PEANUT SCIENCE

The Journal of the American Peanut Research and Education Society

ARTICLE

Revised Thresholds for Runner Peanut Harvest Maturity Pertaining to Recent Cultivars in South Carolina

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ARTICLE INFORMATION

Keywords:
Arachis hypogaea L, cumulative degree days, digging decision, economic value, pod

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DOI: 10.3146/0095-3679-51-PS23-9

ABSTRACT

In the absence of complicating factors, economic value of harvested farmer stock peanut is greatest at optimal maturity. Traditional harvest maturity thresholds for runner market type peanut have included when approximately 75% of pods exhibit characteristics of physiological maturity, i.e., coloration of the endocarp or seed testa, or pod mesocarp color being orange, brown, or black (OBB). However, these thresholds were developed based on cultivars (e.g., Florunner) released more than 5 decades ago that are no longer commercially grown with appreciable market share. Production data in South Carolina from 2018 to 2022 indicated relative optimal economic value for FloRun 331, Georgia-16HO, or TUFRunner 297 was reached prior to acquiring 75% OBB pods. Updated pod maturity thresholds more reliably predicted periods of optimal harvest compared to the traditional pod maturity threshold and several environment or degree-day-based criteria. Rate parameters of pod maturity increase for runner peanut approaching or subsequent to having reached optimal economic value differed (0.82 to 1.6% and 0.42 to 0.81% per day, respectively), incorporation of which further improved threshold performance in instances where environmental conditions adversely affected maturity development. Results are anticipated to afford farmers greater flexibility in scheduling digging times for applicable fields while preserving corresponding economic value.

INTRODUCTION

Crop production decisions and recommendations consider information in order to maximize positive outcomes and minimize regret. The decision of when to dig a peanut crop has a great impact on the ability to maximize harvested yield, grade, and accompanying economic value (Carter et al. 2017; Chapin and Thomas 2005; Fogle et al. 2019; Jordan et al. 2019). When conditions and time allow, economic value is characteristically greatest when peanut is harvested at optimal maturity (Colvin et al. 2014; Jordan et al. 2019; Rowland et al. 2006). However, factors not limited to present or impending weather conditions, disease progression, maturity sample collection and evaluation, and logistical constraints can all influence the actual time a particular field is inverted (Anco et al. 2023; Anco et al. 2020; Jordan et al. 2019).

In South Carolina and the surrounding Virginia-Carolina region, the predominant method of assessing peanut maturity examines the distribution of pod mesocarp color as exposed following pressure washing or hull scraping (Anco et al. 2023; Balota et al. 2021; Jordan et al. 2023; Jordan et al. 2020). Greater pod and kernel maturity, weight, and value are indicated by darker pod mesocarp colors (Jordan et al. 2019; Rowland et al. 2006). In the presence of soil moisture-limiting stress, pod maturity can exhibit irregular development with the saddle or dorsal portion of the mesocarp or endocarp exhibiting the most advanced color (Colvin et al. 2014; Williams and Drexler 1981). Boote (1982) previously reported harvest maturity for the runner market type cultivar Florunner to be when 75% of sample endocarps or testas exhibit coloration, having further noted that these thresholds could likely change across cultivars. The presence of mesocarp coloration characteristically parallels that of corresponding endocarps and testas (Boote 1982). Since Florunner was released over 50 years ago (Norden et al. 1969), examination of the applicability of Boote's threshold to new cultivars alongside his accompanying disclaimer is fitting. In addition to evaluating pod samples, peanut maturity has also been monitored as predicted by various cumulative degree day measures as developed in various production regions (Bell and Wright 1998; Emery et al. 1969; Mills 1964; Rowland et al. 2006).

In view of the above considerations, peanut digging decisions, particularly nearer later portions of the growing season, can become a balance of maximizing potential crop value in the presence of time constraints given diminishing season length and hours of sunlight for drying and increasing risk of frost injury (Anco et al. 2023; Jordan et al. 2019). Consequently, optimal maturity can be broadly considered in two ways. In one line of thought, optimal maturity can be viewed as the singular (theoretical) point in time at which maximum possible value is available to be attained; prior to such a pinnacle of profitability, all other points would simply be considered suboptimal. While this perspective can readily be seen to prioritize potential economic value, it does so at the potential cost of the value of time. Conversely, with respect to the pertinency of the limited nature of time and the acknowledgment of the existence of a practical optimum (e.g., a period of conditions where relative economic value is not notably different from an identifiable optimum), optimal maturity can be considered as the window of maturity at which available economic value would not be significantly less than an alternative time point in a given season. Since 2018, questions have been raised regarding when certain newer runner cultivars (e.g., FloRun 331, Georgia-16HO, and TUFRunner 297) reach optimal maturity. The objective of this work was to evaluate the reliability of several harvest thresholds in determining relative optimal economic value for a selection of recently released runner market type cultivars in South Carolina: FloRun 331, Georgia-16HO, and TUFRunner 297.

