Effect of Pod Maturity and Plant Age on Pod and Seed Size Distributions of Florunner Peanuts

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ABSTRACT

Florunner peanut pods *(Arachis hypogaea* L.) were sampled at nine weekly intervals from 92 to 148 days after planting (DAP) in crop year 1979. The fresh pods were divided into six maturity categories according to the color and structure of the mesocarp. After drying, individual pods and seed for each maturity class and date were sized over a series of screen slots conforming to official grade standards. The cumulative distribution function (CDF) for the logistic distribution was used to quantify the cumulative percentage by weight of pods and seed which rode a designated screen. The parameters of the logistic CDF were regressed separately by maturity class as functions of plant age. These relationships provide a mathematical approach for a better understanding of the influence of pod maturity and plant age on pod and seed sizes.

Key Words: Peanuts, seed size, pod size, maturity, plant age.

Seed size is an important factor to the peanut *(Arachis hypogaea* L). industry because it determines market quality and crop value (3). Pod maturity is an important factor in determining seed size. The relationship of seed size and pod maturity has been difficult to define because fruiting occurs over an extended period that depends on the variety and on the environment. For a particular variety and environment, variations in seed size are therefore functions of both plant age and the variability in maturity of the pods found on the plant at a given age.

Defining pod maturity and seed size relationships have been further hindered by the lack of precision in estimating the maturity and physiological ages of individual pods. Recently, Williams and Drexler (6) developed a non-destructive method of maturity classification based on the changes that occur in the color and structure of the pod mesocarp. The method is commonly called the hull scrape method.

The ability to estimate the distributions of pod and seed sizes in relation to pod maturity and plant age would provide qualitative refinement and predictability to the hull scrape method for determining the optimum harvest interval. It would also provide peanut industry researchers a tool to relate size and maturity to physiological and quality factors and also provide the farmer a valuable tool for decision-making. Rational estimates of the expected seed size distribution and maturity should make possible better estimates of market quality and provide critical information for the planning of market strategies.

Scientists have recognized the need to develop mathematical relationships to quantify pod and seed size. Davidson, *et. al.* (1) used the logistic distribution for describing seed size distributions of Florunner, Florigiant, and Starr varieties at harvest. They also used the logistic distribution for describing certain symmetrical distributions of pod size. Williams, *et al.* (5) showed that, except for the mean, the parameters which describe the shape of seed size distributions were similar over a wide range of harvest dates and growth environments.

This investigation reports the use of the logistic cumulative distribution function (CDF) for describing 1979 crop Florunner seed and pod size distributions as functions of pod maturity and plant age. This approach to characterizing the distributional relationships over all pod maturities at any plant age has a wide range of applications.

Materials and Methods

Field-fresh Florunner peanuts, grown according to conventional, irrigated cultural practices, were hand-harvested at nine weekly intervals from Aug. 2, 92 days after planting (DAP), to Sept. 27 (148 DAP) in crop year 1979. Samples consisted of all of the pods from six, 0.76 m row segment replicates. The pods were carefully removed from the plants by hand and sand-blasted on their top surfaces (normal growth orientation) to remove the exocarp (7). The pods were visually sorted into the major color and structural maturity classes designated as White (Class 2), Light Yellow (Class 3), Dark Yellow (Class 4), Orange (Class 5), Brown (Class 6), and Black (Class 7) as described by Williams and Drexler (6). Pods were air dried and stored in mesh bags. Approximately one month was allowed for moisture to equilibrate after the last samples were taken. A subsample consisting of a maximum of 42 dried pods (or the entire sample where the count was less than 42) was randomly selected from the harvest sample of pods

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of each maturity class and plant age. Each pod from this subsample was weighed and sized according to thickness over a series of screen slots that conformed to U.S. commercial grade standards for peanuts. The screen slots had widths of 13.5 mm (Screen No. 34), 12.7 mm (Screen No. 32), 11.9 mm (Screen No. 30), 11.1 mm (Screen No. 28), and 10.3 mm (Screen No. 26). After hand-shelling the apical and basal seeds were each weighed. Each seed was sized according to thickness over a series of screen slots having widths of 10.3 mm (Screen No. 26), 9.5 mm (Screen No. 24), 8.7 mm (Screen No. 22), 7.9 mm (Screen No. 20), 7.1 mm (Screen No. 18), 6.4 mm (Screen No. 16), and 5.6 mm (Screen No. 14). For purposes of analysis, thickness or size categories were designated by the median screen size which represents the midpoint between the last screen slot that passed a pod or seed and the screen slot on which the pod or seed was retained. Sizes are presented in units of commercial screen number (size in mm = screen no. x 0.397). Weights were recorded to the nearest 0.001 g.

