Article

Effect of Digging Date on Yield Performance of Four Market Types of Peanut (*Arachis hypogaea* L.)

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ABSTRACT

Peanut (*Arachis hypogaea* L.) is an important legume crop valued for its high protein and oil content. Its indeterminate growth and belowground pod development result in variable pod maturity. Variation in maturity makes digging date an important management factor for peanut production across market types. This study evaluated the effects of digging date on yield, grade, and maturity-related traits in 18 accessions representing Runner, Virginia, Spanish, and Valencia market types during 2024 and 2025 in Portales, New Mexico, USA. Accessions were evaluated at approximately 130 and 150 days after planting. Statistical analysis revealed a significant effect of digging date on pod yield and related yield traits ($p < 0.001$). The second digging resulted in higher pod yield across all four market types, with the magnitude of the response varying by market type and genotype. Virginia exhibited the greatest yield loss due to early digging (12.1% in 2024; 12.3% in 2025), followed by Runner (9.3%; 8.0%), Spanish (5.8%; 4.0%), and Valencia (3.2%; 4.6%). The consistent response across years indicates greater sensitivity to early digging in Virginia and Runner types, whereas Spanish and Valencia types exhibited less pronounced responses. These findings support market type-specific digging strategies, with digging at approximately 150 days favoring Runner and Virginia types, while earlier digging at around 130 days is suitable for Spanish and Valencia types. These findings can help growers select genotypes based on environments and desired harvest windows.

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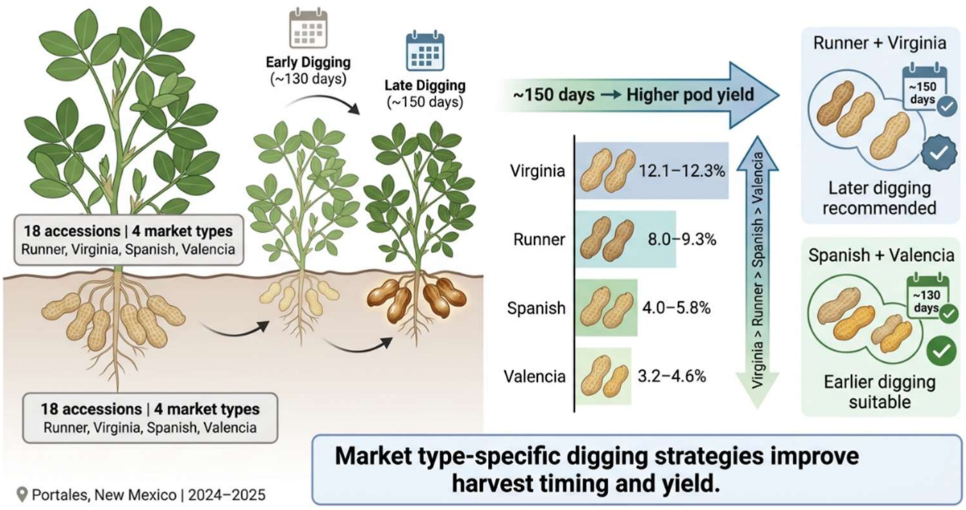
KEYWORDS: digging; harvesting; market types; peanut; yield; maturity; yield loss



Graphical Abstract

INTRODUCTION

Peanut (*Arachis hypogaea* L.) is an important legume crop cultivated primarily for human consumption because of its high nutritional value and desirable sensory properties. In 2025, United States peanut production reached a record 7.18 billion pounds from 1.91 million harvested acres, with an average yield of 3767 pounds per acre [1]. Peanut production in the United States is concentrated in three major regions: the Southeast (Florida, Georgia, Alabama, and Mississippi), Virginia and the Carolinas, and the Southwest (Arkansas, Oklahoma, Texas, and New Mexico). Regional preferences for peanut market types (Runner, Virginia, Spanish and Valencia) are largely shaped by environmental adaptation and market demand. In the southwestern United States, particularly eastern New Mexico, Valencia peanuts are the predominant market class due to their early maturity and suitability for the region's relatively short growing season. Most Valencia peanut production in the United States is concentrated within a 100-mile radius of Portales, New Mexico, where warm temperatures, low humidity, and well-drained sandy soils provide highly favorable conditions for cultivation. Valencia cultivars have adapted well to these climatic and edaphic conditions, contributing to their widespread adoption and economic importance in the region. The Runner type dominates national production and is mainly used for peanut butter, while the large-seeded Virginia type is marketed as in-shell or snack peanuts. Spanish and Valencia types are less common and primarily used for snacks, confections, and roasting in-shell [2].

The Runner and Virginia market types belong to the subspecies *hypogaea*, whereas the Spanish and Valencia types fall under *fastigiata* [3]. These subspecies differ markedly in morphology, growth habit, and agronomic traits. *Hypogaea* types have a spreading growth habit and larger seeds, while *fastigiata* types are erect with smaller seeds and flower on the mainstem in a sequential pattern [4]. Maturity duration also differentiates them. *Fastigiata* matures in approximately 90–120 days, making it suitable for short-season environments, whereas *hypogaea* requires 130–170 days and performs best in long-season or irrigated conditions [3]. These differences in growth duration are closely linked to environmental influences, as seasonal conditions play a critical role in regulating peanut growth, pod development, and seed maturation [5,6]. The indeterminate growth habit and subterranean pod formation complicate determination of the optimal digging time [7]. Harvesting too early reduces yield and the proportion of sound mature kernels, whereas delayed digging increases pod loss due to weakened peg strength, particularly when digging occurs after a freeze [7]. Improper harvest timing has been reported to increase digging losses from approximately 8% to as high as 40%, and even a one-week deviation from the optimum can reduce yield by up to 560 kg ha^{-1} [8]. Therefore, accurate determination of the optimal digging time is essential to maximize yield, quality, and economic returns in peanut production [9].