MATERIALS AND METHODS

Data Set

The suitability of cultivar maturity experiments conducted in South Carolina from 1998 to 2022 for incorporation in a collective analysis was determined according to several criteria. To be included, experiments needed to identify individual cultivars, possess a minimum of two digging dates, report pod mesocarp maturity and economic value data (i.e., as a function of farmer's stock pod yield and USDA grade, [USDA FSA 2022]), and be reasonably free of confounding factors (e.g., excessive pest damage or gross nutrient imbalances). A total of 12 experiments satisfied these selection criteria. Experiments were conducted at the Edisto Research and Education Center in Blackville, SC (33.364N, -81.329E) on predominantly Barnwell loamy sand: fine-loamy, kaolinitic, thermic Typic Kanhapludults. Pod maturity was estimated as the proportion of pods with orange, brown, or black (OBB) mesocarp coloration through manual counts (2016 and prior) or BLIP v.1.1 (Batch Load Image Processing) software (2017 and later) developed by Clemson University (Kirk 2022).

Analysis

From each experiment, pod maturity and economic value was estimated per cultivar and harvest date using the glimmix procedure of SAS 9.4 (SAS Institute, Cary, NC) specifying a beta (pod maturity) or gamma (economic value) distribution and including random effects for replicate and cultivar *x* replicate. Corresponding fixed effects were cultivar, digging date, and the interaction thereof. Periods of relative optimal economic value (i.e., those in the upper most statistical grouping per cultivar-year) were determined at an alpha of 0.05 according to Fisher's protected least significant difference.

To model relationships of daily pod maturity increase toward and subsequent to having reached relative optimal economic value of a given cultivar in a given experiment (environment), pod maturity data was grouped into *pre* and *post* categories, whereby the fulcrum of separation was dually utilized (i.e., the endpoint of *pre* was the beginning of *post*). Pod maturity data were analyzed according to the following formula:

$$OBB_{ij} = DAP_i \cdot r + I + S_j + e_{ij} \qquad [1]$$

where OBB_{ij} is the proportion orange, brown, or black pods of cultivars corresponding to the *i*th day after planting of the *j*th study, *DAP* is days after planting with corresponding rate parameter *r*, *I* is an intercept, *S* is the random effect of study *j*, and e_{ij} is the residual error associated with the *i*th DAP and *j*th study. Linear regressions for *pre* and *post* groupings were performed separately using the lmer function in R 4.1.2 (R Core Team 2021). Analogous versions of equation 1 were analyzed to compare pod-maturity predictive capabilities of cumulative degree days (cDD, Fahrenheit-based for reference; base 56 F, ceiling 95 F) or cumulative adjusted degree days (caDD, Celsius-based; base 13.3 C, ceiling 35 C; i.e., cumulative [degree days plus mm rainfall and irrigation]) in place of DAP.

The ability of individual harvest maturity criteria to accurately determine periods of relative optimal economic value for FloRun 331 (n = 5 years), Georgia-16HO (n = 6 years), or TUFRunner 297 (n = 6 years) from screened experiments conducted from 2017 to 2022 (Table 1, n = 47 cultivar-digging dates) was described utilizing information theory measurements. Criteria were evaluated according to their accompanying true positive proportion (TPP, i.e., criterion indicates crop is at optimal maturity when it indeed is: true positives/total cases) and false positive proportion (FPP, i.e., criterion indicates crop is at optimal maturity when it actually is not: 1 – true negatives/total controls) (Hughes 2012) of digging date classifications. A criterion's TPP is referred to as its sensitivity, whereas the proportion of its predictions that are truly negative is referred to as its specificity (Hughes 2012). In the context of digging peanuts, conventional information theory terminology refers to an instance where digging is unambiguously warranted as a case and an instance where digging is unambiguously not warranted as a control. Thus, periods of relative optimal economic value would be considered cases, whereas controls would refer to periods of relative suboptimal economic value. Harvest thresholds examined for their performance in correctly classifying periods of relative optimal economic value are listed in Table 2. The 750Mills_ criterion (Mills 1964) was excluded from further information theory analyses due to its lack of improvement compared to simpler environmental indices. Weather data was collected from NOAA (etcman.shinyapps.io/EREC_Weather_App/ and ncei.noaa.gov/access/search/data-search/daily-summaries).