The weights of each pod and each seed were summed independently for each plant age, maturity class, and screen size. These total weights were mathematically adjusted by the ratio of the number of pods in the subsample to the number of pods in the sample in order for the combined analysis to reflect the composition of the original distribution and to obtain a representative composite sample. The cumulative percentage by weight of the pods and seed which rode a designated screen were calculated for each pod maturity and plant age.

The data for each plant age and pod maturity as well as for the composite samples were fit to the logistic CDF (2). The CDF can be defined as

$$F(x) = [1 + e^{-\gamma(x-\mu)}]^{-1} \qquad (1)$$

Our primary concern is its use for characterizing the cumulative percentage by weight of pods and seed (y) which ride a designated screen size (x). The functional form of the logistic CDF for characterizing this relationship is given by

$$y = 100\,[1 - 1/(1 + e^{-\gamma(x-\mu)})] \qquad (2)$$

where the parameter, μ, is the mean pod or seed size and γ is a rate parameter which is inversely correlated with the standard deviation. The parameters μ and γ were estimated for each date and maturity class as well as the composite samples at each date by solving Eq. [2] for the observational data using the nonlinear statistical procedure, NLIN (4). Since the logistic distribution is a symmetrical distribution, the mean and median occur at the same central point, and thus, 50% of the pods or seeds are larger than μ.

The parameter estimates, μ and γ were regressed separately by maturity class and for the composite samples as functions of DAP. For a clearer illustration of trends, the parameter estimates are presented graphically by lines connecting the data points in lieu of showing the regression lines.

A "goodness of fit" measure for nonlinear regression models similar to the R^2 for linear regression models is difficult to define since the ratio of regression sum of squares to the corrected total sum of squares may exceed 1.0 for nonlinear models. Therefore, for this study, R^2 for fits to the CDF was defined as 1.0 minus the ratio of the residual sum of squares to the corrected total sum of squares.

Results and Discussion

Figure 1 illustrates the application of the logistic CDF [Eq. 2] for describing the seed size data corresponding to the optimum harvest at 141 DAP (net yield 6854 kg/ha). A summary of the parameters estimates and R^2 values for the curves are presented in Table 1. Estimates of the mean seed size (μ) range from Screen No. 19.55 to 23.52 for Maturity Classes 3 through 7, while estimates of the slope parameter (γ) range from 0.75 to 1.38. Parameter estimates for Maturity Class 2 (seed of white, soft, watery pods) are excluded as most seed fell through the smallest screen (No. 14). However these seed are included in the parameter estimates for maturity composites.

The estimates of μ and γ for the composite sample are 22.80 and 0.90, respectively. For example, 50% of the seed are larger than Screen No. 22.8, the estimated mean for the composite sample. Of the proportion of the composite sample attributable to Maturity Class 3, 50% of the seed are larger than Screen No. 19.5. Therefore, the least harvestable maturity class (Class 3) contained a considerable proportion of the larger seed sizes. Alternatively larger screen sizes are expected to contain a considerable range of maturities. The "goodness of fit" measure, R^2, shows the logistic CDF provides an excellent fit for the seed of each pod maturity class and explains over 99 percent of the variability in the cumulative seed size distribution.

Estimates of the values of the logistic CDF parameter μ for Eq. [2] fit to the seed size data for each maturity class and date are shown in Fig. 2. The larger values for the estimates of μ for each successive maturity class reflect generally greater seed thicknesses associated with increased maturity. The magnitude of increase was less between Maturity Classes 6 and 7 than between the other classes. This was expected because we considered a seed to be fully mature by the early stages of Class 7. The corresponding estimates of the logistic CDF parameter γ also increased with maturity (Fig. 3). The larger values of γ for the greater maturity classes indicated that a smaller variance in seed thickness was associated with increased maturity. However the smaller values of γ associated with increasing DAP for each maturity class reflect an increase in the variability of seed sizes with time.

