

ORIGINAL ARTICLE

Crop Economics, Production, and Management

Evaluating selected skip-row planting patterns for upland cotton (*Gossypium hirsutum* L.) in North Carolina

Michael M. Phillips  | Keith L. Edmisten  | Guy D. Collins  | Lori U. Snyder  |
Jeremy Hendricks 

Department of Crop and Soil Sciences,
North Carolina State University, Raleigh,
North Carolina, USA

Correspondence

Michael M. Phillips, Department of Crop
and Soil Sciences, North Carolina State
University, Raleigh, NC, USA. Email:
mphilli5@ncsu.edu.

Assigned to Associate Editor Ignacio
Macedo.

Funding information

North Carolina Cotton Producers
Association through the Cotton
Incorporated State Support Program;
Cotton, Grant/Award Number: 23-736NC

Abstract

Input costs associated with cotton (*Gossypium hirsutum* L.) production systems have increased exponentially in recent years, prompting interest for innovative cost-saving methods, such as alternative row configurations. The objective of this study was to evaluate the ability of various skip-row systems to achieve similar, or greater, net returns to that of conventionally planted cotton without row skips across multiple years and environments in North Carolina. The alternative row configurations evaluated were a four and one skip-row, a two and one skip-row, and an ultra-wide-row (UWR) that were then compared to solid-planted cotton without skips. Net returns for each configuration were developed using recent economic data and a range of potential lint valuations. Field studies were conducted from 2021 to 2024 at several research stations in Eastern North Carolina, totaling 17 site-years. The 2×1 and UWR configurations generally yielded significantly lower net returns than solid-planted cotton in all years except 2023 when accounting for seed and harvest costs, suggesting limited utility in North Carolina cotton production. In 2024, the 4×1 configuration netted a greater return than solid-planted cotton at a lint price of $\$1.433 \text{ kg}^{-1}$ when accounting for seed and harvest costs, but similar returns should be expected from these two systems in most years. These results suggest that the 4×1 skip-row system in NC may occasionally yield greater net returns than conventionally planted cotton when lint prices are relatively low, after accounting for savings on planting seed and harvest operation costs.

Plain Language Summary

Cotton production costs have increased dramatically in recent years, prompting evaluation of cost-saving methods, such as alternative row configurations. The objective of this study was to evaluate alternative row configurations for their ability to achieve

Abbreviation: UWR, ultra-wide-row.

This is an open access article under the terms of the [Creative Commons Attribution](https://creativecommons.org/licenses/by/4.0/) License, which permits use, distribution and reproduction in any medium, provided the original work is properly cited.

© 2026 The Author(s). *Agronomy Journal* published by Wiley Periodicals LLC on behalf of American Society of Agronomy.

a similar, or greater, net return when compared to a traditional solid-planted row configuration in North Carolina. The alternative row configurations evaluated were a four and one skip-row, a two and one skip-row, and an ultra-wide-row (UWR) that were then compared to solid-planted cotton without skips. The 2×1 and UWR configurations resulted in lower net returns in most cases than solid-planted cotton after deducting seed and harvest costs, suggesting limited utility for these systems. The 4×1 configuration resulted in a similar net return to solid-planted cotton in all years at higher commodity prices. In one year of the study, the 4×1 configuration netted a greater return than solid-planted cotton at low commodity prices after deducting seed and harvest costs. These results suggest that the 4×1 skip-row system in North Carolina may occasionally result in greater net returns than a traditional solid-planted row configuration when commodity prices are low.

1 | INTRODUCTION

Cotton (*Gossypium hirsutum* L.) boll distribution is largely dependent on environmental stressors such as drought events (Bednarz & Nichols, 2005; Snowden et al., 2013), nutrient availability (Boquet et al., 1993), and pest pressure (Bednarz & Roberts, 2001). The indeterminate nature allows a cotton plant to be extremely fluid, setting and retaining bolls in accordance with environmental cues (Hawkins & Peacock, 1973). Decisions made at planting, including plant density, row spacing, and row arrangement, can have a dynamic impact on boll distribution and fruit retention. Plant population density has an inverse relationship with fruit retention on monopodial branches and the outer positions of sympodial branches (Bednarz et al., 2000). In conventional row spacings and row arrangements, the contribution to yield is generally minimal from monopodial branching, and the majority of sympodial fruit production is restricted to inner positions on the branch (Lawton et al., 2024; McCarty et al., 2017). Bolls located on the first position of sympodial branches are responsible for as much as 75% of total yield. In comparison, monopodial branches contribute only 9% to total yield in a conventional row pattern spaced 1 m apart (Jenkins et al., 1990). Jenkins categorized the bulk of fruit production to be located on nodes 5–12 for conventional row spacings and arrangements, while S. Hall, Dodds, et al. (2024) noted an increase in zone 3 (nodes 12 and above) for a 2×1 skip-row arrangement. This indicates the fruiting site distribution for skip-row cotton is more expansive than in solid-planted cotton.

Cotton production systems employing skip-row patterns have been scientifically evaluated in many production regions, including North Carolina, as early as the 1960s for their potential economic benefits (Hawkins & Peacock, 1968). Skip-row patterns are generally denoted by the term “planted row(s) $\times$ unplanted row(s),” where a “ 2×1 ” describes a pattern of two planted rows followed by a singular unplanted row repeated

across a field (Parvin et al., 1999). Recent evaluations of skip-row cotton vary widely in their results depending on location, row spacing, row arrangement, and input costs considered. Several groups evaluated the 4×1 row arrangement in the early 2000s. Field experiments conducted in Mississippi in 2002 determined that a 4×1 row arrangement produced lower lint yields than solid-planted cotton on a land area basis (Nichols & Snipes, 2004). Field experiments were conducted throughout East Georgia from 2001 to 2003 to evaluate the viability of a 2×1 and 4×1 skip-row pattern across a broad range of environments, accounting for seed, harvest, and in-furrow insecticides (Jost et al., 2004). Their findings indicated that the 4×1 arrangement yielded results similar to those of conventionally planted cotton, while the 2×1 arrangement yielded significantly less than conventionally planted cotton. Jost et al. (2004) determined that net returns of skip-row cotton became more reliable in low-yielding environments. This sentiment of skip-row efficacy in low-yielding environments is echoed by field studies in Texas from 2017 to 2020, where a 2×1 row arrangement increased yields in the driest years when compared to conventionally planted cotton (Menefee et al., 2023). The 2×1 skip-row configuration has been periodically evaluated and frequently utilized by growers in the Texas High Plains as a means of increasing water conservation and preserving yield in the arid environment (US EPA, 1997).

Field studies conducted from 2003 to 2005 in Tennessee found that cotton planted in a 2×1 skip-row pattern achieved similar or greater net returns than solid-planted cotton on 25- and 76-cm rows when lint prices were less than $\$1.36 \text{ kg}^{-1}$ (Larson et al., 2009). Seed and harvest cost savings alone were enough to justify a skip-row configuration. This same study determined that seed and harvest cost savings for skip-row cotton on 102-cm rows were insufficient to provide a greater net return than solid-planted cotton, suggesting that skip-row cotton should only be considered for a relatively narrow row

spacing. Multi-state studies conducted in 2019 and 2020 in Alabama, Tennessee, and Mississippi investigated net returns for a 2×1 skip-row pattern on either 76- or 97-cm rows (S. Hall, Dodds, et al., 2024). This group concluded that transitioning from solid planted cotton to a 2×1 row arrangement reduced yields by 19% and subsequently net returns by 21%, regardless of row spacing.

