Impact of Plant Spacing and Population on Yield for Single-Row Nonirrigated Peanuts (*Arachis hypogaea* L.)

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ABSTRACT

Poor peanut emergence often results in lower yield and loss of revenue. Farmers attempting to recapture lost income sometimes lose even more by replanting because replant costs may exceed the benefits of added yield. The purpose of this study was to develop an empirical equation to predict peanut yield based on total emergence 21 d after planting and an estimate of yield for a full stand of peanuts. Field experiments were conducted in Terrell Co., Georgia during 1997 and 1998 for nonirrigated peanut (cv. Georgia Green) grown in an Americus sand (thermic Rhodic Paleudults). To mimic poor emergence and concomitant random plant spacing, rows within plots were thinned at random locations to attain populations of 4.4, 3.3, 2.6, 2.1, and 1.6 plants/m-row. Control plots were not thinned and total emergence was approximately 12.7 plants/m-row. As total emergence and population decreased, yield also decreased whereas pod mass per plant increased. This increase was likely attributed to a reduction in competition from adjacent peanut plants for water, nutrients, and light. Higher population treatments had smaller pod mass/plant and greater overall yield than lower population treatments with higher pod mass/plant. Random plant-to-plant spacing associated with poor emergence was used to predict pod mass/plant as a function of average plant spacing. Results from this research established models defining the relationship of the rate of change of pod mass per plant with average plant spacing and provided a new method of predicting yield in the event of poor emergence.

Key Words: Emergence, pod mass, pod yield.

Producers in the southern U.S. commonly plant runner-type peanuts at a rate of approximately 20 seed/m on 0.91 m row widths (Wehtje *et al.*, 1994). The relatively high seeding rate is used as a hedge against poor emer-

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gence with the hope of attaining approximately four plants/30 cm row (Baldwin, 1997). Higher seeding rates offer the additional benefits of (a) accelerated canopy coverage (Mozingo and Wright, 1994), (b) enhanced weed suppression (Hauser and Buchanan, 1981; Buchanan *et al.*, 1982), and (c) reduced tomato spot wilt virus severity (TSWV) (Brown *et al.*, 1997).

Poor plant emergence, associated with inferior seed quality, pests, or adverse environmental conditions reduces plant populations and often leads to reduced yield and economic returns. Farmers trying to recapture an expected loss in income by replanting sometimes lose even more income because replanting costs may exceed the financial benefits of greater yield.

The impact of population as determined by various row and plant spacings on peanut yield has been reported with mixed results. A 3-yr experiment in Oklahoma compared pod yields of the spanish-type peanut Argentine on 0.25, 0.5, 0.75 and 1-m rows using 12.5, 6.7, and 3.1-cm seed spacing (Chin Choy *et al.*, 1982). Highest yields for both irrigated and rain-fed treatments were associated with the narrowest (0.25 m) row spacing. In a study of five cultivars, it was reported that the closest (5.1 cm) seed spacing produced greater yields than 15.2 cm on 91-cm rows (Mozingo and Steele, 1989). A 2-yr study (Igbokwe and Nkongolo, 1996) in Mississippi reported the effect of 10.2, 15.2, and 20.3-cm seed spacing on yield for cv. Alcon Pat using 1.07-m rows. Greatest yield was associated with the 15.2-cm treatment as opposed to the narrowest rows. In another study, three of six cultivars had a significant yield increase when spacing was decreased from 30.5 to 10.2 cm/seed on 91-cm rows (Knauft *et al.*, 1981). However, no significant yield difference was reported when spacing decreased from 15.2 to 10.2 cm.

Other studies observed diminishing yield when the population passed a critical saturation spacing. Yield of the cv. Florunner planted at 19.6, 11.9, 8.4, 6.6, and 5.3 cm/seed on 0.9-m rows progressively increased as seed spacing decreased from 19.6 to 6.6 cm/seed (Wehtje *et al.*, 1994). However, a further reduction in seed spacing from 6.6 to 5.3 cm/seed reversed the positive trend in yield. Yield decreased when the plant population became too high. Apparently, excessive interplant competition for water, nutrients, and light reduced yield.

The relationship of plant spacing and population on grade is unclear. Knauft *et al.* (1981) reported five of six cultivars showed no significant difference in grade with changing population. In contrast, Mozingo and Wright (1994) reported significantly higher sound mature kernels (SMK), total kernels (TK), and lower other kernels (OK) for six virginia-type cultivars associated with more compact planting patterns. Chin Choy (1982) reported highest quality was associated with 6.7 cm rather than 3.1- or 12.5-cm plant spacing.