Several approaches have been developed to assess peanut maturity and determine optimal digging time. These include counting days after planting, assessing internal hull and oil color, performing methanolic extraction (to measure internal chemical markers, such as sugars and maturity pigments), determining kernel density, calculating the seed-to-hull ratio, using arginine or physiological maturity indices, and applying growing degree day models [7]. The standard method involves scraping the hull and comparing mesocarp color to a reference profile board [7,9,10]. However, this technique was developed for mid-maturing cultivars (~140 days from planting to harvest) that are no longer widely cultivated. To date, no comprehensive study has evaluated all four peanut market types or assessed the influence of digging time on pod yield. Evaluating all four peanut market types within a single study provides a unique opportunity to assess genetic and phenotypic variation for digging time across the major cultivated classes of peanut because these market types differ in maturity duration, growth habit, and adaptation to diverse production environments. Therefore, this study evaluated the effects of different digging times on four market-type peanuts in New Mexico, USA.

MATERIALS AND METHODS

Plant Materials and Experimental Design

The study included eighteen peanut accessions, representing four market types: seven Runner, three Spanish, five Valencia, and three Virginia accessions (Table 1). These accessions represent diverse genetic backgrounds and market classes, including recently developed high-yielding breeding lines and improved varieties, thereby ensuring greater relevance to current breeding objectives and enhancing the practical applicability of the findings. The field experiment was conducted on a grower's farm in Portales, New Mexico, USA (34.146936° N, 103.148884° W), over two consecutive years (2024 and 2025). The soil at the Portales site was classified as sandy loam. The trials were laid out in a randomized complete block design (RCBD) with four replications. Separate plots were established for each genotype and digging date, with each genotype represented by four independent replications at each digging date. Each replication consisted of 4 m long double rows, with 75 cm between beds and 10 cm between double rows. Sowing was carried out on 14 May 2024 and 21 May 2025. Standard agronomic practices were followed throughout the growing seasons to minimize damage caused by insects, pests, and diseases, and irrigation was applied as needed. In both seasons, the first and second diggings were conducted at approximately 130 and 150 days after planting, respectively.

Table 1. List of peanut genotypes representing four market types and their origins.

Genotypes	Market Type	Origin/obtained from
ARSOK R109-1L	Runner	USDA-ARS, Oklahoma Breeding Program
Georgia-09B	Runner	University of Georgia [11]
TP200625-3-2	Runner	Texas A&M AgriLife
TX144370Ru	Runner	Texas A&M AgriLife
TxL100212-03-03	Runner	Texas A&M AgriLife
Span 17	Small-seeded runner	USDA-ARS, Oklahoma Breeding Program
ARSOK S58B	Small-seeded runner	USDA-ARS, Oklahoma Breeding Program
ARSOK S1042-E	Spanish	USDA-ARS, Oklahoma Breeding Program
Schubert	Spanish	Texas A&M AgriLife [12]
TP210656-2-1	Spanish	Texas A&M AgriLife
MO-1	Valencia	New Mexico State University
MO-2	Valencia	New Mexico State University
MO-3	Valencia	New Mexico State University
MO-4	Valencia	New Mexico State University
New Mexico Valencia C	Valencia	New Mexico State University [13]
ARSOK V99	Virginia	USDA-ARS and Oklahoma Breeding Program
Comrade	Virginia	USDA-ARS and North Carolina State University [14]
TP220694-5-1	Virginia	Texas A&M AgriLife

Data Collection

After harvesting, all pods were dried to approximately 7%–10% moisture content using a commercial dryer in Portales, New Mexico. Pod yield per plot was recorded and converted to kilograms per acre (kg/acre). A 500 g subsample of dried pods from each plot was graded for size using a "pre-sizer" following the procedure described by Martinez [15]. In this process, a clean sample is fed onto the pre-sizer rollers. As the pods move across the rollers, smaller pods (blue pan or No. 1 grade) pass through the upper portion, medium-sized pods (white pan or fancy grade) pass through the middle to lower portion, and larger pods (red pan or jumbo grade) are collected at the end and weighed. Based on USDA roller-spacing criteria, pods are categorized according to width as follows: blue pan pods are ≤13.5 mm (34/64''), white pan pods range from >13.5 to 15 mm (34/64''–38/64''), and red pan pods are ≥15 mm (38/64'') [15]. The graded pods were then shelled using a mechanical sheller and classified as sound mature kernels (SMK), splits (SPL; intact half-seeds) and other kernels (OK; immature or damaged). The SMK were further classified by size into extra-large, medium and No. 1 (small) kernels. Different grading screens were used for different market types; for example, an extra-large kernel (ELK) screen size of 21/64'' × 3/4'' was used for Spanish, Runner and Valencia types, and 21.5/64'' × 1'' for Virginia types. For No. 1 kernels, a 16/64'' screen was used for all market types. Additionally, a random sample of 100 cleaned seeds from each sample was taken and weighed.