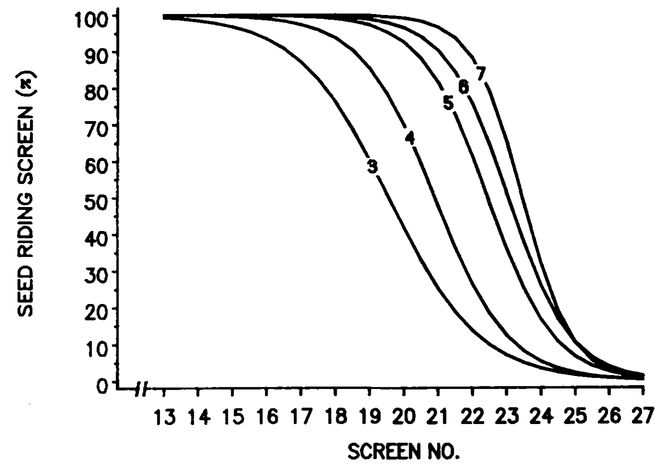

Fig. 1. Cumulative percentages of seed (by weight) riding screen for various maturity classes at 141 DAP.

Table 1. Cumulative logistic seed size distribution function parameters μ, γ, and R^2 for example given in Fig. 1 at 141 DAP.

Maturity Class	μ	γ	R^2
3	19.55	.75	.994
4	20.92	.93	>.999
5	22.54	1.03	>.999
6	23.12	1.09	>.999
7	23.52	1.38	>.999
Composite	22.80	.90	.997

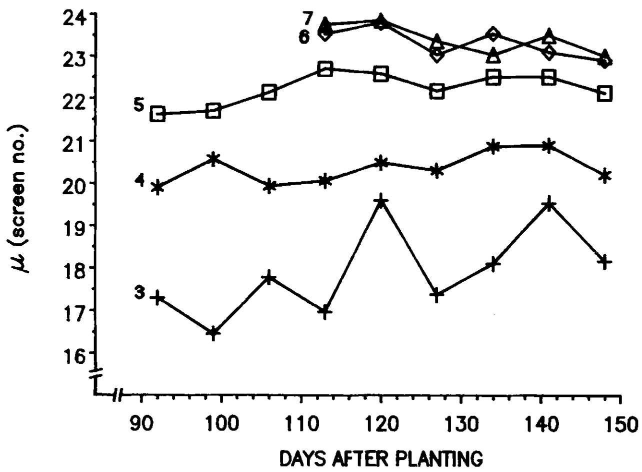

Fig. 2. Estimated CDF parameter μ (mean size) for seed as affected by maturity class and plant age.

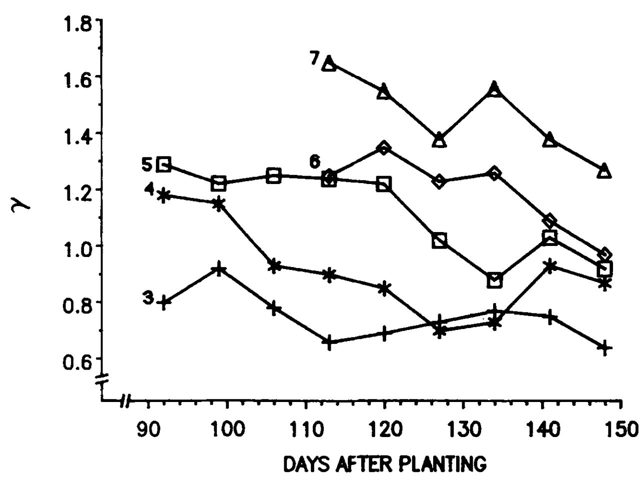

Fig. 3. Estimated CDF parameter γ for seed as affected by maturity class and plant age.