The relatively newer ultra-wide-row (UWR) system utilizing 183-cm rows was evaluated in Georgia from 2021 to 2023, where lint yields were reduced by 22% compared to solid-planted cotton on 91-cm rows (Lawton et al., 2024). Studies conducted in Georgia from 2022 to 2023 found that neither a 2×1 skip-row pattern nor an 183-cm UWR system could achieve yields comparable to those of standard row arrangements (J. M. Hall, Lawton, et al., 2024). The lack of interactions between variety and row arrangement in this study suggest that the highest yielding variety will be the same for solid-planted and skip-row cotton. The majority of recent work has evaluated 2×1 skip-row patterns and UWR systems outside of North Carolina, leaving a gap in knowledge for updated net returns in NC and variations in row arrangements, such as the 4×1 system.

Preserving yield potential and lowering production costs associated with these systems could improve profitability and sustainability and therefore should be evaluated for utility in NC. The objective of this research was to determine if various skip-row production systems, including the UWR system, could be feasible for NC cotton producers and to quantify the economic value of such systems.

2 | MATERIALS AND METHODS

Experiments regarding multiple row configurations for cotton were conducted from 2021 through 2024 at various research stations in eastern North Carolina, totaling 17 site-years (Table 1). In 2021, both early (late April to early May) and late (late May) planted studies were evaluated at the Upper Coastal Plain Research Station (UCPRS) near Rocky Mount, NC (35.89°N , -77.68°W), and the Peanut Belt Research Station (PBRS) near Lewiston-Woodville, NC (36.13°N , -77.17°W). In 2022, both early and late-planted studies were evaluated at the UCPRS and the PBRS, with an additional late-planted study at the Tidewater Research Station (TWRS) near Plymouth, NC (35.52°N , -76.39°W). In 2023, three studies were evaluated at the PBRS: one early-planted study and two late-planted studies, along with an additional late-planted study at the UCPRS. In 2024, two early-planted studies and one late-planted study were evaluated at the PBRS, along with an additional early-planted study at the UCPRS.

At each planting date and location, treatments consisted of (1) solid-planted configuration (every row was planted per customary practice), (2) a 4×1 skip-row configuration (four

adjacent rows planted and one row left fallow), (3) a 2×1 skip-row configuration (two adjacent rows planted and one row left fallow), and (4) a UWR configuration (UWR or 1×1 , one row planted and one row left fallow). All row widths in this study were 91 cm except for the single planting at the TWRS in 2022, where the row width was 97 cm (Table 1). Therefore, the row width in the UWR treatment was 193 cm at the TWRS and 183 cm at all other locations in this study. All treatments were replicated four times for each planting date in a randomized complete block design. Row configuration treatments were established with a four-row John Deere planter calibrated to plant a seeding rate of 107,491 seed ha^{-1} . In-row seeding rates were not adjusted between treatments; therefore, fallow rows within each skip-row treatment were left unplanted without any adjustment to the seeding rate within the planted rows. The solid-planted row configuration was established by engaging all planter units in designated plots for two adjacent passes. The 4×1 skip-row configuration was established by disengaging the second planter unit for designated plots and making two adjacent passes in opposite directions. The 2×1 skip-row configuration was established by disengaging the third planter unit in designated plots and making two adjacent passes in opposite directions. The UWR configuration was established by disengaging the first and third planter units and planting two adjacent passes in the same direction within designated plots. All plots in this study were eight rows or 7.32 m wide (7.72 m for the TWRS) with lengths ranging from 8.5 m to 91.4 m depending on the year, location, and planting date (Table 1).

In 2021, the Stoneville cotton cultivar Stoneville 4550 GLTP (BASF Corp.) was planted on April 27 and May 20 at both the UCPRS and the PBRS. In 2022, the Deltapine cotton cultivar Deltapine 2115 B3XF (Bayer CropScience) was planted on May 4 and May 16 at the UCPRS, on May 5 and May 17 at the PBRS, and on May 19 at the TWRS. In 2023, the Deltapine cotton cultivar Deltapine 2127 B3XF was planted on May 3, May 22, and May 25 at the PBRS and on May 24 at the UCPRS. In 2024, the Deltapine cotton cultivar Deltapine 2127 B3XF was planted on May 1, May 8, and May 22 at the PBRS and on May 7 at the UCPRS (Table 1). Supplemental irrigation was applied as needed to plots using an overhead lateral-move sprinkler boom at both the PBRS and TWRS, while reel irrigation system was used at the UCPRS when soil moisture levels reached a deficit. Daily rainfall and temperature data were collected at a standard weather station located at each of the research stations. Cumulative rainfall and heat units from planting to harvest are summarized in Table 1.

Large plot studies were mechanically harvested using a John Deere four-row 9960 spindle cotton picker at the UCPRS and a 9965 at the PBRS and TWRS. A John Deere two-row 9930 spindle cotton picker was used for small plot studies at both the UCPRS and PBRS. Seed cotton from each plot was weighed at harvest, and a subsample of each treatment was

TABLE 1 Variety, plot dimensions, planting date, harvest date, and season totals for heat units and precipitation by location.

Locations	Variety	Row width (cm)	Plot width (m)	Plot length (m)	Planting date	Harvest date	Heat units (°C)	Precipitation (cm)
2021								
UCPRS ^a	Stoneville 4550 GLTP	91.4	7.32	30.5	April 27	Oct. 7	1333	47.1
					May 20	Oct. 21	1305	51.4
PBRs ^b					April 27	Oct. 19	1354	82.3
					May 20	Oct. 28	1281	81
2022								
UCPRS ^a	Deltapine 2115 B3XF	91.4	7.32	30.5	May 4	Oct. 10	1378	48.8
					May 16	Oct. 18	1346	50.3
PBRs ^b					May 5	Oct. 12	1327	56
					May 17	Oct. 17	1301	50.9
TWRS ^c		96.5	7.72		May 19	Oct. 20	1254	58.6
2023								
PBRs ^b	Deltapine 2127 B3XF	91.4	7.32	91.4	May 3	Oct. 13	1268	49.3
					May 22	Oct. 19	1196	48.5
				8.5	May 25	Oct. 31	1216	49.8
UCPRS ^a				12.2	May 24	Nov. 1	1227	57.2
2024								
PBRs ^b	Deltapine 2127 B3XF	91.4	7.32	55.5	May 1	Oct. 25	1391	54.4
					May 22	Nov. 1	1295	47.9
				12.2	May 8	Nov. 6	1364	53.1
UCPRS ^a				12.2	May 7	Oct. 28	1381	87.5

^aUpper Coastal Plain Research Station near Rocky Mount, NC.
^bPeanut Belt Research Station near Lewiston-Woodville, NC.
^cTidewater Research Station near Plymouth, NC.

TABLE 2 Input costs per unit land area as affected by row configuration^a.

