Peanut Response to Seeding Density and Digging Date in the Virginia-Carolina Region

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ABSTRACT

Large-seeded virginia market type peanut (*Arachis hypogaea* L.) cultivars are common in Virginia and North Carolina, but cost more to plant than runner market type peanut cultivars when the goal is to establish the same plant population. Decreasing seeding density could help growers to reduce production costs, as long as thinner stands do not negatively impact yield and economic return. Selecting the optimum digging time is a decision that could significantly influence growers' production and economics. Field experiments were conducted in Virginia and North Carolina at four site-year environments in 2016 and 2017 to examine the influence of seeding density (109, 143, 180, and 200 thousand seeds/ha) and digging date (130, 140, and 150 days after planting [DAP]) on virginia type peanut cultivar (Bailey, Sullivan, Wynne) performance. Regardless of cultivar and digging date, the greatest pod yield (5930 kg/ha) was achieved from the 200 thousand seeds/ha density, but the 143 thousand seeds/ha density had the highest economic return ($2990/ha). At three of the four site-years, the 140 DAP digging date, i.e. 1400 to 1600 C growing degree days (GDD), produced the greatest pod yield (5470 kg/ha) and had the highest economic return ($2750/ha). While individual site-years should be monitored for digging date, growers should be prepared to dig the currently available cultivars from 1400 to no more than 1600 C accumulated GDD.

Key Words: peanut, digging date, growth degree days

Large seeded virginia type peanut is the preferred market type grown in the Virginia-Carolina (VC) region. The price of certified seed is approximately $2.05/kg making the cost of $277/ha, a significant input cost when planting the recommended seed density of 140 kg/ha or 200 thousand seeds/ha (Jordan *et al*., 2018). Research conducted in Virginia, on virginia type peanut, in the 1980's indicated that higher seeding density (215 thousand seeds/ha) produced significantly ($P<0.01$) higher yield and economic value than lower seeding density (144 thousand seeds/ha) (Mozingo and Coffelt, 1984). Similarly, studies on runner type peanut had positive relationships between seeding density and pod yield. For example, when increasing seeding density from 10 to 20 seeds/m, Sorenson *et al*. (2004) reported 8.5% pod yield increase and Sconyers *et al*. (2007) showed 16% higher yields when planting 22.6 seeds/m compared to 12.5 seeds/m. Sarver *et al*. (2016) reported that increasing seeding density from 3.3 plants/m to 13.1 plants/m increased pod yield from 5200 kg/ha to 6500 kg/ha, and decreased *Tomato spotted wilt virus* (genus *Tospovirus*; family *Bunyaviridae*) (TSWV).

Peanut yield response to seeding density is cultivar dependent in many crops including corn (*Zea mays* L.) (Nafziger, 1994), soybean [*Glycine max* (L.) Merr.] (Buerlein, 1988), and peanut (Sullivan, 1991). The new available virginia type cultivars showed improved yield, i.e. in Virginia, average state yield during the 1980's was 2976 kg/ha and during the last decade 4560 kg/ha, (USDA, 2019); and biomass (Simmons, personal communication) than the old cultivars. Therefore, to produce optimally, the new cultivars may require more nutrients and water, which could be supplied at no additional costs by decreasing plant population to make more resources available to individual plants. If newly released cultivars can produce similar yields with less plants per hectare, reducing the seeding density could greatly lower the cost incurred by growers in the Virginia-Carolina region.

Due to the indeterminate growth habit and the effect of weather on plant development, i.e., dry seasons delay while hot summers rush maturity, determining the optimum digging date is essential for maximizing yield, quality, and the economic return. Jordan *et al*. (2003) showed that digging within the optimum harvest maturity window (Williams and Drexler, 1981) did not affect yield or grade. Literature has consistently reported, however, that digging either too early or too late

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Table 1. Planting and digging dates for three Virginia type peanut cultivars, and corresponding days after planting (DAP), by year and location.