The regression equations for Figs. 2 and 3 for estimating the parameters, μ and γ, as functions of DAP for the various maturity classes and for the composite sample are shown in Table 2. Significant ($P<.05$) negative linear relationships were found for γ and DAP in Maturity Classes 4 through 7. Maturity Class 3 had an observed significance level of $P<.10$. Positive trends were found for μ and DAP in Maturity Classes 3, 4, and 5 with observed significance levels $P<.10$, $P=.14$, and $P=.11$, respectively. Slightly negative trends were found in Maturity Classes 6 and 7 with observed significance levels of $P=.11$ and $P=.07$, respectively.

Table 2. Regression equations for peanut seed parameters μ and γ by maturity class as a function of days after planting (DAP).

Maturity Class	μ for seed		γ for seed	
(3)	$\hat{\mu}_3 = 13.98 + \underset{(0.0173)}{0.0330}$ DAP	P<.10	$\hat{\gamma}_3 = 1.066 - \underset{(0.0014)}{0.0026}$ DAP	P<.10
(4)	$\hat{\mu}_4 = 19.12 + \underset{(0.0063)}{0.0104}$ DAP	P=.14	$\hat{\gamma}_4 = 1.624 - \underset{(0.0023)}{0.0059}$ DAP	P<.05
(5)	$\hat{\mu}_5 = 20.90 + \underset{(0.0063)}{0.0113}$ DAP	P=.11	$\hat{\gamma}_5 = 1.972 - \underset{(0.0015)}{0.0071}$ DAP	P<.01
(6)	$\hat{\mu}_6 = 25.83 - \underset{(0.0094)}{0.0191}$ DAP	P=.11	$\hat{\gamma}_6 = 2.329 - \underset{(0.0029)}{0.0087}$ DAP	P<.05
(7)	$\hat{\mu}_7 = 26.02 - \underset{(0.0080)}{0.0199}$ DAP	P=.07	$\hat{\gamma}_7 = 2.265 - \underset{(0.0030)}{0.0091}$ DAP	P<.05
Composite	$\hat{\mu}_c = -9.83 + \underset{(0.0008)}{0.4768}\,\mathrm{DAP} - \underset{(0.0003)}{0.0018}\,\mathrm{DAP}^2$			P<.001
	$\hat{\gamma}_c = 0.415 + \underset{(0.0012)}{0.0030}$ DAP			P<.01

[1]The standard errors for the regression slope coefficients are enclosed in parentheses.

The estimated parameters, μ and γ, for the composite sample fit to the seed size data are shown in Fig. 4. The estimated mean seed size, γ, increased rapidly up to approximately 120 DAP after which the rate decreased. Regressions of the estimates over all DAP showed significant ($P<.01$) linear and quadratic coefficients for μ and significant ($P<.01$) linear slope for γ. (Table 2). The increasing values of γ with DAP for composite samples reflect a slightly smaller variation in seed thickness with increasing DAP.

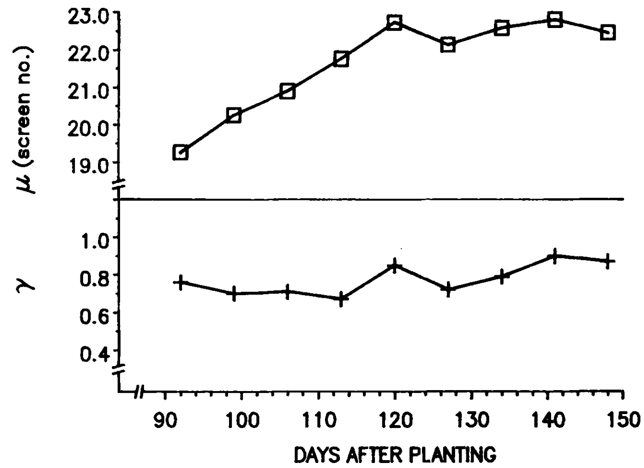

Fig. 4. Estimated CDF paramters μ and γ for seed of composite samples as affected by plant age.