Row configuration	Input costs per hectare (\$ ha ⁻¹)			
	Seed	Harvest	N Fertilizer	Insecticide
Solid planted	332	173	132	78
4 × 1 skip row pattern	266	130	106	63
2 × 1 skip row pattern	221	86	89	53
1 × 1 skip row pattern	166	116	66	39

^aInput costs reflect recent economic data from 2025 (Washburn, 2025).

collected for ginning. Large plot studies were ginned at the West Tennessee Research and Education Center, where all seed cotton samples were ginned with a 20-saw gin assembly that included a stick machine, incline cleaners, and two lint cleaners. Small plot studies were ginned on a Continental Eagle 10-saw gin assembly. Lint yield on a land area basis was defined as the mass of lint harvested per unit ground area, calculated from seed cotton weight, gin turnout, and plot area (this is the same calculation for all treatments). Lint yield on a planted area basis was defined as the mass of lint harvested per unit ground area, calculated from seed cotton weight, gin turnout, and only the planted plot area (this calculation varies by treatment—accounting for fallow rows).

Seed costs associated with each treatment were figured from the North Carolina Cotton Extension Production Guide for conventional-tillage cotton from recent economic data (Washburn, 2025). Seed was estimated to cost \$3.09/1000 seeds with local recommendations and treatments applied at 107,491 seed ha⁻¹ for a total cost of \$332.15 ha⁻¹ for the solid-planted cotton. The 4 × 1 skip-row is 80% of this cost, equaling \$265.72 ha⁻¹ as every fifth row will be left fallow. The 2 × 1 skip-row was 67% of this cost equaling \$222.54 ha⁻¹ as every third row will be left fallow. The UWR skip-row was 50% of this cost equaling \$166.08 ha⁻¹ as every other row will be left fallow. These seed costs would be considered premium pricing, including seed treatment and seed technology fees for commonly used traits. Seed costs are listed by treatment in Table 2.

Harvest costs were evaluated under the assumption of a commercial six-row spindle cotton harvester spaced appropriately to maximize efficiency of the skip-row arrangement, which accounts for its skip-row capabilities. The harvest cost estimates are compiled from a survey from growers and economic data derived from the cost to purchase, maintain, and operate a cotton harvester on a yearly per hectare basis (Cotton Inc., 2010; Hargett, 2000; Parvin et al., 1999). The cost for harvesting solid-planted cotton was estimated to be \$172.97 ha⁻¹ utilizing a six-row harvester with standardized spacing able to harvest 12 rows in two adjacent passes within a field. When harvesting the 4 × 1 skip-row, a space can be extended between units 4 and 5 of the six-row harvester to account for the skipped row, allowing seven rows to be cov-

ered during each pass (six planted and one fallow), with a final fallow row able to be skipped after two adjacent picker passes. This totals 12 planted rows harvested and 15 field rows covered during two adjacent passes for the 4 × 1 skip-row configuration, equating to a 25% increase in harvest efficiency over the solid-planted cotton, equaling \$129.72 ha⁻¹. When harvesting the 2 × 1 skip-row configuration, spaces can be extended between row units 2 and 3 as well as units 4 and 5 of the six-row harvester to account for two fallow rows, allowing eight rows to be covered during each pass (six planted and two fallow rows). An additional fallow row can be skipped following each pass, totaling 12 planted rows harvested and 18 rows covered over the duration of two adjacent passes through the field. This equates to a 50% increase in efficiency over the solid-planted cotton, equaling \$86.49 ha⁻¹ to harvest the 2 × 1 skip-row pattern. When harvesting the UWR configuration, a space can be extended between units 5 and 6 to account for one fallow row, allowing seven rows to be covered during each pass (four planted and three fallow rows). An additional fallow row can be skipped following each picker pass, totaling eight planted rows harvested and 16 rows covered over the duration of two adjacent passes through the field. This equates to a 33% increase in efficiency over the solid-planted cotton, equaling \$115.89 ha⁻¹ to harvest the UWR configuration. A depiction of harvest efficiency by treatment is provided in Figure 1. Harvest costs are listed by treatment in Table 2.

Both seed and harvest input costs were considered the most applicable to all growers with a modern baler harvester and quantifiable when calculating skip-row savings, therefore, analysis including only these two variables is reported first. Growers equipped to apply in-furrow insecticides, fungicides, starter fertilizer adjacent to planted rows, or other at-planting inputs applied to individual rows could hypothetically account for additional savings on inputs; however, these costs may not be applicable to all growers.

Other in-row costs, namely, nitrogen fertilizer and insect management, were considered in this study and approached with caution as many assumptions were made. Nitrogen fertilizer savings were determined under the assumption of a 30-0-0 UAN solution side-dress application where applicator nozzles can be turned off to avoid placing fertilizer on fallow rows within the skip-row arrangement. A secondary