Table 1. Environmental conditions associated with inversion dates within experiments containing FloRun 331, Georgia-16HO, and TUFRunner 297 peanut conducted from 2017 to 2022 in South Carolina.

Year	DAP[a]	Cumulative rain plus irrigation (mm)	Cumulative adjusted degree days[b]	Cumulative degree days[c]
2017	141	508	2191	3020
	154	519	2340	3269
	163	539	2393	3327
2018	140	755	2558	3238
	155	856	2815	3517
	163	865	2860	3587
2019	142	537	2362	3276
	148	538	2449	3431
	155	538	2534	3583
2020	141	615	2295	3016
	147	631	2350	3085
	156	660	2436	3187
2021	140	581	2259	3013
	147	581	2309	3102
	155	581	2346	3168
2022	142	577	2314	3117
	148	577	2345	3173
	154	599	2403	3237

[a] Days after planting of inversion.

[b] Celsius-based; base of 13.3 C, and ceiling of 35 C; includes cumulative rain and irrigation.

[c] Fahrenheit-based; base of 56 F, and ceiling of 95 F.

Table 2. Harvest thresholds examined for their ability to identify periods of relative optimal economic value of runner peanut in South Carolina from 2017 to 2022.

Criterion abbreviation	Description	TPP across full dataset (or excluding 2019)[a]	FPP across full dataset (or excluding 2019)[b]
OBB75	≥75% of pods with orange, brown, or black (OBB) mesocarp coloration. Developed using Florunner (Boote 1982).	0.026 (0.033)	0.000 (0.000)
2300	≥2300 caDD = cDD + c(rain + irrigation mm). cDD = cumulative (maximum air temperature + minimum air temperate)/2 – base. Base of 13.3 C, and maximum air temperature ceiling of 35 C.	0.947 (0.933)	0.333 (0.250)
2350	≥2350 caDD.	0.658 (0.567)	0.222 (0.125)
2400	≥2400 caDD; Peanut FARM guideline.	0.553 (0.500)	0.000 (0.000)
2400Mills	≥2400 cumulative Mills degree days = (maximum air temperature$_{\text{ceiling 35 C}}$ + 13.3 + |minimum air temperature – 13.3|)/2 – 13.3 + |maximum air temperature – 24.4|. Equation modified from Mills 1964 with threshold based on Georgia Green (Rowland et al. 2006).	1.000 (1.000)	n/a (n/a)
750Mills_	≥750 cumulative Mills degree days = (maximum air temperature$_{\text{ceiling 35 C}}$ + 13.3 + |minimum air temperature – 13.3|)/2 – 13.3 – |maximum air temperature – 24.4|. Absolute values were set to zero if the corresponding difference was negative. Original equation from Mills 1964 with empirical threshold from current work.	0.632 (0.800)	0.333 (0.375)
55_50	≥55% (FloRun 331 or Georgia-16HO) or ≥50% (TUFRunner 297) of pods with orange, brown, or black mesocarps.	0.684 (0.867)	0.222 (0.250)
55_50_delta	55_50 threshold with evaluation of the rate of change in OBB per day between two estimates being < 0.82%.	0.816 (0.900)	0.222 (0.250)

[a] True positive proportion = true positives/total cases; sensitivity.

[b] False positive proportion = 1 – true negatives/total controls; 1 – specificity.

Relative entropy, a measure of the amount of expected information (in nats) contained in a corresponding positive or negative prediction from an individual digging criterion (I_+ *or* I_-, respectively) (Hughes *et al.* 2020), was calculated according to the following equations:

$$I_+=\frac{T\cdot p_c}{T\cdot p_c+F\cdot(1-p_c)}\cdot\log\left(\frac{T}{T\cdot p_c+F\cdot(1-p_c)}\right)+\frac{F\cdot(1-p_c)}{T\cdot p_c+F\cdot(1-p_c)}\cdot\log\left(\frac{F}{T\cdot p_c+F\cdot(1-p_c)}\right) \quad [2]$$

and

$$I_-=\frac{f\cdot p_c}{f\cdot p_c+t\cdot(1-p_c)}\cdot\log\left(\frac{f}{f\cdot p_c+t\cdot(1-p_c)}\right)+\frac{t\cdot(1-p_c)}{f\cdot p_c+t\cdot(1-p_c)}\cdot\log\left(\frac{t}{f\cdot p_c+t\cdot(1-p_c)}\right) \quad [3]$$

where T and F are TPP and FPP, respectively, as described above, f is the false negative proportion (FNP = 1 – TPP), t is the true negative proportion (TNP = true negatives/total controls), p_c is the prior probability of there being a case (i.e., akin to the likelihood of the need for digging within a group of environments or conditions), and log is the natural logarithm.

