disease or severe defoliation. Bourgeois *et al.* (1991), suggested that leaf spot disease can attack pegs and thus increase peg deterioration and pod detachment. They also suggested that decayed leaf material on the soil surface enhances soilborne microorganism activity, thus increasing decay of pegs and pod detachment. In these two treatments, pod detachment was apparently initiated before maximum mass per pod occurred. Detachment in the disease experiment probably resulted from leaf spot disease randomly attacking some pegs, causing deterioration and pod detachment. In the control experiment, increased leaf matter on the soil surface may have increased peg deterioration by increasing soilborne microorganism activity on pegs.

Cumulative Detachment of Tagged Pods. Cumulative percent of tagged pods detached vs. thermal days after initiation of detachment of tagged pods were plotted for all treatments (Fig. 11). Thermal days were calculated beginning on the first day that detachment was observed in the tagged cohort of each experiment. The cumulative tagged pod detachment curves in Fig. 11 have similar shapes. An exponential function with a cutoff was used to describe the cumulative detachment of pods in a cohort once detachment was initiated by:

$$Y = Y_o e^{(\mu t)} \qquad for\ 0 \le t < t_f$$
$$Y = Y_f \qquad for\ t \ge t_f \qquad \text{[Eq. 2]}$$

In this equation, Y_f is the maximum detachment of 100% occurring at t_f thermal days after initiation of detachment. The parameter Y_o is the initial percent detachment and m is a detachment rate parameter with units (thermal d)$^{-1}$. Time is measured in thermal d.

Since plant death caused 100% detachment for the shade treatment on 21 thermal d after detachment was initiated, this point was not included in the fitting procedure. The simplex optimization procedure (Press *et al.*, 1989) was used to estimate the parameters Y_o, m, and t_f with the criteria of minimizing the error sum of squares for the truncated exponential function. The values for Y_o and m were 4.76% and 0.927 (thermal d)$^{-1}$, respectively, and t_f was 34 thermal d. The coefficient of determination was 0.93. A plot of the exponential equation is also shown in Fig. 11 . Once detachment was initiated in a tagged cohort, cumulative pod detachment in the cohort progressed at the same exponential rate irregardless of the mechanism causing pod detachment. The Gompertz function was also fit to these data using the same procedure, but the coefficient of determination (0.91) was lower than for the truncated exponential function. The exponential equation also was fit to the same data using calendar days after initiation of detachment as the ordinate; however, the results were not as good.

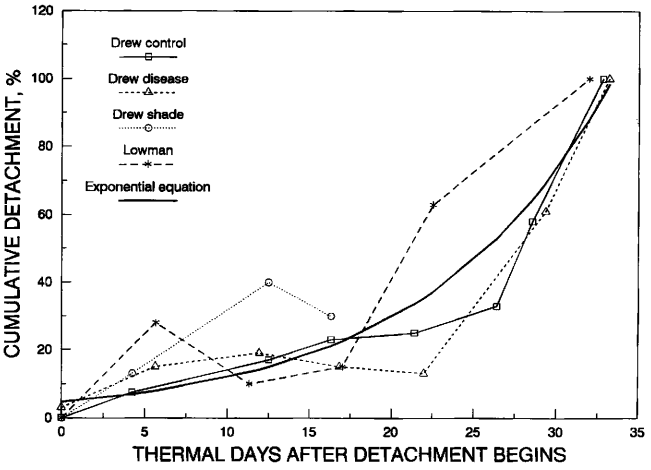

Fig. 11. Exponential equation describing cumulative detachment of tagged pods based on thermal days after initiation of detachment for Drew control, disease, and shade and Lowman experiments.

Summary and Conclusions

The hypothesis that pod detachment is initiated when carbohydrate transport to a pod is terminated was tested using the tagged pod data for Lowman and Drew experiments. In Lowman and Drew shade treatments, initiation of tagged pod detachment corresponded to maximum mass per pod. We assumed that after maximum mass per pod occurred, carbohydrate translocation to the cohort was terminated because no more growth occurred. In the Lowman experiment, termination of carbohydrate was caused by plant aging while, in the Drew shade treatment, termination of carbohydrate was caused by shading 95% of the incoming light. In both experiments, detachment was initiated when carbohydrate supply to pods was terminated, irregardless of the cause of carbohydrate limitation.

In the Drew control and disease experiments, initiation of tagged pod detachment occurred before maximum mass per pod occurred. This probably resulted from other external factors causing peg deterioration. Severe defoliation occurred in both experiments, which