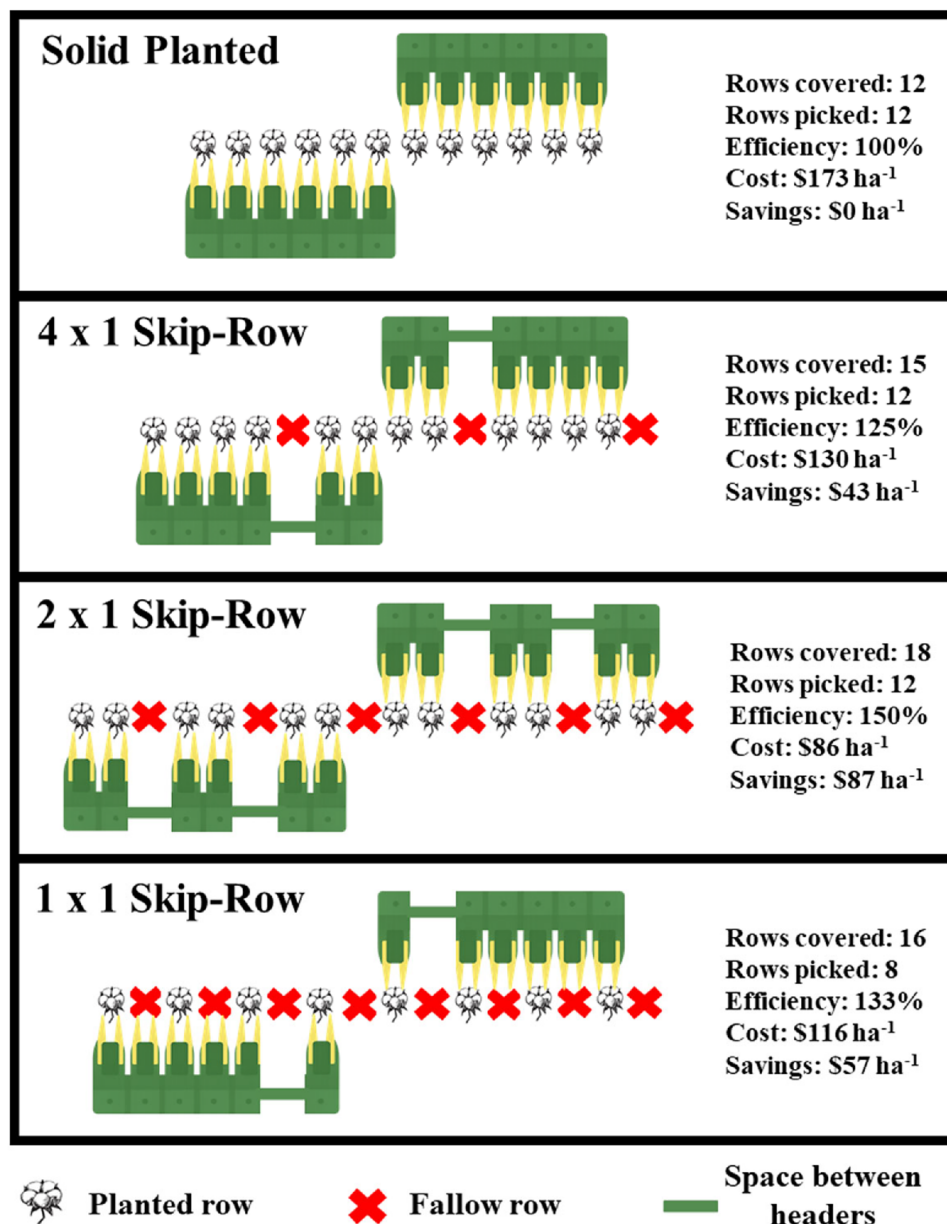


FIGURE 1 Harvest efficiency as affected by row configuration.

assumption was made, maintaining that nitrogen rates on a per-planted-hectare basis can remain the same for skip-row arrangements without a yield penalty (Boquet, 2005; Li et al., 2017). The costs of this 30% UAN solution were figured to be \$1.47 kg N applied (USDA-ERS, 2025) with 90 kg N ha⁻¹ needed throughout the season (Gatiboni & Hardy, 2026). The solid-planted cotton would incur \$132.30 ha⁻¹ for these nitrogen applications. The 4 × 1 skip-row pattern would be 80% of this cost as applicator nozzles on every fifth row can be disengaged, or skipped entirely, equaling \$105.84 ha⁻¹. The 2 × 1 skip-row pattern would be 67% of this cost as applicator nozzles on every third row can be disengaged, equaling \$88.64 ha⁻¹. The UWR would be 50% of this cost as applicator nozzles on every other row can be disengaged,

equaling \$66.15 ha⁻¹. Without further scientific evaluation, net returns accounting for nitrogen fertilization costs should only be viewed as a hypothetical proof of concept. The results only reflect the general potential of skip-row systems using the same values for lint yield if more input cost savings can be employed beyond seed and harvest costs. Nitrogen costs discussed here are listed by treatment in Table 2.

Insect management savings were established under the assumption of increased efficacy (Hutchins & Pitre, 1984) and decreased pest incidence (Mogalapu, 2013; Scott et al., 1994) associated with reduced planted populations on a hectare basis. This, along with not applying in-furrow insecticides in fallow rows, is the basis for proportionately decreasing the cost for insect management for each successive skip-row

TABLE 3 Lint yield per planted unit land area as affected by row configuration, 2021–2024^a.

Row configuration	Lint yield per planted hectare (kg planted ha ⁻¹)			
	2021	2022	2023	2024
Solid planted	1790d	1492c	1269c	1691c
4 × 1 skip row pattern	2038c	1839b	1503b	2124b
2 × 1 skip row pattern	2253b	1773b	1561b	2105b
1 × 1 skip row pattern	2712a	2577a	2003a	2737a

Note: Means within a column followed by the same letter are not statistically different according to Fisher's Protected LSD ($p \leq 0.05$). For columns beginning with NS, means are not statistically different.

^aData are pooled over all locations within each year.

arrangement. The cost of in-furrow insect management in North Carolina was estimated to be \$78.41 ha⁻¹ for solid-planted cotton (Washburn, 2025). The 4 × 1 skip-row pattern would be 80% of that cost as every fifth row will not require insect management, equaling \$62.72 ha⁻¹. The 2 × 1 skip-row pattern would be 67% of that cost as every third row will not require insect management, equaling \$52.54 ha⁻¹. The UWR cotton would be 50% of that cost as every other row will not require insect management, equaling \$39.21 ha⁻¹. Without further scientific evaluation, net returns accounting for insect management costs should only be viewed as a hypothetical proof of concept. The results only reflect the general potential of skip-row systems using the same values for lint yield if more input cost savings can be employed beyond seed and harvest operational inputs. Insect management costs discussed here are listed by treatment in Table 2.

Multi-year data from all tests were subjected to analysis of variance using the Generalized Linear Mixed Model procedure of JMP PRO 18 software (SAS institute Inc.) ($\alpha = 0.05$). Treatment means were separated using Fisher's Least Significant Difference (LSD) ($p \leq 0.05$). For all analyses, replication nested within planting timing, location, and year, and location nested within year were considered random effects, while row arrangement, year, planting timing and their interactions were considered fixed effects.

3 | RESULTS AND DISCUSSION

3.1 | Lint yield—planted area basis

The main effect of row arrangement was significant for lint yield on a planted area basis ($p = < 0.0001$). The two-way interaction of row arrangement and year ($p = 0.038$), as well as the two-way interaction of row arrangement and planting timing ($p = 0.026$), was significant for lint yield on a planted area basis. Therefore, data for lint yield on a planted area basis is presented by year (Table 3) and for each row configuration at both early and late plantings (Table 4). Lint yield per planted hectare is reported to illustrate the ability

of each row configuration to compensate for additional space provided by fallow rows, despite utilizing less seed per unit land area. The calculation for yields on a hectare basis and a planted hectare basis are the same for solid planted cotton, since all rows were planted without skips. As hypothesized, the solid-planted configuration resulted in significantly lower lint yields per planted hectare than all other treatments in every year of this experiment (Table 3). The UWR configuration resulted in the highest lint yields per planted hectare in all years, while both the 2 × 1 and 4 × 1 configurations resulted in lint yields per planted hectare that were significantly lower than that of the UWR but were greater than those of the solid planted configuration during 2022 through 2024. A similar effect was observed in both early-planted and late-planted trials across all years (data not shown). These results are similar to those documented in previous studies regarding the yield per unit length of row for a 2 × 1 configuration compared to solid planting (Bruce, 1965; Hons & McMichael, 1986). Table 4 illustrates the effect of planting date on lint yield per planted hectare for each row configuration. Planting date had no effect on lint yield planted ha⁻¹ for the solid planted, the 4 × 1, or the 2 × 1 configurations across all years suggesting that these configurations can achieve the same level of compensation regardless of planting timing (early vs. late planting) in NC, despite the potential delays in maturity presented by skip-row systems that have been noted by previous research (Buehring et al., 2006; Gwathmey et al., 2011).

As previously mentioned, the UWR configuration resulted in lint yield planted ha⁻¹ that was significantly greater than all other treatments across years (Table 3). This represents an average of 62% increase in yield planted ha⁻¹ when compared to the solid-planted treatment. Interestingly, there was a significant difference in yield planted ha⁻¹ for the UWR configuration across different planting timings (Table 4). The UWR resulted in 2613 kg planted ha⁻¹ for late-planted studies, which was significantly greater than the 2401 kg planted ha⁻¹ for early-planted studies. These results are somewhat surprising, as several contrasting previous studies have suggested that delayed maturity in later plantings, combined with

TABLE 4 Lint yield per planted unit land area as affected by row configuration and planting timing^a.

