**ABSTRACT**

BUNCH, LILLY. Developing and Delivering Soybean Production Recommendations Through Field Research (soybean growth habit influence on growth, yield, and seed quality) and Dynamic Tool Development (Beans Gone Wild). (Under the direction of Dr. Rachel A. Vann).

Soybean (*Glycine max* (L.) Merr.) is a crucial crop in North Carolina, where growers are now able to select between determinate and indeterminate growth habits within the same relative maturity group. Traditionally, soybean production in the state has favored later-maturing, determinate varieties. However, growing interest in earlier-maturing, indeterminate cultivars has led to questions about how growth habit affects agronomic performance in North Carolina.

The study investigated in chapter one observes the influence of soybean growth habit on aspects such as plant height, number of nodes, lodging, green stem, yield, and seed quality across nine environments over the 2023–2024 growing seasons, within relative maturity group 5. The trial included five determinate and five indeterminate varieties, planted from late-April to early-May. Growth habit significantly impacted characteristics like plant height, node number, and green stem, but its effect on yield varied depending on the environment. Indeterminate varieties generally showed increased height and more nodes at maturity, reflecting their prolonged vegetative growth phase. Nonetheless, growth habit alone did not consistently affect yield or seed quality across all environments.

Chapter two takes advantage of aiding the soybean sector by utilization of a dynamic interface. Soybean production in North Carolina is supported by a network of knowledgeable field-based professionals, including Extension agents, crop consultants, and agronomists, who regularly diagnose and manage in-field issues. Despite the wealth of information exchanged through these interactions, much of it is never formally documented or shared for broader educational use.

To address this gap, Beans Gone Wild (BGW) was launched as a collaborative, statewide initiative to centralize and publicly catalog real-time soybean production issues. Developed with input from Extension specialists, the NC Plant Disease and Insect Clinic (PDIC), and industry partners, BGW features an interactive map and searchable problem library supported by research-based references. Following its beta year in 2023, BGW expanded its contributor base and outreach efforts in 2024, resulting in a 56% increase in reported issues and significant growth in user engagement. By linking field-based observations with science-backed resources, BGW empowers farmers, consultants, educators, and students to make informed, timely decisions.

Developing and Delivering Soybean Production Recommendations Through Field Research (soybean growth habit influence on growth, yield, and seed quality) and Dynamic Tool Development (Beans Gone Wild)

by
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## DEDICATION

This thesis is dedicated to my parents, Ricky and Denise Bunch, my sisters and their families Kaitlin Layden and Abigayle Colson, and Jeremy Guelfi. Thank you all for the unwavering love, support, and prayer you all have poured into me. Thank you for the sacrifices each of you made for me.

To my high school agriculture teacher and FFA advisor, Chelsea Leary, thank you for truly encouraging my love for agriculture and always pushing me to be my best.

## BIOGRAPHY

Lilly Bunch, daughter of Ricky and Denise Bunch, was born on January 11, 2002 in Edenton, North Carolina. She was raised in a farming community and had a loved for agriculture at a young age. That interest grew throughout high school where she graduated in the spring of 2020 from John A. Holmes. Following high school, she attended College of the Albemarle for one year, then transferring to North Carolina State University where she graduated in the Spring of 2023 with a Bachelors degree Agricultural Science and a minor in Crop Science. In the Summer of 2023, she started to pursue a Master of Science degree in Crop Science under Dr. Rachel A. Vann. Lilly enjoys spending time at home with her family, and eating Mexican food with her friends. She also enjoys outdoor activities such as hunting, playing tennis, boat rides on the river, and playing with her nieces and nephew.

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# CHAPTER 1

## Investigating soybean growth habit influence on development, yield, and seed quality in North Carolina full-season soybean production (Metric Units)

**ABSTRACT**

Soybean (Glycine max (L.) Merr.) is a vital crop in North Carolina, where growers are increasingly presented with the option to choose between determinate and indeterminate growth habits within the same maturity group. Historically, North Carolina soybean production has relied on later maturing, determinate varieties, but recent interest in earlier maturing, indeterminate cultivars, common in the Midwest, has raised questions about growth habit effects on agronomic performance in North Carolina. This study evaluated the impact of soybean growth habit on plant height, node count, lodging, green stem, yield, and seed quality across nine environments over two years (2023–2024) within relative maturity 5. Trials were conducted using five determinate and five indeterminate varieties planted between late-April and early-May. While growth habit significantly influenced aspects such as plant height, node count, and green stem, the effect on yield was variable and environment-dependent. Indeterminate varieties exhibited greater height and node count at maturity, consistent with their extended period of vegetative growth. However, growth habit alone did not consistently influence final yield or seed quality outcomes across environments. These findings provide clarity for North Carolina soybean producers evaluating new varietal options.