Statistical Analysis

Mean values, percentage changes, and other descriptive statistic calculations were performed using Microsoft Excel (Microsoft 365 MSO, Version 2601). Three-way analysis of variance (ANOVA) was performed to evaluate the effects of genotype, digging date, and year on all measured traits using R (version 4.5.3; R Core Team, 2026) with the "*stats*" package. The percentage change was calculated as (D2 − D1)/D2 × 100, representing early-digging yield loss relative to second digging. Where D1 and D2 denote the trait values at the first and second digging dates, respectively. Correlation analysis was performed using the "*corrplot*" package in R.

RESULTS

Weather Conditions During Peanut Growing Seasons

During the peanut growing seasons, weather conditions varied between 2024 and 2025 (Table S1). The 2024 growing season was warmer, with a higher average temperature (74.7 °F) than in 2025 (71.9 °F), along with a higher maximum temperature (88.8 °F vs. 85.5 °F). In contrast, minimum temperatures remained relatively stable between years (58.0 °F–58.6 °F), indicating similar early- and late-season thermal conditions. Atmospheric moisture conditions differed substantially, with

2025 showing higher average dew point (51.1 °F) and relative humidity (54.5%) than 2024 (46.5 °F and 44.3%, respectively), suggesting a drier growing environment in 2024. Precipitation was notably greater during the 2025 growing season (12.3 inches) compared with 2024 (7.9 inches), indicating more favorable natural water availability in 2025. Overall, the 2024 season was characterized by warmer temperatures, lower humidity, and reduced rainfall, representing a relatively higher atmospheric and soil moisture stress environment that may have influenced peanut growth, physiological responses, and yield performance.

Sources of Variation Affecting Peanut Agronomic and Quality Traits

The three-way analysis of variance indicated that genotype was the major source of variation, significantly affecting all agronomic traits ($p < 0.001$) except small kernels (Table 2). Digging date significantly affected most traits ($p < 0.01$), whereas fancy pods and large pods were not significantly influenced. Year significantly affected small pods, fancy pods, large pods, sound mature kernels, other kernels, hull percentage, and yield per acre ($p < 0.05$). Among the interactions, genotype by digging date significantly affected splits, hull percentage, extra-large kernels, and medium kernels, genotype by year influenced fancy pods, large pods, small kernels, and yield per acre, and digging date by year affected fancy pods, large pods, splits, and other kernels. The three-way interaction of genotype, digging date, and year was significant for small pods, fancy pods, large pods, other kernels, and small kernels (Table 2). The average peanut yield under second digging was slightly higher in 2025 (4577 kg acre^{-1}) than in 2024 (4444 kg acre^{-1}), representing an increase of approximately 3%. Similarly, hundred seed weight increased from 66.8 g in 2024 to 67.3 g under second digging in 2025, indicating improved seed filling under the 2025 growing conditions.

Table 2. Three-way analysis of variance showing the effects of genotype, digging date, year, and their interactions on peanut traits.

Source of Variation	df	p values											
		SP	**FP**	**LP**	**SMK**	**SPL**	**OK**	**HU**	**ELK**	**MK**	**SK**	**HSW**	**Yield**
Genotypes	17	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	0.1901	**<0.001**	**<0.001**
Digging	1	**0.0037**	0.2856	0.8150	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Year	1	**0.0287**	**<0.001**	**<0.001**	**0.0040**	0.1021	**<0.001**	**0.0016**	0.7270	0.6690	0.0743	0.2000	**0.0119**
Genotypes × Digging	17	0.3513	0.0534	0.0690	0.1181	**<0.001**	0.0859	**0.0018**	**<0.001**	**<0.001**	0.0637	0.6230	0.8822
Genotypes × Year	17	0.1099	**<0.001**	**<0.001**	0.2905	0.7210	0.0717	0.1166	0.1120	0.1740	**<0.001**	0.1970	**<0.001**
Digging × Year	1	0.2433	**<0.001**	**<0.001**	0.5691	**0.0021**	**<0.001**	0.1659	0.1470	0.1090	0.2283	0.6920	0.8979
Genotypes × Digging × Year	17	**0.0234**	**<0.001**	**<0.001**	0.4970	0.7060	**0.0107**	0.1556	0.6290	0.6420	**0.0172**	0.6430	1.0000

Small pods (SP); Fancy pods (FP); Large pods (LP); Sound mature kernels (SMK); Splits (SPL); Other kernels (OK); Hull (%) (HU); Extra-large kernels (ELK); Medium kernels (MK); Small kernels (SK); Hundred-seed weight (HSW); Yield per acre (Yield); Degrees of freedom (df). Significant effects ($p < 0.05$) are highlighted in bold.

Effect of Digging Date on Grading

Pod and kernel grading were consistently influenced by digging date and market type across both years (Table 3). In 2024, delayed digging reduced small pods, other kernels, and hull percentage, and also reduced medium and small kernel fractions. Conversely, delayed digging increased fancy pods, large pods, sound mature kernels, and extra-large kernels, indicating improved pod maturity and kernel filling. However, split kernels increased substantially with delayed digging. The shift toward larger kernel sizes was associated with increases in hundred seed weight and yield per acre (Table 3).

Table 3. Mean values and effects of digging dates on yield and grading traits in peanut over two consecutive growing seasons.