Planting timing	Lint yield per planted hectare (kg planted ha ⁻¹)			
	Solid	4 × 1	2 × 1	1 × 1
Early planted	1557NS	1853NS	1951NS	2401b
Late planted	1563	1900	1895	2613a

Note: Means within a column followed by the same letter are not statistically different according to Fisher's Protected LSD ($p \leq 0.05$). For columns beginning with NS, means are not statistically different.

^aData are pooled over all locations and years.

TABLE 5 Lint yield per unit land area as affected by row configuration, 2021–2024^a.

Row configuration	Lint yield per hectare (kg ha ⁻¹)			
	2021	2022	2023	2024
Solid planted	1787a	1490a	1201a	1678a
4 × 1 skip row pattern	1630b	1471a	1199a	1726a
2 × 1 skip row pattern	1502c	1184c	1051b	1420b
1 × 1 skip row pattern	1356d	1293b	1053b	1399b

Note: Means within a column followed by the same letter are not statistically different according to Fisher's Protected LSD ($p \leq 0.05$). For columns beginning with NS, means are not statistically different.

^aData are pooled over all locations within each year.

lower plant populations, result in decreased yields (Iqbal & Khan, 2011; Wrather et al., 2008). Other studies, however, indicate little advantage for early planting dates in regions with low heat accumulation early in the growing season, such as the Carolinas (O'Berry et al., 2008). Several factors likely contributed to the increased productivity of the UWR in late-planted studies. The rate of boll opening (percent open bolls in late September) has been observed to increase with later planting dates (Wang et al., 2016), which could greatly benefit the elevated bolls plant⁻¹ of the UWR. Late planting can also often avoid risks such as premature cutout due to drought in late summer and boll rot and hard lock resulting from prolonged overcast and wet conditions as bolls approach maturity, both of which would be detrimental to the yield potential of earlier planted cotton.

3.2 | Lint yield—land area basis

The main effect of row arrangement was significant for lint yield on a land area basis ($p = < 0.0001$). The two-way interaction of row arrangement and year was significant for lint yield on a land area basis ($p = 0.002$). Therefore, data for lint yield on a land area basis (Table 5) is presented by year, pooled across all locations within each year. The solid-planted cotton resulted in the greatest lint yield per unit land area of all row configurations during 2021–2023, with the 4 × 1 configuration yielding similar results to solid planting during 2022–2024. The only year the lint yield of the 4 × 1 row configuration was significantly less than that of solid-planted

cotton was in 2021, which was a relatively high yielding year with ideal heat unit accumulation and timely rainfall (Table 1) and is in agreement with previous research suggesting that higher yielding environments can lessen the ability for skip-row systems to compete with conventionally planted cotton (Jost et al., 2004). These findings contrast with some previous research, where a 4 × 1 arrangement resulted in lower yields compared to solid-planted cotton (Nichols & Snipes, 2004). However, this study evaluated a 4 × 1 on 102-cm rows, whereas the 4 × 1 on 91-cm rows may have allowed for greater canopy closure, less fallow area, and subsequently more similar yields to solid-planted cotton. These results suggest that the lint yield plant⁻¹ of the 4 × 1 configuration was sufficient for allowing compensation for the 20% reduction in seed planted ha⁻¹ in 2022 through 2024.

The 2 × 1 row arrangement resulted in a significantly lower lint yield ha⁻¹ than the solid planted cotton and the 4 × 1 row arrangement in every year of the study (Table 5), suggesting that compensation exhibited by the 2 × 1 row arrangement was insufficient to overcome the 33% reduction in seed planted ha⁻¹. These results contrast with previous research conducted in other regions of the Cotton Belt, where yields ha⁻¹ of a 2 × 1 configuration were similar, or greater than, that of solid planted cotton (Gwathmey et al., 2011; Hawkins & Peacock, 1968; Larson et al., 2009; Parajulee et al., 2011). These contrasting results could be a reflection of lower yielding environments as previously noted. However, other recent research identified yield penalties associated with a 2 × 1 row arrangement (S. Hall, Dodds, et al., 2024; Nichols & Snipes, 2004), similarly to these results.

The UWR treatment resulted in significantly lower yields ha^{-1} compared to all other configurations during 2021 and both the solid-planted and 4×1 configurations during 2022 through 2024 (Table 5). This suggests that yields of the UWR configuration could not compensate for the 50% reduction in seed planted ha^{-1} . Lawton et al. (2024) reported results in agreement with these findings, where cotton planted on 183-cm rows yielded less than cotton on 91-cm rows, equating to a 20% reduction in yield (Lawton et al., 2024). However, J. M. Hall, Lawton, et al. (2024) noted contrasting results in Georgia in 2022, where a 183-cm UWR achieved similar yields to standard row arrangements, although relatively lower yields may have contributed to these results.

3.3 | Lint value

The main effect of row arrangement was significant for all lint valuations evaluated for gross receipts on a ha^{-1} basis ($p = < 0.0001$), as well as the two-way interaction of row arrangement and year ($p = 0.002$), encompassing the market prices of \$1.433, \$1.654, \$1.874, and \$2.094 kg^{-1} . Therefore, data are presented by year for all lint valuations per hectare on a land area basis (Table 6). As expected, the mean separation results are identical to the lint yield ha^{-1} results, where the solid-planted treatment had the highest gross value. The effect of row configuration on all High Volume Instrumentation (HVI) parameters was relatively insignificant and not sufficient in offsetting differences in yield, and therefore results regarding HVI (data not shown) were not used in calculating value per hectare for each treatment.

3.4 | Net returns adjusted for seed and harvest costs

The main effect of row arrangement ($p = < 0.0001$) and the two-way interaction of row arrangement and year ($p = 0.002$) were significant for all lint valuations evaluated for net returns on a land area basis after deducting planting seed and harvest input costs from gross receipts. Therefore, data for net returns after planting seed and harvest costs are presented by year (Table 7). The general trend across all years and lint prices suggested that as the amount of skipped area increased in the various skip-row configurations, net returns adjusted for both seed and harvest costs decreased with some variation between years. This was not observed in 2023, where there was no effect of row configuration on net returns at any lint value. Environmental conditions pertaining to 2023 may have allowed all skip-row arrangements to be competitive with solid planted cotton net returns. Three of the four locations in 2023 received the lowest total heat accumulation in the multi-year study, along with the lowest precipitation totals in some

locations (Table 1). The lowest yielding year was 2023 for every treatment in the study (Table 5). This low-yielding environment is conducive to skip-row net returns (Jost et al., 2004; Menefee et al., 2023; Parajulee et al., 2011). During 2022 and 2024, both the solid-planted and the 4×1 row configurations resulted in similar net returns ha^{-1} at nearly all lint prices and were greater than those of both the 2×1 and UWR configurations. These results contrast those of Larson et al. (2009), where seed and harvest costs alone were enough to justify a 2×1 arrangement. A similar effect was observed during 2021; however, the 2×1 configuration resulted in similar net returns to that of the 4×1 configuration at all lint prices, and the UWR configuration resulted in the lowest net returns compared to all other configurations. Interestingly, in 2022, the UWR configuration resulted in greater net returns than the 2×1 configuration at all lint prices, which was inconsistent with results from all other years. Similarly, in 2024, at the lowest lint price of \$1.433 kg^{-1} , the 4×1 arrangement had a greater net return than solid-planted cotton, also in contrast with results from other years of this experiment. This illustrates the ability of skip-row systems to obtain more competitive net returns when lint prices are low, as observed in previous studies (Larson et al., 2009). This effect was not observed when utilizing lower seed costs (data not shown), suggesting that greater net returns may only be obtained with premium seed pricing.