The cost of an individual false positive or false negative was estimated from the data in terms of $/ha deficit (lost) from digging prior to the period of relative optimal economic value or days digging would have been delayed subsequent to the initiation of the period of relative optimal economic value, respectively. An individual false negative cost was estimated along the lines of an opportunity cost in the sense of effective days delayed until another (independent) determination could be made during a subsequent digging date, reflective of the unit-level nature of the FNP descriptor. For criteria based on pod maturity levels, the absence of data from any digging dates satisfying corresponding threshold conditions within a cultivar-year was treated as a single instance of that criterion having failed to trigger a recommendation to initiate digging (termed a terminal false negative). This reflects the consideration that although economic value may differ from year to year based on several factors, in general the crop still needs to be dug at some point in order to realize (relative) economic value (excluding external insurance, abandonment, or other such considerations). For criteria based on accumulated conditions (e.g., caDD levels), a false negative associated with the last assessed digging date in a given cultivar-year was considered in the context of the date from corresponding subsequent weather data that was associated with the realization of accumulated environmental conditions (with respect to initiation of the period of relative optimal economic value).

RESULTS AND DISCUSSION

Among the 47 evaluated cultivar-digging dates from experiments conducted in South Carolina from 2017 to 2022, a total of 38 cases and 9 controls were identified regarding digging being warranted as associated with periods of relative optimal economic value for cultivars within experiments. In the absence of rounding, there was a single instance when OBB pod maturity of FloRun 331, Georgia-16HO, or TUFRunner 297 reached or exceeded 75% (Table 3) and six instances when pod maturity exceeded 70% OBB (equivalent TPP of 2.6 and 15.8%, respectively). Conversely, with the exception of results from 2019 when drought conditions were acutely stressful, there were only 1, 2, and 1 instances where empirical (data-derived) OBB thresholds for FloRun 331 (≥55% OBB), Georgia-16HO (≥55% OBB), and TUFRunner 297 (≥50% OBB), respectively, did not include an instance of a digging date with corresponding relative optimal economic value (equivalent collective FNP of 13.3%).

Table 3. Total sound mature kernels, pod maturity, and economic value of cultivars harvested at varying durations after planting from 2017 to 2022 in South Carolina.

		FloRun 331			Georgia-16HO			TUFRunner 297		
Year	DAP[a]	TSMK[b]	OBB[c]	Hectare value ($/ha)[d]	TSMK	OBB	Hectare value ($/ha)	TSMK	OBB	Hectare value ($/ha)
2017	141	n/a	n/a	n/a	66.5	32	2355 b	66.6	36.9	2427 b
	154	n/a	n/a	n/a	69.8	n/a	2884 a	70.6	n/a	2753 a
	163	n/a	n/a	n/a	73	n/a	2600 a	70.2	n/a	2637 a
2018	140	71.4	45	2142 a	73.1	57.3	2137 a	70.3	54.3	2088 a
	155	70.9	66.8	2219 a	71.3	70.7	2244 a	72.1	57.4	2135 a
	163	71.2	72.9	2296 a	75.1	61.3	2170 a	65.5	56	1806 a
2019	142	66.2	39.8	1423 a	67	37.8	1386 b	66.4	48.1	1428 a
	148	67.8	46.5	1539 a	71.4	43.7	1678 a	69.5	37.2	1633 a
	155	67.3	50.6	1594 a	73.3	46.5	1900 a	70.4	40	1735 a
2020	141	67.2	38.7	1955 b	71.2	34.5	2199 b	69.8	26.1	2199 a
	147	69.3	64.4	2110 a	73.4	67.4	2283 b	71.5	61.4	2276 a
	156	70.3	64.5	2313 a	74.9	65.4	2637 a	72.5	64.5	2370 a
2021	140	69	50.4	1841 b	72	51.5	2367 a	73	48.8	2501 b
	147	70.6	57.5	2320 a	74	50.1	2550 a	74.8	51.4	2886 a
	155	71.4	56.2	2449 a	73.4	57.7	2758 a	75.2	51.8	3037 a
2022	142	71.6	71.3	2562 a	73.8	64.8	3002 a	73.4	54.1	2469 b
	148	72.6	70.8	2740 a	73.8	64.3	3042 a	73	54.1	2711 a
	154	72.6	76.4	2706 a	74.4	71.1	3262 a	73.4	68.1	2864 a

[a] Days after planting.