Trait	2024		% Change	2025		% Change
	D1	D2		D1	D2	
SP (%)	2.9 ± 0.42	2.4 ± 0.39	−19.0	2.7 ± 0.39	2.3 ± 0.35	−19.7
FP (%)	83.6 ± 2.04	85.2 ± 1.86	1.9	84.8 ± 2.15	87.0 ± 1.85	2.5
LP (%)	11.8 ± 1.48	13.9 ± 1.68	15.2	10.65 ± 1.52	12.9 ± 1.76	17.9
SMK (%)	65.8 ± 0.95	67.6 ± 0.22	2.6	67.0 ± 0.41	69.4 ± 0.44	3.5
SPL (%)	2.3 ± 0.2	4.4 ± 0.36	45.4	2.3 ± 0.19	3.4 ± 0.37	31.5
OK (%)	1.8 ± 0.1	1.6 ± 0.09	−16.6	2.5 ± 0.09	1.7 ± 0.09	−52.6
HU (%)	30.0 ± 0.96	26.3 ± 0.38	−14.0	27.7 ± 0.35	25.4 ± 0.3	−9.1
ELK (%)	32.2 ± 2.35	38.6 ± 2.63	16.6	31.0 ± 2.28	39.3 ± 2.84	21.1
MK (%)	65.8 ± 2.35	60. ± 2.64	−9.6	66.6 ± 2.27	58.7 ± 2.83	−13.4
SK (%)	1.9 ± 0.08	1.3 ± 0.05	−47.0	2.0 ± 0.09	1.5 ± 0.08	−31.3
HSW (g)	62.5 ± 1.67	66.7 ± 1.6	6.3	63.4 ± 1.57	67.2 ± 1.73	5.6
Yield (kg/acre)	4117.4 ± 51.03	4443.9 ± 73.31	7.3	4264.7 ± 58.2	4577.03 ± 76.68	6.8

Small pods (SP); Fancy pods (FP); Large pods (LP); Sound mature kernels (SMK); Splits (SPL); Other kernels (OK); Hull % (HU); Extra-large kernels (ELK); Medium kernels (MK); Small kernels (SK); Hundred-seed weight (HSW); Yield per acre (Yield). First digging (D1); Second digging (D2). Percent change values represent the percentage loss at D1 relative to D2.

A similar response was observed in 2025, where delayed digging reduced small pods, other kernels, and hull percentage, along with reductions in medium and small kernel classes. Conversely, delayed digging increased fancy pods, large pods, sound mature kernels, and extra-large kernels, indicating improved pod maturity and kernel filling. However, split kernels increased by more than 30%, suggesting greater susceptibility to kernel separation with prolonged field exposure. These changes were accompanied by improvements in hundred seed weight (5.6%) and yield per acre (6.8%). Across market types, similar trends in pod and kernel quality traits were observed during 2024 and 2025 (Figure 1).

Small kernel fractions declined substantially, particularly in Runner (−40.5% in 2024; −59.6% in 2025) and Spanish (−50.6% to −22.7%), while other kernels also showed marked reductions (Runner: −18.8% to −67.7%; Spanish: −38.0% to −62.0%). In contrast, split kernels increased, especially in Virginia (68.7% in 2024; 53.8% in 2025) and Runner (49.5% to 22.1%). Hundred seed weight showed moderate improvement in Runner (5.6% to

6.8%), while yield increased across all market types, with the greatest gains observed in Virginia (12.1%–12.3%) and Runner (9.3%–8.0%). Overall, delayed digging improved yield and kernel size distribution by reducing lower-grade kernel fractions and promoting larger, higher-value kernels, although it increased the occurrence of split kernels. The estimated means and associated measures of variability and uncertainty, including standard deviation, standard error, and 95% confidence intervals, all the traits across market types, digging dates, and growing seasons are presented in Table S2.