			Digging Dates		
Year	Location	Planting Date	130 DAP	140 DAP	150 DAP
2016	Suffolk	5/19	9/26	10/6	10/16
	Lewiston-Woodville	5/16	9/18	9/29	10/10
2017	Suffolk	5/8	9/15	9/25	10/5
	Lewiston-Woodville	5/18	9/19	9/30	10/14

produced negative effects on peanut yield and quality (Mozingo *et al*., 1991; Wright and Porter, 1991; Jordan *et al*., 1998). For example, digging peanut two wk early reduced yield by 15% (Wright and Porter, 1991); and delayed digging caused decrease to both pod yield and gross value, with economic loss as high as $500/ha (Mozingo *et al*., 1991; Jordan *et al*., 1998). However, in North Carolina, early maturing cultivars responded differently to digging with some being more stable in terms of yield and economic value over digging dates than others (Jordan *et al*., 1998). Research is limited with respect to defining response to digging date of more recently released virginia market type cultivars. Generally, virginia market types require 135 to 155 DAP to reach maturity, while runners may need over 155 DAP (Balota *et al.,* 2018).

The objective of this research was to determine the effect of seeding density and digging date on yield, market grade characteristics, and economic return of more recently released virginia market type peanut cultivars.

Materials and Methods

Experimental Site and Design

Field studies were conducted at four site-yr in 2016 and 2017 at the Tidewater Agricultural Research and Extension Center in Suffolk, VA (36.665828^0 N, -76.729294^0 W), and the Peanut Belt Research Station in Lewiston-Woodville, NC (36.132204^0 N, -77.169082^0 W). In 2016, experiments at Suffolk were conducted on a Suffolk loamy sand (Fine-loamy, siliceous, semiactive, thermic Typic Hapludults), while soils at Lewiston-Woodville were on Norfolk sandy loam (Fine-loamy, kaolinitic, thermic Typic Kandiudults). In 2017, experiments at Suffolk were conducted on Eunola loamy fine sand (Fine-loamy, siliceous, semiactive, thermic Aquic Hapludults) while at Lewiston-Woodville the experiment was conducted on the same Norfolk sandy loam soil. These soils are representative of soils across the region where peanut is grown. Plot size was 2 rows (91-cm spacing) by 10.7 m in length. Peanut was planted in conventionally-tilled, raised seedbeds in both years of the experiment. Agronomic and pest management practices other than the specific treatments compared in these experiments were administered uniformly across the entire test area based on Cooperative Extension recommendations for North Carolina and Virginia (Balota *et al*., 2018; Jordan *et al*., 2018).

The experimental design was a split-factorial plot arranged in a randomized complete block design with four replications. The main plots were the digging dates including early (130 DAP), physiological maturity (140 DAP), and late (150 DAP) digging. Sub-plots consisted of a factorial arrangement of seeding densities (109, 143, 180, and 200 thousand seeds/ha) and cultivars (Bailey, Sullivan, and Wynne). Plots were planted using a two-row Cole planter on May 19 in Suffolk and on May 16 in Lewiston-Woodville in 2016, and on May 8 in Suffolk and on May 18 in Lewiston-Woodville in 2017. All pertinent information on planting and digging dates are provided in Table 1. Air temperature and precipitation were recorded at each site-year within less than a mile from the plots, and used to calculate the growing degree days (GDD); GDD and precipitation are presented in Table 2. Cumulative GDD [$GDD = T_{avg} - T_{base}$] was calculated using 13 C as the base temperature, i.e. temperature below which growth ceases. T_{avg} is the average daily temperature. (Balota *et al.,* 2018).

Yield and Grade Measurements

Harvest was conducted approximately seven to ten d after digging. Pod yield was determined from the plot weight adjusted to 7% moisture and percent foreign material in a 500 g subsample. The same sub-sample was used for grade evaluations. First, fancy pod percentage, pods that do not pass 13.5 mm × 76.2 mm spacing set on the pre-sizer, was determined. Then, pods were shelled and kernels were sorted by size including extra-large kernels (ELK), kernels passing the larger screen but did not pass a 25.4 mm (1-in) × 8.5 mm (21.5/64) screen; mediums, kernels passing the larger screens but did not pass a 25.4 mm × 7.1 mm (18/64-in)

Table 2. Cumulative rainfall and growing degree days (GDD)[a] by year and location for the growing cycles of 130, 140, and 150 days after planting (DAP).