3.5 | Net returns after seed, harvest, nitrogen, and insecticide costs

The main effect of row arrangement ($p = < 0.0001$) and the two-way interaction of row arrangement and year ($p = 0.002$) were significant for all lint valuations evaluated for net returns on a land area basis after deducting seed costs, harvest costs, nitrogen fertilizer costs, and in-furrow insecticide costs from lint value. Therefore, net returns adjusted for these in-row costs are presented by year (Table 8). Similarly, to the net returns adjusted for only seed and harvest costs, there was no effect of row configuration on net returns in 2023, implying that similar returns could be equally likely regardless of row configuration. However, row configuration significantly affected net returns in the other three years of this experiment. The 4×1 arrangement yielded similar net returns, adjusted for all in-row costs, to those of solid-planted cotton at all lint prices in 2021 and 2022. During 2021, net returns generally declined as fallow space increased within the various row configurations at the higher three lint prices. At the lowest lint price in 2021, only the UWR configuration resulted in lower net returns when compared to the other configurations. Additionally, 2021 was the only year in which the 2×1 configuration resulted in similar net returns to that of the 4×1 configuration. Interestingly, during 2022, the 2×1

TABLE 6 Value per unit land area as affected by row configuration and lint price, 2021–2024^a.

Row configuration	Value per hectare			
	2021	2022	2023	2024
	\$1.433 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	2560a	2135a	1721a	2404a
4 × 1 skip row pattern	2337b	2107a	1718a	2474a
2 × 1 skip row pattern	2153c	1697c	1506b	2034b
1 × 1 skip row pattern	1943d	1852b	1509b	2005b
	\$1.654 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	2955a	2464a	1986a	2775a
4 × 1 skip row pattern	2696b	2432a	1982a	2855a
2 × 1 skip row pattern	2484c	1957c	1738b	2348b
1 × 1 skip row pattern	2242d	2137b	1742b	2314b
	\$1.874 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	3349a	2792a	2251a	3144a
4 × 1 skip row pattern	3056b	2756a	2246a	3235a
2 × 1 skip row pattern	2815c	2218c	1970b	2661b
1 × 1 skip row pattern	2541d	2422b	1974b	2622b
	\$2.094 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	3743a	3120a	2515a	3514a
4 × 1 skip row pattern	3415b	3080a	2510a	3615a
2 × 1 skip row pattern	3146c	2479c	2201b	2973b
1 × 1 skip row pattern	2840d	2707b	2206b	2930b

Note: Means within a column followed by the same letter are not statistically different according to Fisher's Protected LSD ($p \leq 0.05$). For columns beginning with NS, means are not statistically different.

^aData are pooled over all locations within each year.

configuration resulted in lower net returns when compared to all other row configurations, with even the UWR configuration resulting in similar returns to those of the 4 × 1 and solid planted configurations. This was not observed in any other year. These findings suggest that the 2 × 1 configuration requires additional savings beyond seed, harvest, nitrogen, and insecticide (\$266 ha⁻¹) to make a greater, or consistently similar, net return than solid-planted cotton. Likewise, these findings also suggest that the UWR configuration would require additional savings beyond seed, harvest, nitrogen, and insecticide (\$328 ha⁻¹) to net a greater return than solid-planted cotton. Throughout all years of this experiment, the UWR configuration either resulted in similar or lower returns when compared to the solid planted configuration but never resulted in greater returns.

Lastly, the 4 × 1 configuration resulted in greater net returns than all other configurations, including solid planted, at all lint prices in 2024. This, again, suggests that only a small amount

of additional savings (\$41 ha⁻¹ total for nitrogen and insecticide) beyond seed and harvest costs is required to elevate the 4 × 1 configuration above the solid-planted cotton at all lint prices in some years, with no risk to net returns in other years. At the highest lint prices in 2024, both the 2 × 1 and UWR configurations resulted in lower net returns than both the solid planted and 4 × 1 configurations. Throughout all years of this experiment, net returns of the 4 × 1 system were similar to or greater those that of the solid planted configuration when considering additional potential in-row cost savings such as fertilizer and insecticide.

4 | CONCLUSIONS

The 4 × 1 row arrangement achieved similar yields to the conventional solid row configurations in most years, regardless of yield environment. Net returns of the 4 × 1 configuration

TABLE 7 Net return per unit land area after planting seed and harvest input costs as affected by row configuration and lint price, 2021–2024^a.

Row configuration	Net return per hectare after seed and harvest input costs			
	2021	2022	2023	2024
	\$1.433 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	2056a	1630ab	1216NS	1899b
4 × 1 skip row pattern	1941ab	1712a	1322	2079a
2 × 1 skip row pattern	1845b	1388c	1198	1727c
1 × 1 skip row pattern	1661c	1570b	1227	1723c
	\$1.654 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	2450a	1958a	1481NS	2270a
4 × 1 skip row pattern	2301ab	2036a	1587	2460a
2 × 1 skip row pattern	2176b	1649c	1430	2040b
1 × 1 skip row pattern	1960c	1855b	1460	2032b
	\$1.874 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	2844a	2287a	1745NS	2639a
4 × 1 skip row pattern	2660ab	2360a	1851	2840a
2 × 1 skip row pattern	2507b	1910c	1662	2353b
1 × 1 skip row pattern	2259c	2140b	1692	2340b
	\$2.094 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	3238a	2615a	2010NS	3009a
4 × 1 skip row pattern	3020ab	2684a	2115	3220a
2 × 1 skip row pattern	2838b	2171c	1893	2665b
1 × 1 skip row pattern	2558c	2425b	1924	2648b

Note: Means within a column followed by the same letter are not statistically different according to Fisher's Protected LSD ($p \leq 0.05$). For columns beginning with NS, means are not statistically different.

^aData are pooled over all locations within each year.

were never less than those of solid-planted cotton, regardless of commodity pricing, when planting seed and harvest costs were considered. Although this research suggests there would be no economic penalty from switching to the 4 × 1 row arrangement, it would require an operational transition that is unfamiliar to many growers. There were scenarios (2024) where a 4 × 1 row configuration resulted in greater net returns than that of solid planted cotton when lint prices were relatively low and if only planting seed and harvest costs were considered. If relatively small additional in-row savings can be found beyond seed and harvest operational costs, such as fertilizer and in-furrow insecticide, or if greater seed costs are considered, the 4 × 1 may net a greater return more consistently across lint prices in some years.

The 2 × 1 and UWR arrangements resulted in lower yields than solid-planted cotton in all years, especially in higher-yielding environments. The lowest-yielding environment (2023) allowed both the 2 × 1 and UWR to achieve

similar net returns to solid-planted cotton, regardless of lint prices, when accounting for seed and harvest cost savings. Despite a significant increase in production per planted hectare and a decrease in production costs, neither of these row arrangements appears to be economically feasible for North Carolina growers. The 2 × 1 arrangement rarely achieved a similar return to that of solid-planted cotton, even when adjusting for additional savings beyond seed and harvest costs. The UWR configuration was only able to achieve a similar return to that of solid-planted cotton when lint prices were at their lowest and all potential cost savings were considered. However, the UWR configuration could only produce similar returns in some years, whereas returns from this configuration were lower than those of most other configurations in other years. In summary, the 4 × 1 skip-row configuration was the most economically feasible alternative for North Carolina when compared to a solid row configuration, but similar returns should be expected from these two systems in most

TABLE 8 Net return per unit land area after planting seed, harvest, nitrogen fertilizer, and insecticide input costs as affected by row configuration and lint price, 2021–2024^a.