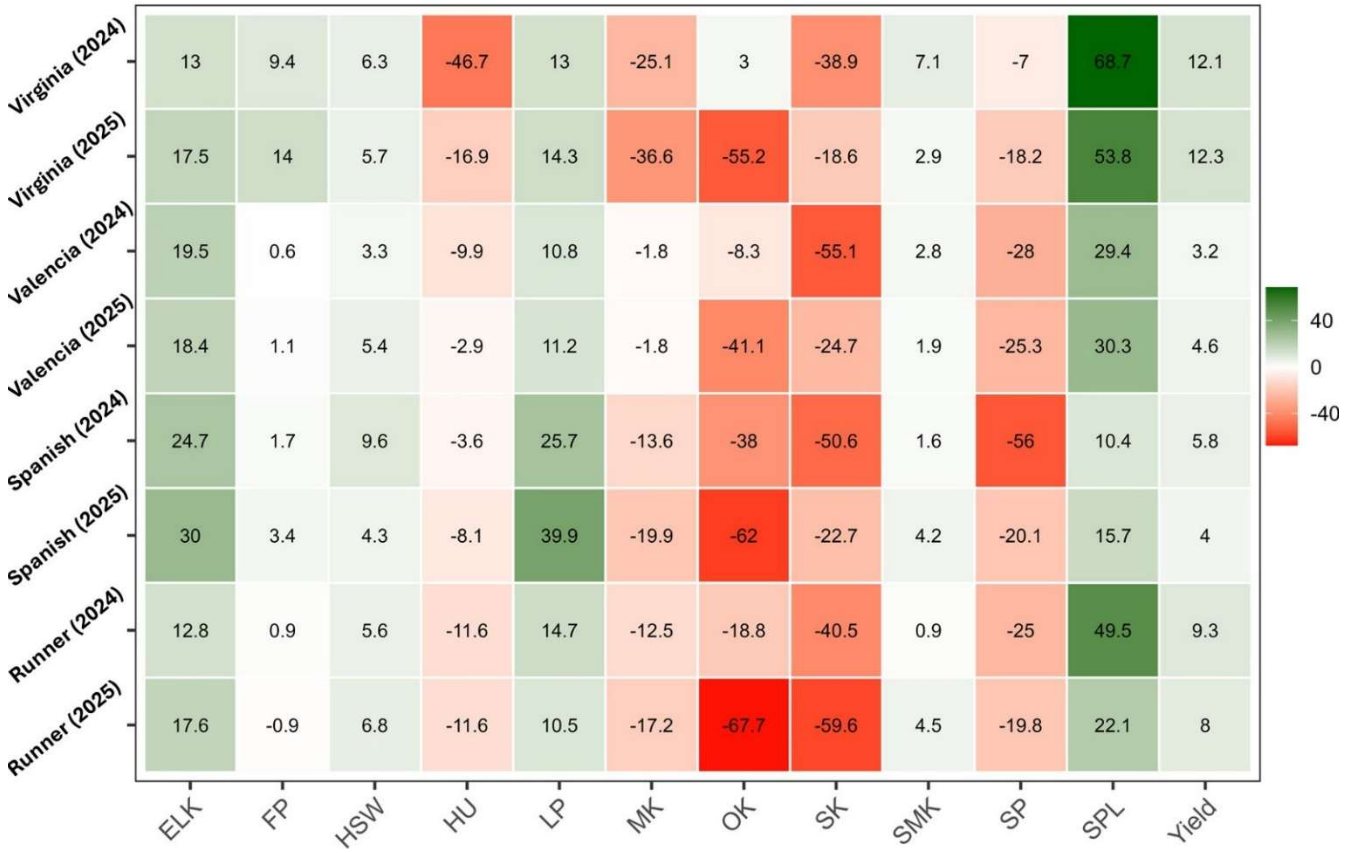


Figure 1. Heat map showing the percentage change in trait values among peanut market types in response to different digging times. Percentage change values represent the percentage loss at first digging relative to second digging. Positive values (green) indicate an increase in trait values with delayed digging, whereas negative values (red) indicate a decrease in trait values with delayed digging. Small pods (SP); Fancy pods (FP); Large pods (LP); Sound mature kernels (SMK); Splits (SPL); Other kernels (OK); Hull % (HU); Extra-large kernels (ELK); Medium kernels (MK); Small kernels (SK); Hundred-seed weight (HSW); Yield per acre (Yield).

Effect of Digging Date on the Yield Performance of Peanut Genotypes

The effect of digging dates on peanut yield traits over two consecutive years revealed considerable variation. Second digging consistently enhanced fancy pods, large pods, sound mature kernels, hundred-seed weight, and overall yield, while reducing small pods, other kernels, hull percentage, and medium and small kernels (Table 3). During the 2024 growing season, all peanut genotypes, regardless of market type, exhibited higher yields under the second digging date compared to the first, although the magnitude of increase varied considerably. The percent yield increase varied among genotypes, with Virginia showing the highest improvement (12.1% in 2024 and 12.3% in 2025), followed by Runner (9.3% and 8.0%), Spanish (5.8% and 4.0%), and Valencia (3.2% and 4.6%). Among the Runner types (ARSOK R109-1L, Georgia-09B, TP200625-3-2, TX144370Ru, ARSOK S58B, Span 17 and TxL100212-03-03), yields ranged from 3755 to 4709 kg per acre under first digging and 4123 to 5030 kg per acre under second digging (Figure 2). The most responsive Runners were TxL100212-03-03 (13.2%), TP200625-3-2 (12.4%) and TX144370Ru (8.9%), suggesting these genotypes benefited from prolonged pod filling with delayed harvest. Among the Spanish types (ARSOK S1042-E, Schubert and TP210656-2-1), yields were generally lower than the Runners, ranging from 3608 to 4623 kg per acre (first digging) and 3862 to 5063 kg per acre (second digging), with moderate percent increases (2.8%–8.7%). The Valencia group (MO-1, MO-2, MO-3, MO-4 and Val-C) showed relatively stable yields with minor changes (1.5%–4.5%), reflecting a shorter growth duration and limited advantage from delayed digging. In contrast, the Virginia types (ARSOK V99, Comrade and TP220694-5-1) displayed the highest responsiveness, with yield gains of 10.4%, 12.3% and 13.3%, respectively, highlighting their extended reproductive period and capacity to utilize additional growing time effectively.