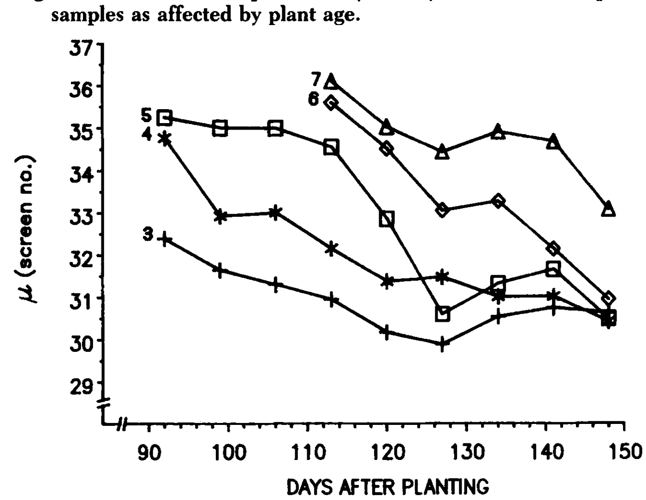

Fig. 5. Estimated CDF parameter μ (mean size) for pods as affected by maturity class and plant age.

Figures 5 and 6 show the pod size distribution parameters for μ and γ as affected by pod maturity and plant age. The estimated parameter μ for mean pod thickness generally increased for each successive maturity class. However the estimated parameter γ varied widely among maturity classes. Regressed as a function of DAP, the estimated parameter μ for pod thickness showed significant ($P<.05$) negative slopes for each maturity class (Table 3). This indicates that a greater proportion of smaller pods occurred within each maturity class with increasing DAP. The estimated parameter γ showed only significant ($P<.05$) negative relationships with DAP for Maturity Classes 6 and 7. For the composite sample of pods (Fig. 7), μ as a function of DAP had a significant ($P<.05$) negative slope of 0.030 per day.

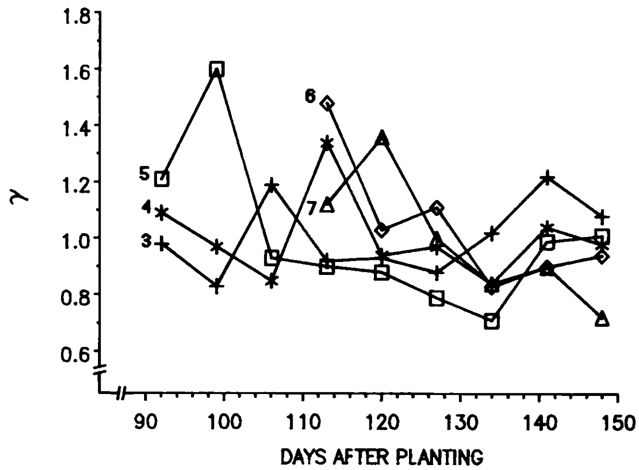

Fig. 6. Estimated CDF parameter γ for pods as affected by maturity class and plant age.

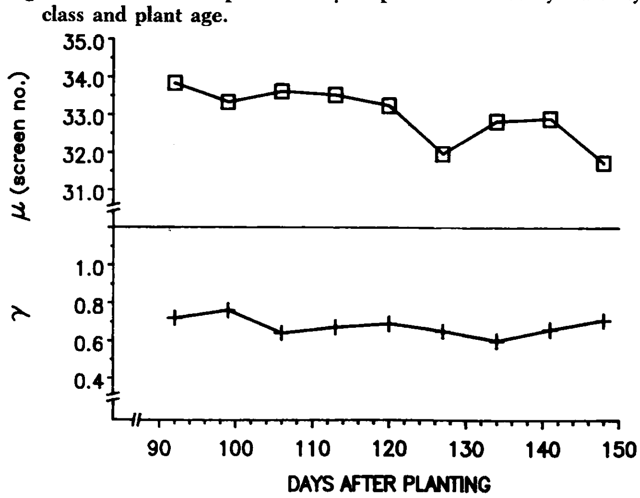

Fig. 7. Estimated CDF parameters μ and γ for pods of composite samples as affected by plant age.

The estimated parameter γ for the same composite sample also had a significant ($P<.05$) negative relationship with DAP ($\hat{\gamma}_c$ = 0.618 - 0.00117 DAP). A summary of the regression equations for estimating μ as functions of DAP for the various maturity classes and for the composite sample is shown in Table 3.