Row configuration	Net return per hectare after seed, harvest, nitrogen, and insecticide input costs			
	2021	2022	2023	2024
	\$1.433 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	1845a	1419a	1005NS	1689b
4 × 1 skip row pattern	1773a	1543a	1154	1910a
2 × 1 skip row pattern	1704a	1247b	1057	1585b
1 × 1 skip row pattern	1556b	1465a	1122	1618b
	\$1.654 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	2239a	1748a	1270NS	2059b
4 × 1 skip row pattern	2132ab	1868a	1418	2291a
2 × 1 skip row pattern	2035b	1508b	1289	1899b
1 × 1 skip row pattern	1855c	1750a	1355	1927b
	\$1.874 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	2633a	2076a	1535NS	2428b
4 × 1 skip row pattern	2492ab	2192a	1682	2671a
2 × 1 skip row pattern	2366b	1769b	1521	2211b
1 × 1 skip row pattern	2154c	2035a	1587	2235b
	\$2.094 kg ⁻¹			
	\$ ha ⁻¹			
Solid planted	3027a	2405a	1799NS	2798b
4 × 1 skip row pattern	2851ab	2516a	1946	3051a
2 × 1 skip row pattern	2697b	2030b	1752	2524c
1 × 1 skip row pattern	2453c	2320a	1818	2543c

Note: Means within a column followed by the same letter are not statistically different according to Fisher's Protected LSD ($p \leq 0.05$). For columns beginning with NS, means are not statistically different.

^aData are pooled over all locations within each year.

years. In years where returns are similar between these two configurations, growers can utilize the 4 × 1 configuration to extend their operating finances over a larger hectareage. Conversely, in some years, returns may be greater than those of the commonly used solid row configuration. However, the 2 × 1 and the UWR configurations were seldom comparable, and never greater, than the economic returns of either the 4 × 1 or solid planted configurations, and therefore have little to no utility in North Carolina cotton production.

AUTHOR CONTRIBUTIONS

Michael M. Phillips: Formal analysis; investigation; methodology; writing—original draft. **Keith L. Edmisten:** Conceptualization; funding acquisition; methodology; project administration; resources; supervision; validation; writing—review and editing. **Guy D. Collins:** Conceptualization; funding acquisition; methodology; project administration; resources; supervision; validation; writing—review and editing. **Lori**

U. Snyder: Supervision; validation; writing—review and editing. **Jeremy Hendricks:** Investigation; methodology; resources; writing—review and editing.

ACKNOWLEDGMENTS

Funding for this research was provided by the North Carolina Cotton Producers Association through the Cotton Incorporated State Support Program. The researchers express their sincere gratitude to the staff of the Upper Coastal Plain Research Station, the Peanut Belt Research Station, and the Tidewater Research Station for their assistance.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

ORCID

Michael M. Phillips  <https://orcid.org/0009-0005-3019-1930>

Keith L. Edmisten  <https://orcid.org/0000-0002-9470-5882>
 Guy D. Collins  <https://orcid.org/0000-0002-6764-6661>
 Lori U. Snyder  <https://orcid.org/0000-0001-8968-0126>
 Jeremy Hendricks  <https://orcid.org/0009-0005-7586-1248>