[b] Total sound mature kernels (%).

[c] % orange, brown, or black pod mesocarps.

[d] Values followed by an "a" were estimated to reflect relative optimal economic value for a given cultivar-year according to Fisher's protected least-squares means at an alpha of 0.05.

Prior to periods of relative optimal economic value (*pre* data), OBB pod maturity was estimated to increase at 1.2% per day (95% confidence intervals: 0.82 and 1.63%) ($P < 0.0001$); the corresponding intercept was estimated at -1.14 ($P < 0.0001$). The reliability (i.e., agreement as per Lin's concordance correlation coefficient) of the model in predicting the data was 80.2% (Fig 1A), which was greater than the reliability of models in which cDD or caDD were evaluated as predictors (CCC = 74.6 and 74.0%, respectively). Within periods of relative optimal economic value (*post* data), pod maturity increased at the lesser rate of 0.61% per day (95% confidence intervals: 0.42 and 0.81%) ($P < 0.0001$); the intercept for the *post* data was estimated to be -0.27 ($P = 0.064$). Reliability of the *post* regression model with DAP as the independent variable was 81.3% (Fig 1B), compared to 80.3% and 81.0% for models with cDD or caDD as the independent variable, respectively.

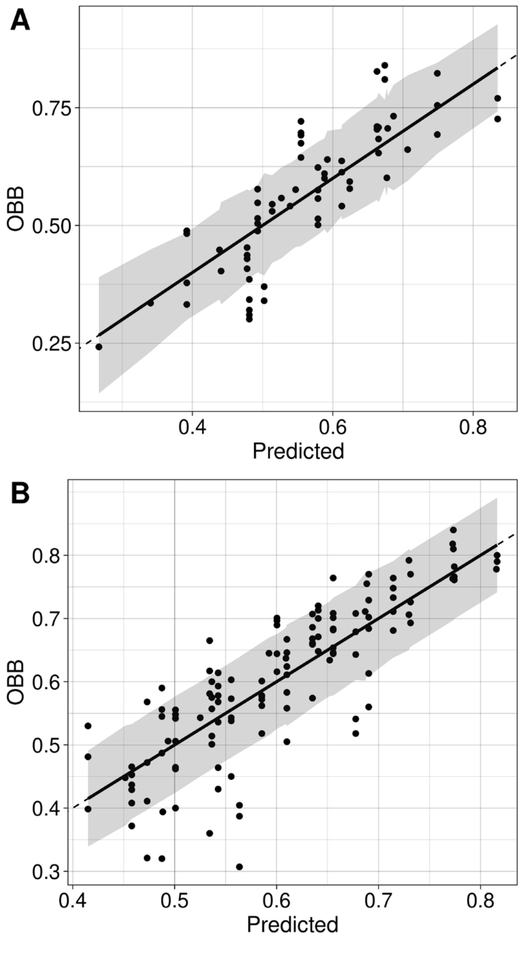

Figure 1. Relationship of observed (y-axis) versus predicted (x-axis) pod maturity (proportion orange, brown, or black mesocarp) for runner peanut (A) approaching or (B) subsequent to having reached optimal economic value within a given cultivar-year in South Carolina. Shaded ribbons represent 95% confidence intervals inclusive of the random effect of study. Lin's concordance correlation coefficient was (A) 80.2% and (B) 81.3%.

Decision support tools, thresholds, and criteria provide value when their predictions of an event occurring or not occurring represent useful information. Relative entropy is a means of quantifying the information content of a positive or negative prediction across a range of event-likelihoods or prior probabilities (Hughes 2020) that is derived from and adds context to a predictor's sensitivity and specificity.