Evidence highlighting the impact of plant competition expressed as the dependency of yield per plant on population has been reported for other crops. Bakelana and Regnier (1991) studied domestic oat (*Avena sativa* L.) and reported crop dry matter, leaf area, and tiller number per plant increased when population decreased. Zadeh and Mirlohi (1998) reported rice (*Oryza sativa* L.) yield per unit area was less but grain yield per plant was more when population was reduced.

Since plant population, plant spacing, and yield were thought to be interrelated, it was felt that these relationships needed to be quantified to help growers predict yield. Because earlier studies dealt primarily with the relationship of plant population to yield and not specifically with pod mass per plant, the goal of this study was to quantify the impact of plant population on pod mass per plant and pod yield. Thus, the objectives of this study were to (a) determine if a distinct relationship between average plant spacing and pod mass per plant exists, (b) quantify that relationship to show the combined impact of plant spacing and plant population on yield in a single row pattern, and (c) use this relationship to predict yield for imperfect plant stands.

Materials and Methods

In 1997 and 1998, the runner-type cultivar Georgia Green (75% labeled germination) was planted on 0.91-m rows using a Monosem pneumatic planter set to 20.8 seeds/m. The cultivar was selected for its resistance to TSWV (Brown *et al.*, 1999) as well as its popularity in the Southeast. Peanuts were planted in Americus sand (thermic Rhodic Paleudults) with less than 1% organic matter and 0 to 5% slope. Row length was 7.6 m in 1997 but was extended to 15.2 m in 1998 to reduce end-of-row border effects. The experimental design was a randomized complete block (RCB) with treatments replicated four times. In mid-May, approximately 21 d after planting, noncontrol plots were hand-thinned to average plant spacings of 22.9, 30.5, 38.1, 48.3, and 61.0 cm/plant corresponding to 4.4, 3.3, 2.6, 2.1, and 1.6 plants/m, respectively. Plant population for these respective plant spacings were 47,800, 35,900, 28,700, 22,700, and 17,900 plants/ha.

To mimic the nature of poor emergence and the random plant spacing associated with it, the number of plants per treatment was held constant while individual plant-to-plant spacing within each treatment varied. To simulate nonuniform emergence, randomized distances from 2 to 100+ cm between individual plants within treatments were established by hand thinning. For example, to achieve 3.3 plants/m in the 15.2-m treatment row, all but 50 plants in the plot were removed. Fifty computer-generated randomized values were used to create a "template" of 50 distances along a 15.2-m section of rope. The marked rope was placed parallel to a row, and healthy plants nearest the markings were retained with all others removed. Multiple program runs were used to create different thinning patterns for adjacent rows within the same treatment. The same procedure was followed on all noncontrol plots. Control plots were not thinned and total emergence was approximately 12.7 plants/m with a corresponding plant population of 138,900 plants/ha.

Following digging in mid-September, peanuts were windrow-cured for 2 d. Rows three and four of each six-row treatment were threshed using a stationary picker in 1997 and weights recorded. Wet weight samples were recorded after leaving the field and dry weights (9% moisture) recorded following forced air-drying in peanut wagons. Grades were recorded but results are outside the scope of this study. All methods and procedures were identical in 1997 and 1998, with the exception of plot length. This was doubled in 1998 to reduce end-of-row border effects and to accommodate a peanut combine. Regression and one-way ANOVA operations were performed using the Statistical Analysis System (SAS, 1993).

Results and Discussion

Relationship of Pod Mass per Plant to Average Plant Spacing. Pod mass per plant consistently increased with average plant spacing. Higher pod mass per plant associated with lower total emergence can be attributed to an overall reduction in competition for water, nutrients, and light (Humphrey and Schupp, 2000). Reduced competition caused by poor emergence permits extant plants to divert more energy from growth and maintenance functions to reproductive production (pod mass per plant).

The effect of plant spacing on pod mass per plant is illustrated in Fig. 1. Residual values of log-transformed data were calculated and plotted to aid in selecting the simplest and most appropriate model for data. Residual values were computed as the difference between the log of observed and the log of predicted pod mass per plant. Residual values for 1997 and 1998 indicated that Fig. 1 data were best modeled by the geometric form:

$$Y = \beta_0 X^{\beta 1} \quad \text{[Eq. 1]}$$

where:
Y = pod mass per plant (g),
X = plants per meter,
β_0 = least squares estimator of intercept, and
β_1 = least squares estimator of slope.

To estimate regression coefficients, Eq. 1 was linearized by taking the log of both sides:

$$\log Y = \log\beta_0 + \beta_1 \log X$$

and setting

$$Y' = \log Y,\ X' = \log X \quad \text{[Eq. 2]}$$

then substituting:

$$Y' = \log\beta_0 + \beta_1 X' \quad \text{[Eq. 3]}$$

and solving:

$$Y'_{1997} = 2.069 - 0.636X' \quad \text{[Eq. 4]}$$

and

$$Y'_{1998} = 2.402 - 0.823X' \quad \text{[Eq. 5]}$$

Statistical details of the analysis are provided in Table 1.