		Rainfall			Growing degree days		
		mm			°C		
Year	Location	130 DAP	140 DAP	150 DAP	130 DAP	140 DAP	150 DAP
2016	Suffolk	917	935	1252	1475	1555	1583
	Lewiston-Woodville	559	808	1110	1491	1600	1675
2017	Suffolk	633	634	644	1303	1399	1458
	Lewiston-Woodville	561	589	604	1392	1495	1607

[a]Cumulative GDD [GDD= $T_{avg} - T_{base}$ (T_{base}: 13 C)] was calculated using 13 C as the base temperature, i.e. temperature below which growth ceases.

screen; and number 1's, kernels passing the larger screens but did not pass a 25.4 mm × 5.9 mm (15/64-in) screen. Lastly, percent of sound mature kernels (SMK) was determined as the sum of ELK, mediums and number 1's. (USDA, 2019). Farmer stock grade characteristics were used to calculate the crop economic value ($/ha) using the USDA Agricultural Marketing Service approach (USDA, 2019).

Statistical and Economic Analysis

The PROC Mixed procedure in SAS (SAS Institute, 2012) was used to determine if there were differences between site-year, seeding density, digging date, cultivar, and their interactions. Block was considered a random effect. When treatment effects were significant ($p \leq 0.05$), predicted means for each treatment were obtained and a post hoc comparison was done. Fischer's protected least significant difference (LSD) was used to separate the means.

To determine which seeding density was the most economical, a cost analysis was performed. Seed weight (kg/ha) was calculated for each individual seeding density. Since there was no interaction with cultivar, seed weight was averaged across the three cultivars. Seed price was $0.38/kg (Jordan *et al.*, 2018). Total cost of seed/ha was calculated using [1].

$$\text{Total seed cost } (\$/\text{ha}) = \text{kg seed/ha} \times \text{seed price } (\$/\text{kg}) \quad [1]$$

Gross return ($/ha) was also calculated for each seeding density using a selling price of $0.09/ha (Jordan *et al.*, 2018).

$$\text{Gross return } (\$/\text{ha}) = \text{Yield (kg/ha)} \times \text{ selling price } (\$/\text{kg/ha}) \quad [2]$$

Economic return for seeding density was calculated by subtracting the total seed cost from the gross return, and it was used to determine which seeding density was most profitable. A sensitivity analysis was performed in which the selling price was increased in increments of 10% until the highest yielding seeding density produced the highest economic return. In addition, we decreased seed cost in increments of 10% until the highest yielding seeding density produced the highest economic return. Finally, the seed cost was dropped simultaneously with increasing price until the highest yielding seeding density produced the highest economic return.

Results and Discussion

Weather Conditions

Peanut requires at least 600 mm precipitation from planting to physiological maturity (Rowland *et al.*, 2012); and this standard was achieved in both years of this experiment. In 2016, peanuts received 917 mm cumulative precipitation from planting to 130 DAP in mid-Sep and 34% additional precipitation before dig at 150 DAP in mid-Oct, in Suffolk (Table 2). A similar precipitation pattern was recorded at Lewiston and, in both locations, the amount of rainfall received from mid-May to mid-Oct exceeded by 70% the 30-yr average precipitation of 685 mm in Suffolk and 691 mm in Lewiston-Woodville. Year 2017 was, however, close to normal and cumulative precipitation from planting to first dig (130 DAP) was 633 mm in Suffolk and 561 in Lewiston-Woodville; then cumulative precipitation slowly increased at both locations but not more than 644 mm in Suffolk and 604 mm in Lewiston-Woodville in mid-Oct.

Peanut is known to require 2200 GDD from planting to physiological maturity, but new cultivars are increasingly earlier maturing than older cultivars. For example, virginia market type cultivars developed at the turn of the century needed 1800 GDD to mature, in comparison with