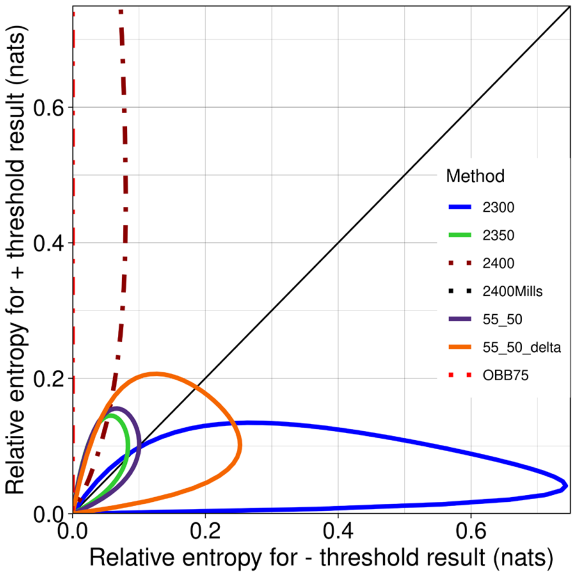

Figure 2. Relative entropy (in nats) of a positive or negative result associated with different threshold criteria for determining harvest maturity of runner peanut in South Carolina from 2017 to 2022. Solid contour lines reflect the use of actual sensitivity and specificity values. Dot-dashed contour lines reflect the approximation of a criterion's specificity (to 0.99999 from 1.0) to avoid otherwise undefined calculations. Contour intersection with the main diagonal (slope = 1), if applicable, represents its point of balanced positive and negative harvest maturity prediction. Methods of determining harvest maturity are levels of cumulative adjusted degree days (≥2300, ≥2350, and ≥2400), cumulative Mills degree days (2400Mills), or pod mesocarp maturity levels (OBB75 = ≥75% of pods with orange, brown, or black mesocarp; 55_50 = ≥55% OBB for FloRun 331 or Georgia-16HO or 50% OBB for TUFRunner 297); 55_50_delta supplements the criteria for 55_50 with assessing the rate of pod maturity increase between two consecutive sampling periods as being ≤ 0.8%.

While greater instances of information content can be seen for individual harvest threshold criteria under specific conditions (Fig 2), the 55_50_delta method exhibited the most balanced contribution of useful information across a range of likelihood conditions (p_c). For example, 2300 caDD had a greater TPP than 55_50_delta (0.947 compared to 0.816, respectively, at p_c = ~0.81), but its maximum relative entropy for a positive prediction was ~65% that of 55_50_delta (0.134 compared to 0.207 nats, respectively, corresponding to p_c of ~0.3), reflective of how the 2300 caDD method had a greater tendency to report false positives. Similarly, while the maximum relative entropy for a negative prediction from the 2300 caDD criterion was approximately three times greater than that of the 55_50_delta method (0.743 versus 0.252, respectively), their corresponding p_c (0.85 and 0.72, respectively) reflect how the greater relative entropy of 2300 caDD was associated with situations in which the likelihood of a control event (true negative) is also less likely. Specificity rates for OBB75 and 2400 caDD as originally calculated were 1.0 (Table 2) due to the absence of any false positives but were modified to 0.99999 to allow relative entropy calculation (I_+ and I_- estimates for 2400Mills remained undefined and thus do not appear on Fig 2). A positive prediction from the OBB75 or 2400 caDD methods represented the greatest I_+estimates (4.8 and 7.5 nats, respectively, albeit at $p_c < 0.01$) among the examined criteria, but these criteria were simultaneously associated with the lowest TPP (Table 2) and least I_- values: 0.00 and 0.08 nats, respectively (p_c of 0.50 or 0.63, respectively). The greatest native uncertainty of the need for management, excluding external factors, would be associated with situations corresponding to a p_c of 0.5, which represents an equal uncertainty of the need to dig or not dig. The criterion with the greatest relative entropy for both a positive and negative prediction at a p_c of 0.5 was 55_55_delta: 0.17 (I_+) and 0.20 (I_-). Similarly, a criterion's capacity to balance producing accurate predictions of the presence or absence of an event is reflected by the point at which its relative entropy curve intersects the main diagonal (Hughes *et al.* 2020). The corresponding value for 55_50_delta (~0.187 nats at a p_c of ~0.45) was distinguishably greater than that of the next greatest ranking criterion, 55_50 (~0.10 nats at a p_c of ~0.65). Relative entropy curves for OBB75, 2400 caDD, and 2400Mills did not intersect the main diagonal at any non-zero point and therefore reflect their imbalanced performance across the spectrum of p_c.