Coefficients of determination (R^2) were 0.69 and 0.96 for Eqs. 4 and 5, respectively. Greater variability was associated with the 1997 data because end-of-row border effects probably impacted yield. Variability was reduced in 1998 by doubling row length.

Table 1. Parameter estimates of log-transformed data.

Parameter	Estimate	Standard error	t	Pr >|t|
$\log\beta_{0(1997)}$	2.069	0.05501	37.62	<0.0001
$\beta_{1(1997)}$	-0.6359	0.09555	-6.660	<0.0001
$\log\beta_{0(1998)}$	2.401	0.02169	110.7	<0.0001
$\beta_{1(1998)}$	-0.8228	0.03452	-23.84	<0.0001
$\beta_{1(\text{pooled})}$	-0.7439	0.04803	-15.49	<0.0001

Trend lines modeling the transformed data (Fig. 2) suggested a possible common slope for 1997 and 1998. To determine if slopes and intercepts were statistically equivalent the following hypotheses were tested:

$$H_0: \beta_{1\ (1997)} = \beta_{1\ (1998)}, \text{ and} \quad \text{[Eq. 6]}$$

$$H_0: \beta_{0\ (1997)} = \beta_{0\ (1998)} \quad \text{[Eq. 7]}$$

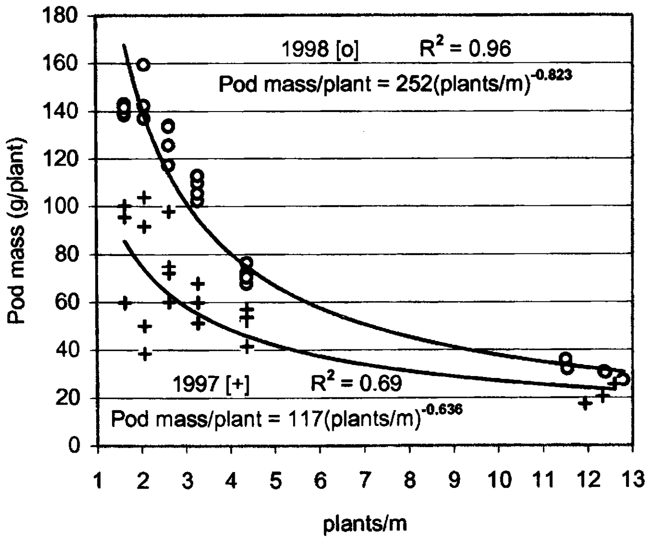

Fig. 1. Regression of pod mass/plant on plants/m for 0.91-row widths.

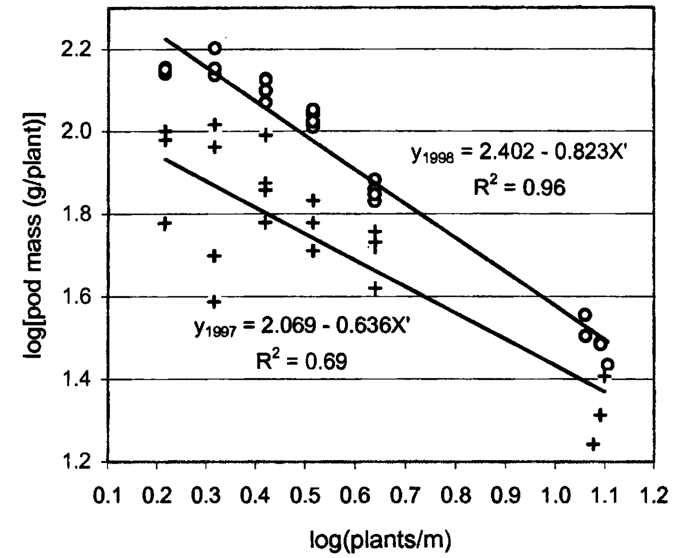

Fig. 2. Regression of log-transformed pod mass/plant on log-transformed plants/m for 0.91-m row widths.

Table 2. Comparison of regression lines for 1997 and 1998 linearized data.

AOV	df	SS	MS	F	P
Equality of slopes	1	0.032	0.0324	3.94	0.054
Residual error	43	0.354	0.0082		
Equality of adjusted means	1	0.634	0.634	72.2	0.000
Residual error	44	0.386	0.0088		

Table 2 lists the results of those tests.

We failed to reject H_0: $\beta_{1\ (1997)} = \beta_{1\ (1998)}$ for $P \geq 0.05$ which meant the rate of change in pod mass per plant as a function of plants/m did not significantly change from 1997 to 1998. This suggests that rate of change in pod mass per plant was physiologically, rather than environmentally, dependent on average plant spacing. In contrast, the null hypothesis of equal intercepts (Eq. 7) was rejected. This was expected because annual variations in rainfall depth, frequency, and other environmental factors affected maximum pod mass per plant (i.e., the intercept).