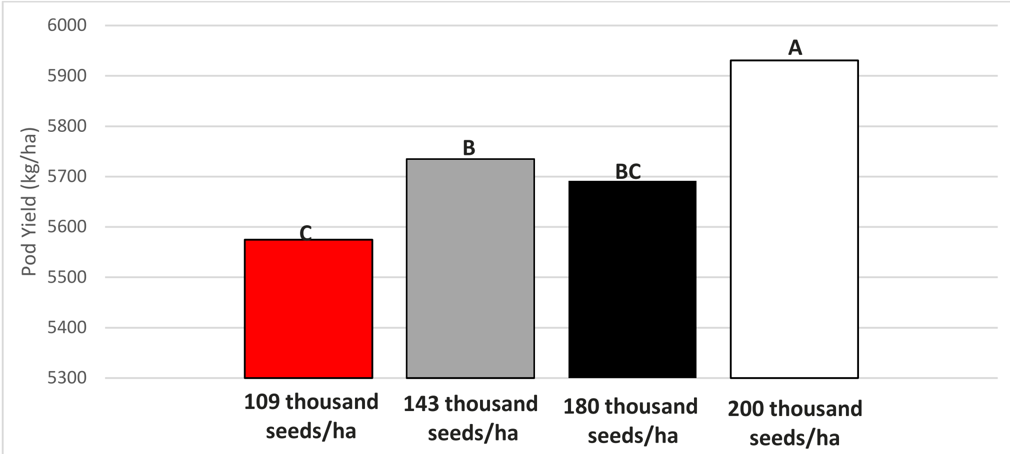

Fig. 1. Peanut pod yield response to seeding density across all site-years, cultivars and digging dates. Means with the same letter are not significantly different from each other according to Fisher's protected LSD test at P ≤ 0.05.

2500 GDD needed by cultivars developed prior to that (Balota and Phipps, 2013; Caliskan *et al*., 2008; Jordan *et al*., 2018). The cultivars included in this work included Bailey, released in 2008, (Isleib *et al.,* 2011); and Sullivan and Wynne released in 2013 (North Carolina Crop Improvement Association, 2020). They are among the most recent cultivars currently in production in the VC region and have optimum maturity at around 140 DAP (Balota *et al*., 2018; Jordan *et al*., 2018). Recorded GDD at 140 DAP was 1578 GDD in average of the two locations in 2016 and 1447 GDD in 2017 (Table 2). Even though more humid than 2017, 2016 was 2 to 3 C warmer in Aug and Sep than same months in 2016. The 30-year GDD average for both locations from 1 May through 30 Oct is 2400 GDD.

Pod Yield

Main effect of site-year, cultivar, seeding density and digging date, and the interaction of site-year × digging date × cultivar were significant for pod yield at $p<0.05$ (Table 3). Because seeding density main effect was significant but none of the interactions of seeding density with the other factors were, the data for seeding density were combined for site-years, cultivars, and digging dates. Unlike in other reports (Sullivan, 1991), the cultivars used in this study responded similarly to the increase of seeding density. The highest seeding density of 200 thousand seeds/ha produced the highest pod yield, 5930 kg/ha (Figure 1). There was no significant difference between the densities of 180 thousand seeds/ha and 143 thousand seeds/ha, as they yielded 5740 kg/ha and 5690 kg/ha, respectively. The 109 thousand seeds/ha density yielded the lowest at 5580 kg/ha. The current seeding density recommendations in Virginia are for 109 thousand to 143 thousand plants/ha (Balota *et al.,* 2018).

At Suffolk in 2016, among the three cultivars, there was no significant difference for pod yield between the 130 and 140 DAP digging dates, i.e. cultivar average was 4900 kg/ha for 130 DAP and 5090 kg/ha for 140 DAP; but the 150 DAP digging date had the lowest pod yield for all cultivars, 3890 kg/ha (Table 4). The cumulative GDD was 1475

Table 3. Analysis of variance for peanut pod yield, economic value, percentage of extra-large kernels (ELK), sound mature kernels (SMK), and fancy pods.

Source	df	Pod Yield	Economic Value	ELK	SMK	Fancy Pods
Site-year	3	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar	2	<.0001	<.0001	0.0001	<.0001	<.0001
Seeding Density	3	<.0001	<.0001	0.6551	0.2765	0.7127
Digging Date	2	<.0001	<.0001	<.0001	<.0001	<.0001
Cultivar*Seeding Density	6	0.4320	0.6039	0.8344	0.4613	0.9606
Digging Date*Cultivar	4	0.0683	0.0755	0.0148	0.9477	0.0632
Digging Date*Seeding Density	6	0.9860	0.9604	0.9984	0.9428	0.2825
Digging Date*Cultivar*Seeding Density	12	0.8892	0.9354	0.9970	0.0705	0.8179
Site-year*Digging Date*Cultivar	24	<.0001	<.0001	<0.1262	<.0001	<.0001

Table 4. Effect of site-year, digging date, and cultivar on pod yield.