Table 3. Regression equations for estimating μ for pods by maturity class as a function of days after planting. (DAP).[1]

Maturity Class	μ for pods	
(3)	$\hat{\mu}_3$ = 34.45 - 0.0295 DAP (0.0103)	$P<.05$
(4)	$\hat{\mu}_4$ = 39.95 - 0.0661 DAP (0.0093)	$P<.01$
(5)	$\hat{\mu}_5$ = 44.52 - 0.0962 DAP (0.0156)	$P<.01$
(6)	$\hat{\mu}_6$ = 49.34 - 0.1232 DAP (0.0141)	$P<.01$
(7)	$\hat{\mu}_7$ = 43.11 - 0.0644 DAP (0.0195)	$P<.05$
Composite	$\hat{\mu}_c$ = 36.65 - 0.0304 DAP (0.0085)	$P<.01$

[1]The standard errors for the regression slope coefficients are enclosed in parentheses.

Our concern in this study was for the evaluation of the seed of harvestable (full-size) pods. Pods essentially reached their full size by the end of Maturity Class 2, though slight growth in hull thickness occurred throughout their development. Substantial seed growth, however, did not begin until after the pods reached full size (pod-filling stages). For the composite sample, the estimated mean pod size decreased slightly as a function of DAP at the same time the estimated mean seed size increased. The explanation is that the pods set earlier in the plants' production were larger than those set later. The decrease in pod size over time reflects the accumulation of these pods of smaller maximum size in the population.

Since the first pods to be set are normally the largest pods, the estimated mean seed size of these two most advanced maturity classes (6 and 7) were likely lowered with time because of the accumulation of seed from pods of smaller maximum size typically set later in the season. The positive trend found for μ and DAP in Maturity Classes 3, 4, and 5 suggests that the mean seed thickness of these classes increased slightly over time. We observed in particular for Maturity Class 3 and the latter sampling dates, less space between the seed and pod walls and a greater proportion of pods nearer the transition to Maturity Class 4. This suggests that the seed in these maturity classes may be slightly further developed nearer to the optimum harvest interval than when the earliest pods set were at the same pod maturity level. These biological phenomenon were observed in numerous experiments throughout our studies.

Conclusions

The logistic CDF has been successfully used in our studies to characterize the distributions of Florunner pod and seed sizes as functions of pod maturity and plant age. Through use of the parameters that were estimated for the mean size, μ, and the parameter, γ, which is inversely related to the variance, the cumulative percentage of pods or seed by weight that ride a designated screen may be predicted for a given pod maturity and DAP. These relationships provide a mathematical approach for a better understanding of the influence of pod maturity and plant age on pod and seed sizes.

Consistent trends were found in the estimated parameters μ for seed and pods, and consistent trends were found in the estimated parameter γ for seed. The parameter γ for pods varied widely among maturity classes. Estimates of μ and γ for seed and μ for pods showed positive relationships with maturity. When regressed as a function of DAP, negative linear relationships were found in γ for seed. Positive trends were found in μ and DAP in Maturity Classes 3 through 5, and negative trends were found in Classes 6 and 7. Negative trends were also found for μ and DAP for pods of each maturity class.

For an additional verification of the accuracy of the parameter estimates, a comparison was made with those obtained from a study of four planting dates and multiple harvest dates in 1978. From the 1978 study, the parameter μ for farmers' stock samples ranged from 21.07 to 21.97, while γ ranged from 0.773 to 0.868. These values compare favorably with $\gamma = 0.997$ and $\mu = 22.80$ for composites samples within the interval for optimum harvest. Parameter estimates for the composite samples also compared favorably with $\mu = 20.081$ and $\gamma = 0.756$ reported by Davidson *et al.* (1).

It should be recognized that the peanuts for this study were produced under irrigated culture in an ideal, stress-free growth environment. Further analyses are desirable to show the effect of other varieties, crop years, and plant stresses on the relationships among seed size distribution, pod maturity, and plant age.

The approach used in this study for characterizing the distributional relationships of pod and seed sizes over all pod maturities and plant ages has a wide range of applications for describing other facets of peanut fruit growth and development.

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