While digging decisions can be inherently dynamic across situations, environments, and operations, an ideal harvest maturity threshold or criterion would be both highly effective in identifying instances where digging is warranted (sensitive) and not warranted (specific). Nevertheless, overall, a false positive has the potential to be more costly than a false negative, provided the false negative is not terminal in the sense that digging does neither become delayed indefinitely nor to the point where digging or harvesting efficiencies are adversely impacted. An example of the latter would include if digging was delayed excessively late in the growing season when growing and harvesting conditions deteriorate (Jordan *et al.* 2019), consequently limiting the ability to capture produced value. Under different circumstances, a false negative could be similarly detrimental if it were to delay digging to when the crop becomes over mature and pegs weaken (Chapin and Thomas 2005), which generally has a greater potential to affect Virginia market type cultivars which were not considered in the current work, or when in the presence of significant defoliation (Anco *et al.* 2020). Nevertheless, among the examined criteria, as the FPP increased, the range of the cost of individual false positives also increased (Fig 3A), being the least for 55_50 or 55_50_delta ($319 to 353/ha; FPP = 22.2%) and the greatest for 2400Mills ($257 to 544/ha; FPP = n/a, approximated to 99.9% following the lack of any true negative predictions coupled with the lack of observed digging dates with cumulative Mills degree days < 2560 according to the method of Rowland *et al.* 2006). Digging at the first (true or false) positive prediction from the 55_50_delta criterion was associated with TSMK values that averaged only 0.8% less than that of the final examined digging date per cultivar-year (Table 3), further illustrating the capacity for this method to determine periods of relative optimal economic value in South Carolina.

The 2400Mills criterion was developed around environmental conditions associated with optimizing harvest value of the medium maturity cultivar Georgia Green (Rowland *et al.* 2006), which both in the experiments conducted in GA as reported by Rowland *et al.* (2006) and those of the current South Carolina dataset conducted from 1998 to 2008, relative optimal economic value of Georgia Green developed prior to 140 DAP. Thus, it is not surprising that the FPP of 2400Mills was greater than that of the empirically estimated thresholds for the longer maturity runners examined in the current work (Anco *et al.* 2023; Branch 2017; Tillman 2018, Tillman 2021). Conversely, the presence of a preponderance of terminal false negatives (n = 14, Fig 3B) corresponding to the OBB75 criterion is a clear reflection of the lack of corresponding pod OBB coloration to the same degree as traditional cultivars such as Florunner from which the OBB75 criterion was first developed (Boote 1982), which is likewise supported by the lower total pod production potential of Florunner compared to modern cultivars.

Corroborating genotypic differences in amounts of mesocarp development, runner cultivars Georgia Green, Georgia 03L, ViruGuard, and AT 215 each exhibited OBB >75% from experiments conducted in South Carolina from 2006 to 2008 (caDD = 1875 to 2132, i.e., less than those in Table 1), with several instances of OBB > 80%. Similar to that of the cost of a false positive, criteria with greater FNP exhibited a greater range of the cost of an individual false negative (i.e., digging days delayed following the initiation of the period of relative optimal economic value) and a greater potential for increasingly costly false negatives. When the criterion with the least, non-undefined FNP, 2300 caDD, generated a false negative, this represented a delay of approximately 7 days. Digging delays from false negatives from the environmental predictor with the greatest FNP, 2400 caDD, ranged from 6 to 21 days. Apart from OBB75 (n = 14), terminal negatives were only otherwise associated with the 55_50 criterion (n = 3) during 2019 when OBB pod maturity did not surpass 51% (Table 3). When the 55_50 criterion (examples of which that would be above threshold are shown in Fig 4) was supplemented with the evaluation of the daily change in OBB between sequential assessments (55_50_delta), terminal false negatives were no longer predicted, and the median delay was reduced from 11 to 7 days. This illustrated the utility of monitoring OBB progression across sampling dates in the presence of adverse weather and growing conditions to identify when maturity development tapers off, at which point its slope reflects having entered the window of relative optimal economic value. Similar to variation in criteria performance related to cultivar differences (i.e., those with which criteria development took place), environmental differences exist among reported locations. To illustrate this, average cumulative degree days (i.e., excluding precipitation) from 1 May to 30 Sep from 2010 to 2020 fairly near to Dawson, GA (Rowland et al. 2006) in Macon, GA was ~2077 but was only 88% of this (~1831) in Blackville, SC. The importance of verifying model performance in different environments or as applied to new cultivars prior to implementation has previously been declared (Bell and Wright 1998; Boote 1982; Mills 1964; Mozingo et al. 1991). Accordingly, while the 55_50_delta method examined in the present study exhibited better overall performance compared to other examined criteria, further work would need to be conducted before its use could be recommended for cultivars not considered in the present work or for peanut grown in different production regions.