	Pod Yield (kg ha^{-1})											
	Suffolk 2016			Suffolk 2017			Lewiston 2016			Lewiston 2017		
Cultivar	130 DAP (1475 GDD)	140 DAP (1555 GDD)	150 DAP (1583 GDD)	130 DAP (1303 GDD)	140 DAP (1399 GDD)	150 DAP (1458 GDD)	130 DAP (1491 GDD)	140 DAP (1600 GDD)	150 DAP (1675 GDD)	130 DAP (1392 GDD)	140 DAP (1495 GDD)	150 DAP (1607 GDD)
Bailey	5290a[a]	5410a	4710b	6240b	8900a	9150a	4620b	5400a	4260b	4620b	5900a	5880a
Sullivan	5010a	5190a	3080b	5890b	8430a	9240a	4680b	5770a	4720b	4600c	5940a	5160b
Wynne	4410a	4470a	3880b	5950b	8110a	8680a	4710b	5530a	4250b	4940b	5640a	4990b

[a]Letters show the difference between digging dates within each cultivar and site-year; means sharing the same letter(s) are not statistically different, at P=0.05 based on the Fisher's protected LSD test

GDD at 130 DAP, 1555 GDD at 140 DAP and 1583 GDD at 150 DAP digging dates. Small GDD differences between digging times cannot explain lower yield at 150 DAP compared with earlier digs, but rather heavy precipitation in Oct could have caused yield reduction when waiting 150 days to dig. In 2017, digging at 130 DAP when only 1303 C GDD were accumulated caused significant yield reduction for all cultivars, cultivar average yield was 6030 kg/ha. Instead, pod yield increased significantly when dig was performed at 140 DAP (~1400 GDD) and even more when digging was performed at 150 DAP with the crop having available 1458 GDD, i.e. cultivar average was 8480 kg/ha when dug at 140 DAP and 9020 kg/ha when dug at 150 DAP. Yield data in both years suggested that optimum digging date for Suffolk, VA, is between 140 and 150 DAP, when a min of 1500 GDD are achieved and in absence of heavy precipitation close to or at digging time.

At Lewiston-Woodville in 2016, the 140 DAP digging date produced significantly greater pod yield for all three varieties than 130 and 150 DAP digging dates (Table 4). The least average yield, 4400 kg/ha, was for the last dig and, as in the case of Suffolk, this was mostly related with the heavy precipitation recorded in October 2016. In 2017, digging at 130 DAP or less than 1400 GDD resulted in yield decrease for all cultivars (Table 4). Cultivar Bailey produced similar pod yield at 140 DAP and 150 DAP digging dates, in average 5890 kg/ha, while for Sullivan and Wynne digging when 1495 GDD were accumulated ensured the highest yields in comparison with digging at 130 DAP or 150 DAP when less than 1400 GDD or more than 1600 GDD were recorded.

Market Grade Characteristics and Gross Economic Value

For grade characteristics, ELK, SMK, and fancy pods, main effects were significant for site-year, cultivar and digging date, but not for the seeding density. With the exception of digging date × cultivar for the ELK and site-year × digging date × cultivar interaction for all grades, the other interactions were not significant (Table 3). This indicates that regardless of cultivar and digging time, seeding density may have no effect on peanut grade; unlike for site-year, cultivar, and digging date that could significantly affect grade, resulting in differences for yield and economic value. For example, Sullivan produced the largest ELK percentage only when pods were dug at 140 DAP or between 1400 and 1600 GDD (Tables 2 and 5). For Bailey and Wynne, extending digging from 140 to 150 DAP did not result in ELK reduction; but

Table 5. Effect of digging date and peanut cultivar on extra-large kernels (ELK).

Cultivar	ELK (%)		
	130 DAP	140 DAP	150 DAP
Bailey	36c[a]	48a	48a
Sullivan	38b	50a	47b
Wynne	40b	50a	49a

[a]Letters show the difference between digging dates within each cultivar; means sharing the same letter(s) are not statistically different, at P=0.05 based on the Fisher's protected LSD test.

digging too early, 130 DAP, produced significantly less ELK for both cultivars regardless the site-year.