**NOMENCLATURE**

Soybean, Glycine max (L.) Merr, flowering, maturity, determinate, indeterminate

**KEYWORDS**

Soybean, growth habit, stand, height, node count, lodging, green stem, yield,

**INTRODUCTION**

Soybean (Glycine max (L.) Merr.) is a critical worldwide crop that has many end uses including animal feed, food products, oil, and industrial products (USDA-ERS, 2025a). The

United States agricultural industry plays a large role in worldwide soybean production as demand continues to increase. Soybean producers in the United States also play a vital role in the country's agricultural trade volume for grains, feed, and the oilseed sector (USDA-ERS, 2025a). In 2023 alone, soybeans accounted for $56.1 billion in total U.S. cash crop receipts (USDA-ERS, 2025b.). This economic significance highlights the crop's role in both domestic and international agricultural markets.

In North Carolina, soybeans rank first in row crop acreage, covering approximately 667,731 hectares (Vann et al., 2021). The prominence of soybeans in North Carolina can be attributed to the state's diverse cropping systems and strong demand. Growers in North Carolina frequently rotate soybeans with crops such as tobacco, sweet potatoes, cotton, wheat, and peanuts (Vann et al., 2021).

North Carolina has diverse soybean management practices due to geographic variability and rotational complexity that include the use of a wide range of maturity groups and an extended planting window (Vann et al., 2021). Although maturity groups 2-7 are utilized in North Carolina, maturity groups 5-7 have historically been the most commonly grown varieties (Vann et al., 2021).

Soybeans can be classified into two main growth habits: determinate and indeterminate. Determinate soybeans cease vegetative growth on the main stem once reproductive growth begins, leading to a more uniform and predictable development pattern. In contrast, indeterminate soybeans continue vegetative growth for several weeks after reproductive growth begins, allowing for greater adaptability to varying environmental conditions (Vann & Stowe, 2022). In the field, there are distinct differences between determinate and indeterminate varieties. Growers can note the difference by looking at the terminal node of the determinate variety with a long flowering raceme while the indeterminate variety will have a dominant apical growing point (Conley et al., 2018).

In the United States, indeterminate varieties are primarily grown in the North and Midwest, typically within maturity groups <4.5 (Mourtzinis & Conley, 2017). Conversely, determinate varieties are used more in the Southern regions, utilizing maturity groups >4.5 (Mourtzinis & Conley, 2017).

Growers in North Carolina often associate higher yields with earlier maturing, indeterminate varieties that are grown in regions such as the Midwest United States. Historically, North Carolina soybean producers have grown later maturing varieties. However, in recent years there has been a shift to using earlier maturing varieties due to their association with higher yields (Vann et al., 2021). Studies conducted by Heatherly (2005) are considered a contributing factor to this shift. In these studies, Heatherly (2005) observed that yield in the midsouthern United States is affected by maturity group and planting date. Heatherly (2005) noted the average yield of the maturity group 4 cultivars was greater than maturity group 5 cultivars. While average yield from the earlier planting date (before April 16) was greater than the later planting date (April 16- May 1). Concluding, planting cultivars that are later than what is required to reach maximum yield results in a greater risk for damaging late-season effects (Heatherly, 2005). To date, it has been hard to determine the cause for earlier maturing varieties maximizing yield in the North Carolina environment and the role that soybean growth habit plays.

Advances in breeding techniques and genetics have also altered the maturity groups where an indeterminate growth habit are available. Growers are now being marketed later maturing, indeterminate varieties (DONMARIO Seeds, n.d.). These later maturing indeterminate varieties have led to an overlap in growth habit within maturity groups that are commonly grown in North Carolina, more specifically maturity group 5. As a result, many North Carolina soybean growers have raised questions about the effect of soybean growth habit on yield.

Even though there is increasing interest surrounding soybean growth habit and its effect on yield within certain maturity groups, there is limited research addressing this specific topic. There are a few studies that provide insight into the relationship between growth habit, pest management, nutrient uptake, and production practices. Possebom et al. (2024) looked at the relationship of soybean growth habit and corn earworm oviposition throughout the canopy. In this study they evaluated four varieties, two indeterminate and two determinate, all within relative maturity group 5. After two years of this study, no yield differences were found between the indeterminate and determinate varieties within the same relative maturity group in the mid-June planting date (Possebom et al., 2024).