In 2025, the same trend persisted, with all genotypes showing higher yield at D2 (Figure 2). Among Runner types, yield increases ranged from 5.3% in Georgia-09B to 13.3% in TP200625-3-2, confirming their consistent positive response to delayed digging. Spanish varieties recorded moderate increases (3.7%–4.9%), whereas Valencia accessions remained less responsive (3.8%–6.2%), reinforcing their relative insensitivity to extended harvest timing. The Virginia types once again demonstrated the strongest improvement, particularly TP220694-5-1 (15.0%), Comrade (10.3%), and ARSOK V99 (12.0%), which achieved the highest overall yields across both years. Comparatively, while the absolute yield levels were similar across 2024 and 2025, the percent increase between digging dates tended to be slightly higher in 2025, suggesting more favorable late-season environmental conditions. Across both years, TP220694-5-1, Comrade, and ARSOK V99 (Virginia market type) consistently ranked highest for yield gain, indicating strong adaptability to delayed harvest and potential suitability for environments where extended pod filling is advantageous. Conversely, the Valencia genotypes maintained yield stability with minimal change, while Runners showed intermediate responsiveness. Overall, the results demonstrate that yield response to digging date is strongly influenced by market type, with Virginia and selected Runner genotypes showing the greatest benefit from delayed harvest.

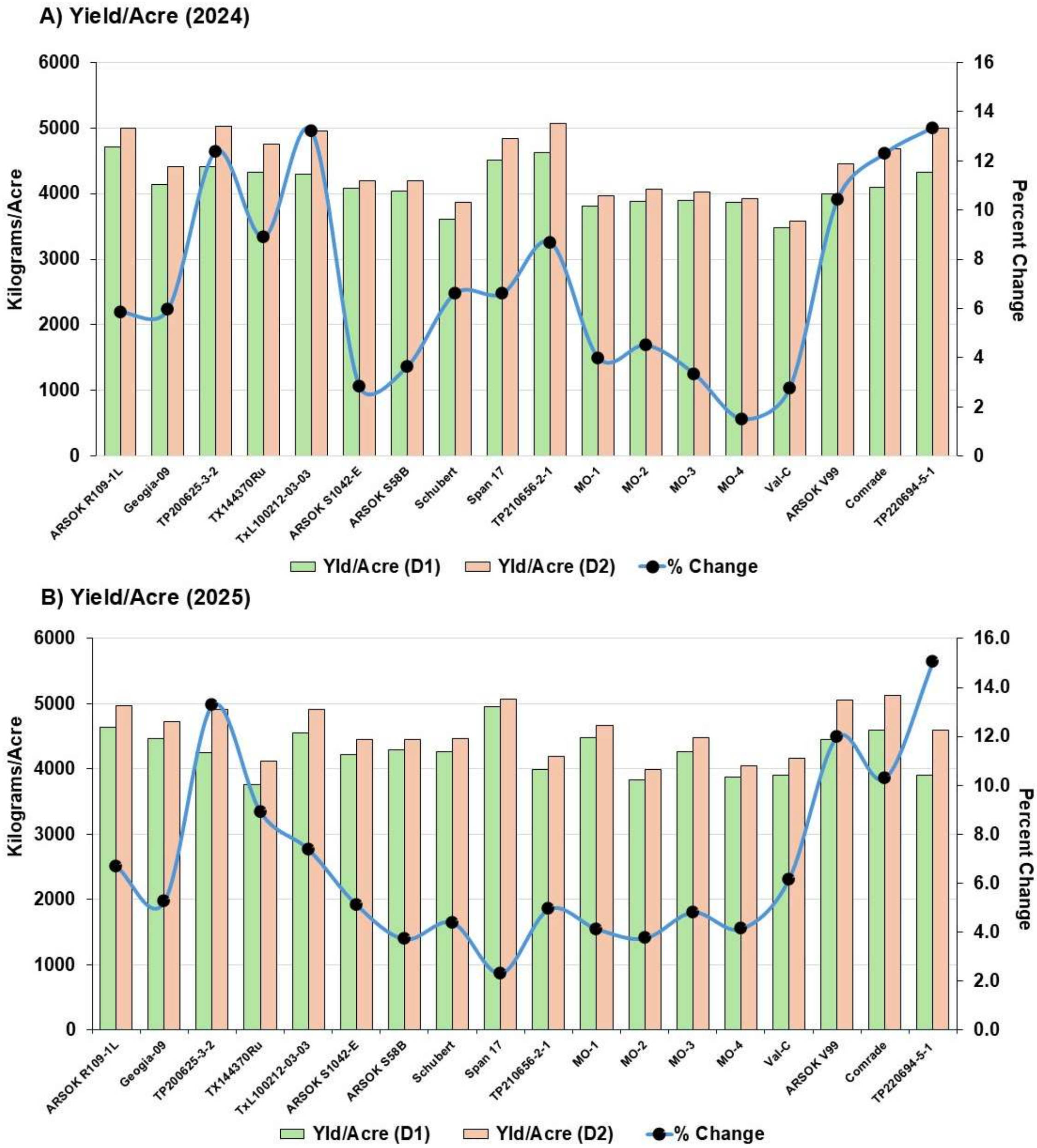


Figure 2. Comparison of yield per acre and percent change across genotypes under two different digging dates. (**A**) yield per acre and percent change in 2024; (**B**) yield per acre and percent change in 2025. Percentage change values represent the percentage loss at first digging relative to second digging. The X-axis represents the genotypes used in this study, while the Y-axis shows yield and percent change. First digging (D1); Second digging (D2); Small pods (SP); Fancy pods (FP); Large pods (LP); Sound mature kernels (SMK); Splits (SPL); Other kernels (OK); Hull % (HU); Extra-large kernels (ELK); Medium kernels (MK); Small kernels (SK); Hundred-seed weight (HSW); Yield per acre (Yield).