Similarly, digging at 140 DAP resulted in the highest SMK for all three varieties at Suffolk in 2016 and Lewiston in 2017; but in other site-years, SMK was cultivar dependent (Table 6). Among cultivars, Bailey was less sensitive to the digging date; unlike for Sullivan and Wynne producing the highest SMK at the 150 DAP dig date. Nonetheless, data in Table 6 suggest that, unless there is a rainy end of the season. SMK production requires a minimum of 1500 GDD and longer time from planting to dig.

While ELK and SMK are major grade factors in calculation of the gross economic return, fancy pod content is not. However, for in-shell product commercialization, fancy pod content is important. Interestingly, and unlike for the ELK and SMK, fancy pods were highest when digging early, at 130 DAP, compared with later digs (Table 7). For this, it seems to be an inverse relationship between kernel and pod size, with immature pods, e.g. pods harvested early, containing higher amounts of water than mature pods when freshly dug. This characteristic is probably not maintained months after harvest and certainly will be lost through pod cooking of the in-shell products.

ANOVA for the economic value followed a similar pattern with pod yield, with main effect of site-year, cultivar, seeding density and digging date, and the interaction of site-year × digging date × cultivar being significant at $p<0.05$ (Table 3). Results were mixed depending on the site-year and digging date (Table 8); but clearly the rainy year 2016, which affected yield and at some extent grade factors, produced the lower revenue at both sites. In 2017, greatest economic value was for crops dug at 140 and 150 DAP, and this is agreement with yield and SMK observations.

Economic Analysis for Seeding Density

This study showed that the highest seeding density of 200 thousand seeds ha^{-1} produced the highest yield (Figure 1); and this is consistent with

Table 6. Effect of site-year, digging date, and peanut cultivar on sound mature kernels (SMK).

Cultivar	SMK (%)											
	Suffolk 2016			Suffolk 2017			Lewiston 2016			Lewiston 2017		
	130 DAP (1475 GDD)	140 DAP (1555 GDD)	150 DAP (1583 GDD)	130 DAP (1303 GDD)	140 DAP (1399 GDD)	150 DAP (1458 GDD)	130 DAP (1461 GDD)	140 DAP (1600 GDD)	150 DAP (1675 GDD)	130 DAP (1392 GDD)	140 DAP (1495 GDD)	150 DAP (1607 GDD)
Bailey	63b[a]	65a	64ab	66a	67a	68a	66b	67a	68a	65b	68a	67b
Sullivan	61b	63a	59c	62b	65b	67a	65b	66ab	67a	64b	66a	64b
Wynne	59b	61a	59b	64b	66ab	68a	66b	67a	67a	65b	66a	65b

[a] Letters show the difference between digging dates within each cultivar and site-year; means sharing the same letter(s) are not statistically different, at P=0.05 based on the Fisher's protected LSD test.

Table 7. Effect of site-year, digging date, and peanut cultivar on percentage of fancy pods.

	Fancy Pods (%)											
	Suffolk 2016			Suffolk 2017			Lewiston 2016			Lewiston 2017		
Cultivar	130 DAP (1475 GDD)	140 DAP (1555 GDD)	150 DAP (1583 GDD)	130 DAP (1303 GDD)	140 DAP (1399 GDD)	150 DAP (1458 GDD)	130 DAP (1491 GDD)	140 DAP (1600 GDD)	150 DAP (1675 GDD)	130 DAP (1392 GDD)	140 DAP (1495 GDD)	150 DAP (1607 GDD)
Bailey	93a[a]	88b	93a	94a	88b	88b	90a	86b	81c	93a	87b	93a
Sullivan	92a	89b	92a	95a	92b	91b	90a	86b	85b	92a	89b	92a
Wynne	96a	92b	96a	98a	95b	93c	94a	91b	83c	96a	92b	96a

[a]Letters show the difference between digging dates within each cultivar and site-year; means sharing the same letter(s) are not statistically different, at P=0.05 based on the Fisher's protected LSD test.

Table 8. Effect of site-year, digging date, and peanut cultivar on peanut economic value.