In another study Parvej et al. (2015) compared an indeterminate maturity group 4 or determinate maturity group 5 soybean variety to assess if they were affected differently by potassium deficiency. They evaluated seed yield and certain yield components in long-term plots grown under three potassium fertility levels: low, medium, and high. Parvej et al. (2015) concluded that the yield loss caused by potassium deficiency was attributed to the same principal mechanisms of reduced pod number and increased seed abortions, regardless of growth habit. Additionally, Pyle et al. (1982) compared the yield potential of double-cropped determinate and indeterminate soybean lines in Virginia. Pyle et al. (1982) looked at flowering date, flower color, mid-season height, mature height, days to maturity, pubescence color, leaf type, seed yield, seed size, percent purple seed stain, percent seed coat mottling, and seed quality score. Many soybean lines were crossed and evaluated over two planting dates. While results varied due to weather conditions, indeterminate varieties consistently showed greater lodging than the determinants.

Yield varied across location and planting date, however in most cases the determinate lines were higher yielding than the indeterminate lines (Pyle et al., 1982).

Robinson and Wilcox (1998) compared determinate and indeterminate near-isolines across planting dates and row spacings. After a two year study Robinson and Wilcox (1998) concluded there was no association between isolines for seed yield at the early planting date, but there was a weak association at the later planting date, with the indeterminate isolines having the advantage. This suggested the two growth habits responded differently to environmental factors that affect seed yield (Robinson & Wilcox, 1998).

Studies conducted by Heatherly and Smith (2004) observed soybean height and node count of indeterminate maturity group 4 cultivars and determinate maturity group 5 cultivars. By conducting field trials with April and May planting dates to simulate early soybean production practices in the midsouthern United States, Heatherly and Smith (2004) concluded both height and node count in maturity 5 cultivars were greater at flowering (R1) compared to the maturity group 4 cultivars. However, at stem termination (ST) height and node count were greater in the maturity group 4 cultivars compared to the maturity group 5 cultivars (Heatherly & Smith, 2004).

As soybean genetics and production practices evolve, it is crucial to understand the effect soybean growth habit plays on yield stability within an overlapping maturity group in North Carolina. Especially now, as growers have the opportunity to effectively choose between the two growth habits within the same maturity group when in recent years this was not an option for North Carolina soybean growers.

The objective of this project was to investigate soybean growth habit impact on soybean height, soybean nodes, lodging, green stem, soybean yield, and seed quality in full-season soybean production (planting late-April to mid-May) in maturity group 5 varieties.

## MATERIALS AND METHODS

### Environmental Description and Plot Management

To represent the various growing conditions across North Carolina, field trials were installed at multiple environments (environment=combination and year and location). In 2023, these environments included four on-farm trials in Hyde, Sampson, Yadkin, and Union counties. In 2024, these environments included two on-farm environments in Bladen and Perquimans county and three research stations in Rowan, Granville, and Washington counties. Plots were installed using a Wintersteiger Plotseeder XXL (WINTERSTEIGER Seedmech North America, Elkhart, IA, USA) at 308,881 seeds $ha^{-1}$ in a 7.6 m by 1.5 m plot with four rows at 38.1cm row-spacing. The environment, soil type, tillage, previous crop, planting date, and harvest date can be viewed in Table 1.

### Treatment Description

Trials were installed as a randomized complete block with six replications. Treatments included five determinate and five indeterminate varieties, all maturity group V. Planting occurred between late-April and early-May (Table 1). Variety, growth habit, relative maturity, and seed company for each treatment can be found in Table 2. Two Enlist varieties were planted in both years, one indeterminate (P51A33SE) and one determinate (P52A14SE), however, due to difficulties in managing herbicide drift in Enlist soybeans these varieties were removed from the analysis in both years. In 2024 in Washington county a harvest aid (0.494 kg/L paraquat dichloride – Gramoxone, Syngenta Corporation) was applied at growth stage R6.5. In 2024 in Perquimans, Bladen, Granville, and Rowan counties a harvest aid (0.599 kg/L sodium chlorate – Defol 5, Drexel Chemical Company) was applied at growth stage R6.5.  In 2023, no harvest aid was applied.

**Data Collection**

Soybean stand counts were collected between V2 and V4 by randomly placing two, one meter sticks in the second and third plot rows, counting the number of plants, averaging across the plot, and converting to plants $ha^{-1}$.

Plant heights and node counts were done as each variety reached the R1 (beginning flowering) and R8 (maturity) growth stages. Plant height was measured in cm from the ground to the newest fully formed trifoliate. Node counts were captured by counting each node on the main stem. Five measurements were collected per plot and averaged. It is important to note that Sampson-2023 was removed from analysis for height and node count at R1 due to data of determinate varieties not being collected. Sampson-2023 was added back into analysis for height and node count at R8.

Green stem and lodging ratings were taken as a percentage (0-100) in each plot at harvest at environments where green stem and lodging were present. For each plot, three sets of 10 random plants were assessed for green stem and lodging. The three groups of 10 were averaged to establish the overall plot percentage.