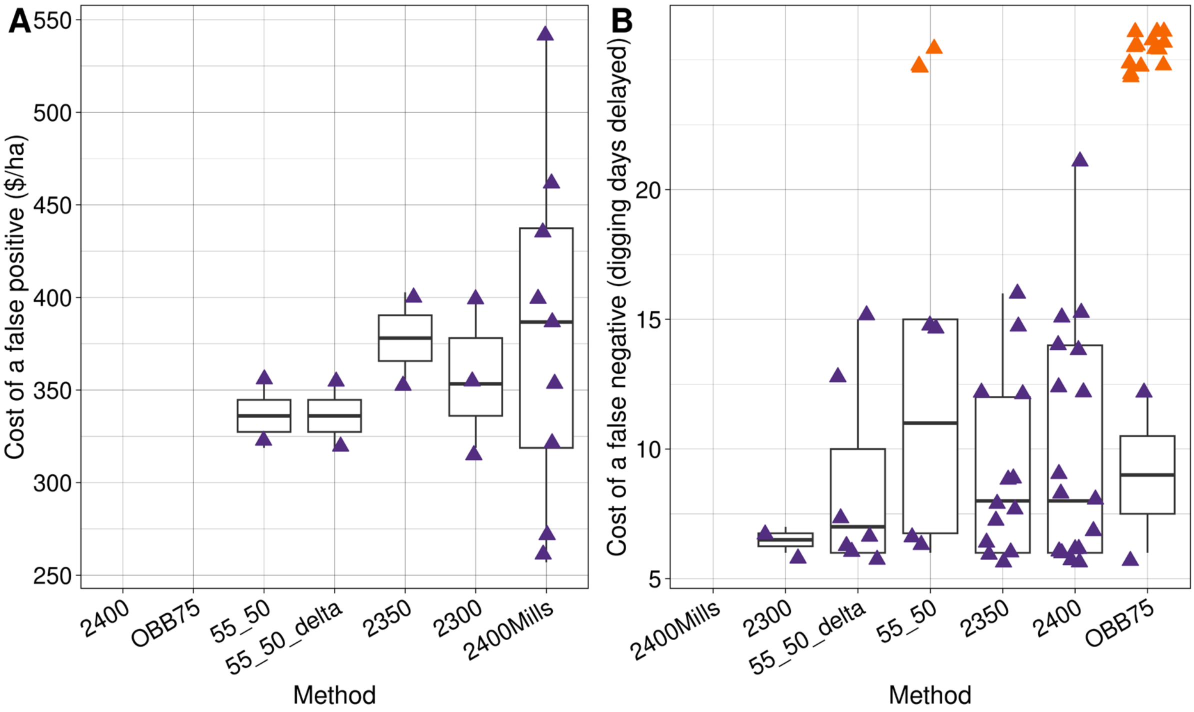

Figure 3. (A) Cost of a false positive ($/ha) associated with different threshold criteria for determining harvest maturity of runner peanut in South Carolina, and (B) cost of a false negative (in days delayed following the initiation of the period of relative optimal economic value) associated with different threshold criteria for determining harvest maturity of runner peanut in South Carolina. Orange triangles represent cultivar-year instances where a criterion's threshold level was not satisfied.

Figure 4. Pod mesocarp samples from (A) FloRun 331 with 61% OBB, (B) Georgia-16HO with 64% OBB, and (C) TUFRunner 297 with 59% OBB. OBB = orange, brown, or black pod mesocarps.

SUMMARY AND CONCLUSIONS

Though runner cultivars examined in the current work may take longer to mature compared to prior cultivars and exhibit different extents of maturity development compared to historical standards, they continue to represent an economic advantage compared to prior cultivar standards (Anco and Hiers 2022). Based on its greater performance and ability to determine periods of relative optimal economic value across years, the 55_50_delta method is recommended for use with FloRun 331, Georgia-16HO, and TUFRunner 297 in South Carolina. Results from the current study are anticipated to afford farmers greater flexibility in scheduling digging times for applicable fields while preserving corresponding economic value.

ACKNOWLEDGMENTS

Gratitude is extended to James Thomas for technical assistance in establishing and maintaining plots. Support for research was provided by the South Carolina Peanut Board, National Peanut Board, and Georgia Seed Foundation. Technical Contribution No. 7177 of the Clemson University Experiment Station. This material is based upon work supported by NIFA/USDA, under project number SC-1700592.

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