Transforming regression Eqs. 4 and 5 back to geometric form gave:

$$Y_{1997} = 117\ X^{-0.636} \qquad \text{[Eq. 8]}$$

and

$$Y_{1998} = 252\ X^{-0.823} \qquad \text{[Eq. 9]}$$

Equations 8 and 9 were plotted with observed data in Fig. 1.

Pooling 1997 and 1998 data to quantify a common slope expressing the physiological dependence of pod mass per plant on plant spacing for a linear pattern gave:

$$Y_{pooled} = \beta_0 X^{-0.744} \qquad \text{[Eq. 10]}$$

The intercept (β_0), which is an estimate of pod mass per plant for a full stand of peanuts, will vary with annual growing conditions.

Relationship of Pod Mass per Plant to Population and Pod Yield. It is important to recognize that the product of average pod mass per plant and plant population equals yield. Population is inversely proportional to average plant spacing for a linear planting pattern. Equation 10 quantifies pod mass per plant as a function of plant spacing. From average plant spacing and row width, plant population for a single row planting pattern can be calculated.

Highest yields for 1997 and 1998 came from 12.7 plant per m control plots. By allowing control plots to serve as our baseline population, yield as a percentage of our baseline population may be calculated by dimensional analysis:

$$E = \frac{100(1/0.914\text{m})(10000\text{m}^2/\text{ha})(X^{-0.744}\text{g/plant})(\text{kg}/1000\text{g})}{(12.7\text{plants/m})(1/0.914\text{m})(10000\text{m}^2/\text{ha})(12.7^{-0.744}\text{g/plant})(\text{kg}/1000\text{g})} \qquad \text{[Eq. 11]}$$

where E = percent of estimated maximum yield. Simplifying Eq. 11 gives:

$$E = 52.2X^{0.256} \qquad \text{[Eq. 12]}$$

for $12.7 \geq X \geq 1.6$ plants/m. Equation 12 is plotted in Fig. 3 for stands ranging from two to 12.7 plants/m. Predicted yield for stands less than 12.7 plants/m can be determined by multiplying estimated yield for a full stand of peanuts by Eq. 12 or by the corresponding abscissa value given in Fig. 3.

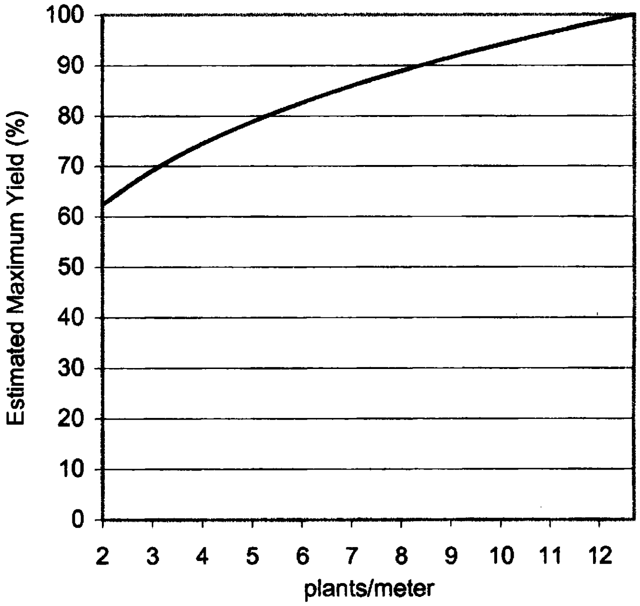

Fig. 3. Percentage of estimated maximum yield vs. plants/m.

Conclusions

Results from this study quantified the dependence of pod mass per plant and yield on plant spacing and population. Maximum yield in a linear row pattern is limited by the dynamics of average plant spacing and population as noted by the following observations: (a) pod mass per plant is positively correlated with average plant spacing, and (b) yield is inversely proportional to average plant spacing in a linear, single-row planting pattern. Increases in average plant spacing increase pod mass per plant but decrease yield because there is a lower plant population.

The following direction for future research is suggested. Based upon the foregoing results, yield for a fixed population can be improved by minimizing competition through maximizing the distance between adjacent plants. For single rows with a fixed bed width, plant spacing will define the population. Spacing cannot be altered without changing population. In contrast, planting in a two-dimensional pattern (i.e., two or more rows per bed) permits changes in plant spacing without changing population or bed width. Results presented in this study suggest farmers could significantly improve yield by simply changing to a two-dimensional planting pattern. Future research should focus on how yield for a fixed population changes with planting pattern.

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