Correlation Analysis of Yield and Quality Traits at Different Digging Times

Pearson correlation analysis across different digging stages revealed significant associations among yield- and quality-related traits, highlighting the key morphological and seed attributes influencing productivity and kernel quality during harvest progression (Figure 3). A similar pattern of associations was observed at both digging stages (D1 and D2). For instance, extra-large kernels showed a significant positive correlation with hundred-seed weight and yield, indicating that kernel size consistently contributes to productivity. Similarly, splits exhibited a significant positive association with hundred-seed weight and yield. In contrast, at the second digging date, fancy pod fraction showed a significant negative correlation with split kernels, whereas large pod fraction was positively correlated with split kernels in both years.

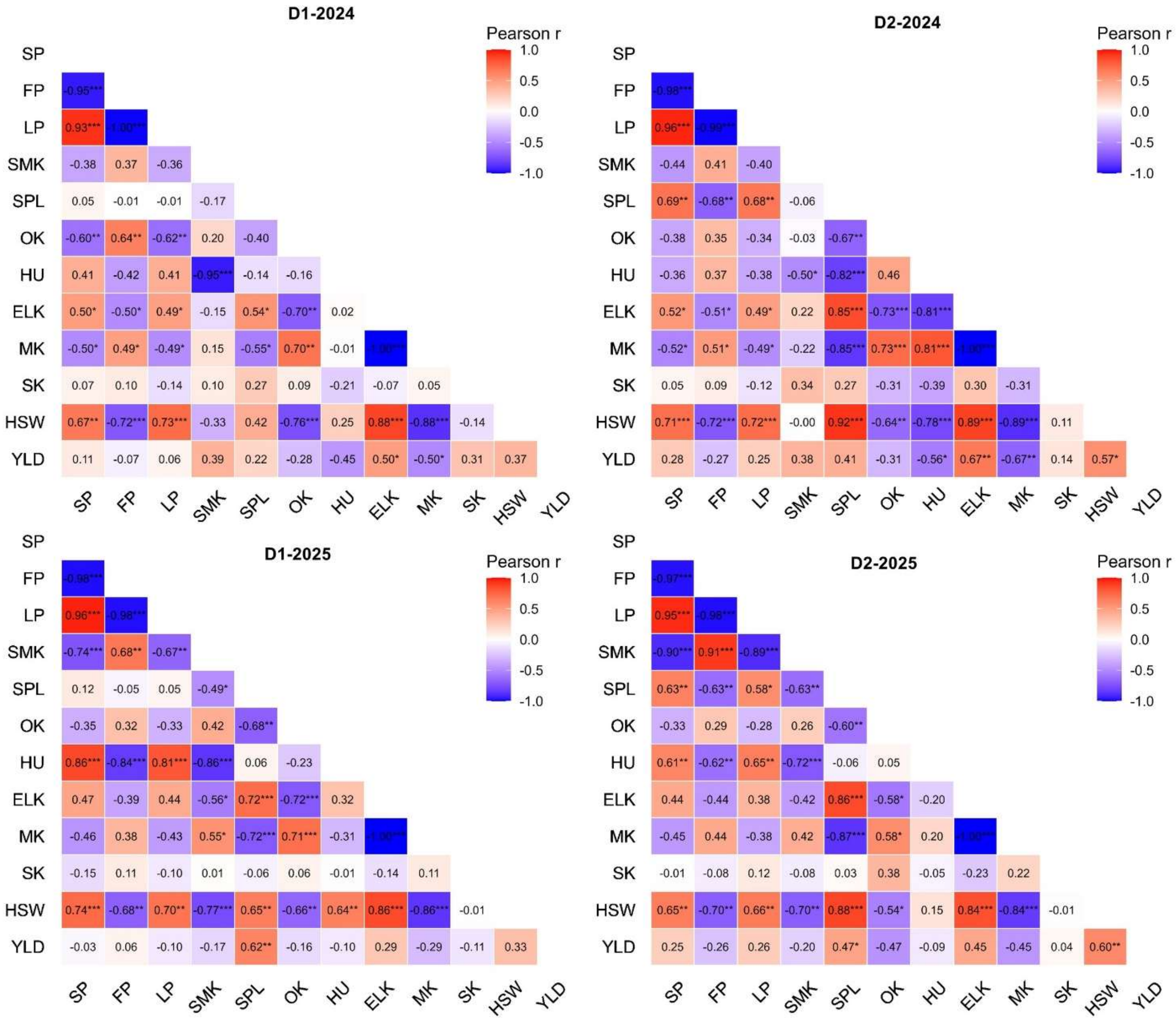


Figure 3. Pearson correlation matrix illustrating the relationships among yield, pod traits, and kernel quality attributes at the first (D1) and second (D2) digging stages across two consecutive years. Color intensity represents the strength and direction of correlations, with positive and negative associations indicated by contrasting color gradients. Significant correlations are denoted by asterisks (* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$). Small pods (SP); Fancy pods (FP); Large pods (LP); Sound mature kernels (SMK); Splits (SPL); Other kernels (OK); Hull % (HU); Extra-large kernels (ELK); Medium kernels (MK); Small kernels (SK); Hundred-seed weight (HSW); Yield per acre (Yield).