REFERENCES

- Bednarz, C. W., Bridges, D. C., & Brown, S. M. (2000). Analysis of cotton yield stability across population densities. *Agronomy Journal*, 92(1), 128–135. <https://doi.org/10.2134/agronj2000.921128x>
- Bednarz, C. W., & Nichols, R. L. (2005). Phenological and morphological components of cotton crop maturity. *Crop Science*, 45(4), 1497–1503. <https://doi.org/10.2135/cropsci2004.0321>
- Bednarz, C. W., & Roberts, P. M. (2001). Spatial yield distribution in cotton following early-season floral bud removal. *Crop Science*, 41(6), 1800–1808. <https://doi.org/10.2135/cropsci2001.1800>
- Boquet, D. J. (2005). Cotton in ultra-narrow row spacing: Plant density and nitrogen fertilizer rates. *Agronomy Journal*, 97(1), 279–287. <https://doi.org/10.2134/agronj2005.0279>
- Boquet, D. J., Moser, E. B., & Breitenbeck, G. A. (1993). Nitrogen effects on boll production of field-grown cotton. *Agronomy Journal*, 85(1), 34–39. <https://doi.org/10.2134/agronj1993.00021962008500010007x>
- Bruce, R. R. (1965). Cotton row spacing as it affects soil water utilization and yield. *Agronomy Journal*, 57(4), 319–321. <https://doi.org/10.2134/agronj1965.00021962005700040001x>
- Buehring, N. W., Willcutt, M. H., Columbus, E. P., Phelps, J., & Ruscoe, A. F. (2006). *Yield and plant characteristics as influenced by spindle picker narrow and wide row patterns; three years progress report*. In *Proceedings of the beltwide cotton conferences* (pp. 1864–1870). National Cotton Council of America.
- Cotton Inc. (2010). *Harvest systems*. Cotton Incorporated. <https://www.cottoninc.com/cotton-production/ag-resources/harvest-systems/the-spindle-type-cotton-harvester/>
- Gatiboni, L., & Hardy, D. H. (2026). Fertilization. In *2026 cotton information* (pp. 63–77). NC State Extension Publications. <https://content.ces.ncsu.edu/cotton-information/fertilization>
- Gwathmey, C. O., Steckel, L. E., Larson, J. A., & Mooney, D. F. (2011). Lower limits of cotton seeding rates in alternative row widths and patterns. *Agronomy Journal*, 103(3), 584–592. <https://doi.org/10.2134/agronj2010.0333>
- Hall, J. M., Lawton, C. B., Snider, J. L., Roberts, P. M., & Hand, L. C. (2024). Investigating upland cotton (*Gossypium hirsutum* L.) varietal performance in alternative row arrangements in Georgia. *Agrosystems, Geosciences & Environment*, 7(3), e20546. <https://doi.org/10.1002/agg2.20546>
- Hall, S., Dodds, D., Pieralisi, B., Raper, T. B., Sandlin, T., Crow, W. D., Catchot, A., Irby, T., Krutz, L. J., Spencer, G. D., & Mills, B. E. (2024). Agroeconomic differences among alternative cotton row spacings and row patterns. *Agronomy Journal*, 116(2), 563–571. <https://doi.org/10.1002/agg2.21524>
- Hargett, J. (2000). Raising Cotton \$50 cheaper and harvesting 75% faster (Hargettspecial, nine-row cotton picker). In *Proceedings of the 2000 Beltwide Cotton Conferences* (pp. 93–94). National Cotton Council.
- Hawkins, B. S., & Peacock, H. A. (1968). Effect of skip-row culture on agronomic and fiber properties of upland cotton (*Gossypium hirsutum* L.) varieties. *Agronomy Journal*, 60(2), 189–191. <https://doi.org/10.2134/agronj1968.00021962006000020014x>
- Hawkins, B. S., & Peacock, H. A. (1973). Influence of row width and population density on yield and fiber characteristics of cotton. *Agronomy Journal*, 65(1), 47–51. <https://doi.org/10.2134/agronj1973.00021962006500010014x>
- Hons, F. M., & McMichael, B. L. (1986). Planting pattern effects on yield, water use and root growth of cotton. *Field Crops Research*, 13, 147–158. [https://doi.org/10.1016/0378-4290\(86\)90017-1](https://doi.org/10.1016/0378-4290(86)90017-1)
- Hutchins, S. H., & Pitre, H. N. (1984). Effects of soybean row spacing on spray penetration and efficacy of insecticides applied with aerial and ground equipment. *Environmental Entomology*, 13(4), 948–953. <https://doi.org/10.1093/ee/13.4.948>
- Iqbal, M., & Khan, M. A. (2011). Response of cotton genotypes to planting date and plant spacing. *Frontiers of Agriculture in China*, 5(3), 262–267. <https://doi.org/10.1007/s11703-011-1099-x>
- Jenkins, J. N., McCarty, J. C., Jr., & Parrott, W. L. (1990). Effectiveness of fruiting sites in cotton: Yield. *Crop Science*, 30(2), 365–369. <https://doi.org/10.2135/cropsci1990.0011183X0030000200024x>
- Jost, P., Shurley, D., Brown, S., McDaniel, R., McNeill, B., Clark, J., & Blackley, R. (2004). Skip-row cotton performance across multiple yield environments. In *2004 Beltwide Cotton Conference Proceedings* (pp. 108–116). <https://www.cotton.org/beltwide/cotton-conference-proceedings/getPDF.cfm?year=2004&paper=I094.pdf>
- Larson, J. A., Gwathmey, C. O., Mooney, D. F., Steckel, L. E., & Roberts, R. K. (2009). Does skip-row planting configuration improve cotton net return? *Agronomy Journal*, 101(4), 738–746. <https://doi.org/10.2134/agronj2008.0135x>
- Lawton, C. B., Snider, J. L., Chee, P. W., Hobby, S. T., Roberts, P. M., Pokhrel, A., Lee, J. M., Virk, G. K., & Hand, L. C. (2024). Impacts of wide row spacings on yield and yield components of upland cotton (*Gossypium hirsutum* L.). *Agronomy Journal*, 116(4), 1688–1696. <https://doi.org/10.1002/agg2.21579>
- Li, P., Dong, H., Zheng, C., Sun, M., Liu, A., Wang, G., Liu, S., Zhang, S., Chen, J., Li, Y., Pang, C., & Zhao, X. (2017). Optimizing nitrogen application rate and plant density for improving cotton yield and nitrogen use efficiency in the North China Plain. *PLoS One*, 12(10), e0185550. <https://doi.org/10.1371/journal.pone.0185550>
- McCarty, J. C., Jenkins, J. N., Hayes, R. W., & Wubben, M. J. (2017). Effects of plant density on boll retention and yield of cotton in the mid-South. *American Journal of Plant Sciences*, 8(04), 891–906. <https://doi.org/10.4236/ajps.2017.84060>
- Menefee, D., Smith, D. R., Zwonitzer, M., & Collins, H. P. (2023). Effects of row spacing and potassium foliar applications on yield of cotton. *Agrosystems, Geosciences & Environment*, 6(4), e20432. <https://doi.org/10.1002/agg2.20432>
- Mogalapu, S. (2013). *Dynamics and management of insect pests in BT cotton as influenced by plant density*. Acharya N. G. Ranga Agricultural University. <https://krishikosh.egranth.ac.in/items/21338ba4-0bc8-4a32-beda-32490ee1f77b/full>
- Nichols, S. P., & Snipes, C. E. (2004). Solid, skip, and wide row configurations in MS cotton. In *2004 Beltwide Cotton Conference Proceedings* (p. 2305). <https://www.cotton.org/beltwide/cotton-conference-proceedings/getPDF.cfm?year=2004&paper=I105.pdf>
- O'Berry, N. B., Faircloth, J. C., Edmisten, K. L., Collins, G. D., Stewart, A. M., Abaye, A. O., Herbert, D. A., Jr., & Haygood, R. A. (2008). Plant population and planting date effects on cotton (*Gossypium hirsutum* L.) growth and yield. *Journal of Cotton Science*, 12(3), 178–187.
- Parajulee, M. N., Shrestha, R. B., Slosser, J. E., & Bordovsky, D. G. (2011). Effects of skip-row planting pattern and planting date on

- dryland cotton insect pest abundance and selected plant parameters. *Southwestern Entomologist*, 36(1), 21–39. <https://doi.org/10.3958/059.036.0103>
- Parvin, D. W., Cooke, F. T., & McCarty, W. (1999). *The impact of current cotton price and production costs on skip-row cotton* (Research report 99-004). Mississippi State University. <https://doi.org/10.22004/ag.econ.15793>
- Scott, W. P., Adams, D. A., & Shaw, R. (1994). The effects of row spacings on cotton pest populations and yield. In *Proceedings of the Beltwide Cotton Conference* (pp. 910–911). National Cotton Council. <https://www.cotton.org/beltwide/proceedings/8395/abstracts/4374.cfm>
- Snowden, C., Ritchie, G., Cave, J., Keeling, W., & Rajan, N. (2013). Multiple irrigation levels affect boll distribution, yield, and fiber micronaire in cotton. *Agronomy Journal*, 105(6), 1536–1544. <https://doi.org/10.2134/agronj2013.0084>
- US EPA. (1997). *Texas cotton*. https://archive.epa.gov/oppefed1/web/html/met_tx_cotton.html?utm_source=chatgpt.com
- USDA-ERS. (2025). *Cotton cost and return—Economic research service*. https://ers.usda.gov/sites/default/files/_laserfiche/DataFiles/47913/CottonCostReturn.xlsx
- Wang, X., Hou, Y., Du, M., Xu, D., Lu, H., Tian, X., & Li, Z. (2016). Effect of planting date and plant density on cotton traits as relating to mechanical harvesting in the Yellow River valley region of China. *Field Crops Research*, 198, 112–121. <https://doi.org/10.1016/j.fcr.2016.09.010>
- Washburn, D. (2025). 2025 Cotton cost of production. In *2025 Cotton Information* (pp. 2–4). NC State Extension Publications. <https://content.ces.ncsu.edu/cotton-information/cotton-situation-and-outlook>
- Wrather, J. A., Phipps, B. J., Stevens, W. E., Phillips, A. S., & Vories, E. D. (2008). Cotton planting date and plant population effects on yield and fiber quality in the Mississippi Delta. *Journal of Cotton Science*, 12(1), 1–7.

How to cite this article: Phillips, M. M., Edmisten, K. L., Collins, G. D., Snyder, L. U., & Hendricks, J. (2026). Evaluating selected skip-row planting patterns for upland cotton (*Gossypium hirsutum* L.) in North Carolina. *Agronomy Journal*, 118, e70392. <https://doi.org/10.1002/agj2.70392>