	Economic value ($ ha^{-1})											
	Suffolk 2016			Suffolk 2017			Lewiston 2016			Lewiston 2017		
Cultivar	130 DAP (1475 GDD)	140 DAP (1555 GDD)	150 DAP (1583 GDD)	130 DAP (1303 GDD)	140 DAP (1399 GDD)	150 DAP (1458 GDD)	130 DAP (1491 GDD)	140 DAP (1600 GDD)	150 DAP (1675 GDD	130 DAP (1392 GDD)	140 DAP (1495 GDD)	150 DAP (1607 GDD)
Bailey	1977ab[a]	2098a	1807b	2337c	3537b	3763a	1866a	2289a	1826ab	1871b	2578a	2059a
Sullivan	1834a	1966a	1478b	2114c	3271b	3758a	1884a	2472a	2034a	1800c	2624a	2319b
Wynne	1557a	1625a	1341b	2188c	3168b	3550a	1876a	2342a	1733b	2057b	2466a	2407a

[a]Letters show the difference between digging dates within each cultivar and site-year; means sharing the same letter(s) are not statistically different, at P=0.05 based on the Fisher's protected LSD test.

Table 9. Economic return for seeding density in peanut. Seed cost represents the cost to the grower, and yield price is the selling price after harvest from Jordan et al., 2018.

Seeding Density (seeds ha^{-1})	Seeding Density (kg ha^{-1})	Seed Cost (\$ kg^{-1})	Total Cost (\$ ha^{-1})	Yield (kg ha^{-1})	Yield Price (\$ kg^{-1})	Return (\$ ha^{-1})	Seeding Density Economic Return (\$ ha^{-1})
109000	95	2.3	218.5	5575c	0.57	3178b	2959a
143000	121	2.3	279.1	5735b	0.57	3269b	2990a
180000	152	2.3	349.6	5691bc	0.57	3244b	2894a
200000	183	2.3	420.1	5931a	0.57	3381a	2961a

what is documented in the literature (Mozingo and Coffelt, 1984; Sorenson *et al*., 2004; Sconyers *et al*., 2007). In order to determine if the 200 thousand seeds/ha density was also the most economical, a cost analysis was performed. Seed weight (kg/ha) was calculated for each individual seeding density and, because there was no interaction between seeding density and cultivar, data were averaged across the three cultivars. Due to increased cost from seed purchase to achieve the highest seeding density, the 200 thousand seeds/ha density did not produce the highest economic return, even though it produced the highest yield (Figure 1). Instead, there was no statistical difference for economic return among the four seeding rates, even though the yields were significantly different (Table 9). The 143 thousand seeds/ha density had the greatest economic return ($2990/ha) numerically, even though it yielded significantly lower than the 200 thousand seeds/ha seeding density (Table 9). This agrees with the current recommendations for peanut seeding density in Virginia (Balota et al., 2018). In order to determine what combination of selling price and seed cost would have ensured the highest economic returned from seeding 200 thousand seeds/ha, a sensitivity analysis was further used. This analysis indicated that either 40% increase in the selling price; 30% decrease in seed cost; or a combination of 20% increase in selling price with a 20% decrease in seed cost could have resulted in the 200 thousand seeds/ha density to have the highest economic return. As such changes in the seed cost and selling price are less probable, the current recommendations for using less seed per hectare at planting, i.e., 143 thousand seeds/ha, seems to be justified for a balanced farm budget.

Summary and Conclusions

Our results indicated that increasing the seeding density from 109 thousand seeds/ha to 200 thousand seeds/ha increased the pod yield across all site-years, similarly for all cultivars. However, the seeding density producing the highest yield did not result in the highest economic return, as the increase in yield was not enough to compensate for the increased seed cost. Instead, the 143 thousand seeds/ha seeding density ensured the greatest economic return for the farmer; this agrees with the current recommendations for peanut production in Virginia. According to our results, the optimal time to dig the Virginia market type peanut cultivars currently grown in the VC region is at 140 DAP. This is because these cultivars appear to need at least 1400 GDD and no more than 1600 cumulative GDD to reach optimum maturity and, therefore, maximum pod yield. However, the decision on when to dig should be monitored on a field-to-field basis as not just temperature, but other factors may affect yield, such as the amount of precipitation at or right before digging.

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