DISCUSSION

Peanut exhibits an indeterminate growth habit, resulting in the simultaneous presence of pods at varying maturity stages throughout the growing season and at harvest [16]. Consequently, accurately determining of pod maturity is critical for optimizing seed weight, quality, and overall economic returns. Digging at an early stage leads to a higher proportion of immature pods, adversely affecting yield, grade, seed quality, and flavor. In contrast, delayed digging increases the risk of over-mature pods detaching from vines during digging or threshing [16]. Furthermore, increasing climatic variability exacerbates these challenges by influencing seed composition and reducing yield potential [17]. Maturity duration varies among peanut market types, ranging from approximately 125 to 150 days; Virginia types mature later than Runner and Spanish types, while Valencia types mature earlier [18]. Based on this variation, two digging dates were selected: around 130 days and around 150 days after planting. Previous studies suggest that 130 days is generally preferred for Valencia and Spanish types, whereas 150 days is more suitable for Virginia and Runner types [18]. Evaluating these two contrasting digging dates enabled us to assess the effects of extended field exposure on pod yield and quality across the genotypes evaluated in this study. Although these two digging dates do not encompass the full range of possible harvest timings and therefore cannot establish an optimum digging date, they provide a useful basis for comparing the effects of earlier and later digging under the study's environmental conditions. To date, studies optimizing digging time across multiple market types remain limited, and this study represents one of the first comprehensive evaluations of all four major market classes for their response to digging time in relation to pod and kernel characteristics.

In the present study, year and digging date significantly affected yield, highlighting the strong influence of environmental conditions and digging timing on productivity. Several yield-related traits also showed significant responses to these factors, indicating their broad impact on pod and kernel development. The significant genotype × year and digging × year interactions further suggest that genotypic performance varied across environments and harvest dates, emphasizing the importance of environment-specific management. Valencia and Spanish types matured earlier and showed limited yield improvement with second digging, whereas Virginia and Runner types benefited from later harvesting. Because genotype was treated as a fixed effect, the observed responses to digging date should be interpreted specifically in the context of the genotypes evaluated in this study. They should not be extrapolated to the broader peanut germplasm within each market class. Validation across a broader and more diverse set of genotypes and environments will be necessary to determine the consistency and generalizability of these responses across peanut market classes. Based on our results, harvesting at around 130 days after planting for Valencia and Spanish types is advantageous, as prolonged field exposure increases the risk of yield loss due to unexpected rainfall, heat stress, and reduced peg and pod strength [19,20]. A higher proportion of split kernels was observed in Virginia types (68.7% in 2024 and 53.8% in 2025), followed by Runner types (49.5% in 2024 and 22.1% in 2025) under the second digging. The increase in split pods may be attributed to prolonged pod maturation and lower moisture content at the second digging, which may weaken the pod walls and increase their susceptibility to mechanical damage during harvesting and processing [21].

Additionally, larger seed size may also contribute to higher splitting incidence due to increased internal pressure within the pod during maturation and handling. Early digging of Runner and Virginia types resulted in yield penalties, reflecting incomplete pod and kernel development. Similarly, Oakes et al. (2022) [22] evaluated Virginia market types at 130, 140, and 150 days after planting, reported that digging at 140 days after planting resulted in the highest pod yield, which may be attributed to prevailing environmental conditions influencing pod development and maturation. In addition, Jordan et al. (2016) [23] observed that later digging dates in Virginia peanuts increased economic returns, further supporting the importance of optimal harvest timing for maximizing productivity and profitability. In the present study, observed increase in yield may be attributed to a concurrent reduction in lower-value fractions, including small pods, other kernels, hull percentage, and medium and small kernels. This shift suggests improved assimilate partitioning toward well-developed pods and larger kernels, enhancing overall seed filling and marketable yield.

CONCLUSIONS

Digging date significantly influenced peanut yield and kernel quality, with responses varying among market types. Valencia and Spanish types exhibited earlier maturity and were better adapted to shorter growing seasons. In contrast, Virginia and selected Runner genotypes were more sensitive to early digging and required additional time for optimum pod filling. Early digging reduced pod yield, market grade, and seed quality by increasing the proportion of small pods and immature kernels, thereby reducing market grade and yield potential. Among market types, Virginia experienced the greatest yield penalty from early digging, with an average yield loss of 12.1%, followed by Runner types with an average loss of 8.7%, highlighting their greater dependence on extended field duration for achieving maximum productivity and profitability. In contrast, timely or slightly delayed digging improved fancy pods, large pods, sound mature kernels, hundred-seed weight, and overall yield by enhancing pod maturity and kernel development. However, prolonged field exposure increased split kernels, particularly in Virginia and Runner types, which may reduce economic value through quality downgrading.

SUPPLEMENTARY MATERIALS

The following supplementary materials are available online, Table S1: Day-wise meteorological conditions during peanut crop growth periods in 2024 and 2025. Table S2: Mean, standard deviation (SD), standard error (SE), and 95% confidence intervals (CI) for different traits across market types, digging dates, and growing seasons.

DATA AVAILABILITY

The study dataset is available from the authors upon reasonable request.

AUTHOR CONTRIBUTIONS

NP, JC, KC, WR, and MB contributed to the experimental conceptualization. NP and YDN conducted field studies. YDN analyzed the data and wrote the first draft of the manuscript, with input from all authors. NP supervised the study and provided resources. All authors have reviewed and edited the manuscript and agreed to the published version.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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