After reaching R8, plots were harvested using a Wintersteiger Quantum Pro small-plot combine. Yields were adjusted to a 13% moisture content. To assess seed damage and purple seed stain following the methods outlined in Morris et al. (2021), a 100 g grain subsample was obtained from each plot and quantified using the USDA injury grading guidelines (USDA-AMS

2023). Cleaned samples were analyzed for protein and oil content using near-infrared spectroscopy (DA-7520 NIR Spectrometer, PerkinElmer Inc.).

**Statistical Analysis**

To investigate the impact of growth habit, a mixed model was fit using PROC GLIMMIX in SAS Version 9.4 (SAS Institute Inc., Cary, NC). Response variables of interest included stand counts, height at flowering and maturity, nodes at flowering and maturity, green stem, lodging, yield, damage, purple seed stain, and protein, and oil. To test the effect of growth habit, results were averaged across varieties.

For all analyses, location and year were combined to create an 'environment' variable. Fixed effects included environment, growth habit, and the interaction of environment and growth habit. Replication nested within environment was considered a random effect. Stand count, yield, and height variables were modeled using normal or lognormal distributions when needed. Node counts were modeled with poisson distribution and percent variables were modeled using beta distribution. Kenward-Rogers adjustment was used for the denominator degrees of freedom. The LSMEANS statement was used with Tukey's adjustment to decompose significant interactions.

## RESULTS AND DISCUSSION

**Plant Stand**

Growth habit did not have an impact on soybean stand in all but one environment (Table 3). In Yadkin-2023, soybean growth habit did influence soybean stand. Determinate varieties resulted in 30,758 plants/ha greater stand than indeterminate varieties. As expected, environment ($p<0.001$) had an influence on soybean stand (Figure 1). While conducting an analysis by environment we observed that the highest plant stands were in Perquimans-2024 with 321,882 plants/ha and Hyde-2023 with 307,873 plants/ha (Figure 1). The lowest plant stands were in Union-2023 with 216,191 plants/ha and Yadkin-2023 204,656 plants/ha (Figure 1). Plant stand is impacted by seeding rate, seed quality, and environmental conditions following planting and this research indicates these factors influence stand more than soybean growth habit

**Plant Height**

Soybean growth habit impacted soybean height differently at each environment (Table 3). For height at R1, environment (E), growth habit (GH), and the interaction of GHxE were all significant with p-values of $< 0.001$ (Table 3). The effect of growth habit on height at R1 was significant at every environment apart from Yadkin-2023 and Rowan-2024 (Figure 2).

Across each of the significant environments, determinate varieties generally resulted in greater height at R1 than indeterminate varieties with differences in height between growth habits ranging from 2.3 to 50.6 cm (Figure 2). Heatherly & Smith (2004) similarly observed that a determinate maturity group 5 is taller at R1 compared to an indeterminate maturity group 4. It was stated that this was likely the result of the determinate R1 growth stage occurring two to three weeks later than the indeterminate R1 growth stage. Pyle et al. (1982) observed that determinate lines were significantly taller than indeterminate lines at midseason height (midway through flowering).

For height at R8, environment, GH, and the interaction of GHxE were all significant with p-values of $<0.001$ (Table 3). Only Sampson-2023, Bladen-2024, and Perquimans-2024 had significant differences between the two growth habits (Figure 2). Within these environments, indeterminate varieties resulted in greater heights than determinate varieties. Similarly observed in other studies, indeterminate varieties were taller than determinate varieties at maturity (Pyle et al., 1982; Heatherly & Smith, 2004; Robinson & Wilcox, 1998).

The significant increase in plant height between growth habits from R1 to R8 can be attributed to indeterminate variety genetics. Indeterminate varieties are bred to flower for a longer period of time compared to determinate varieties. Indeterminate varieties continue vegetative growth after reproductive growth begins (Vann & Stowe, 2022). In other words, an indeterminate stem will continue terminal growth, growing taller and putting on additional branches, as long as lateral growth continues (Heatherly & Smith, 2004).

**Plant Node Count**

Soybean growth habit impacted soybean node count differently at each environment (Table 3). For node count at R1, environment, GH, and the interaction of GHxE were all significant with p-values of $<0.001$ (Table 3). Growth habit impacted node count at R1 in every environment apart from Hyde-2023 and Union-2023 (Figure 3).

Within these significant environments, determinate varieties generally resulted in greater node counts at R1 than indeterminate varieties with differences in node counts between growth habits ranging from 0.45 nodes to 4.5 nodes (Figure 3). Apart from Yadkin-2023, where indeterminate varieties averaged 1.6 more nodes over determinate varieties (Figure 3). This could have been due to Yadkin-2023 being a stressed environment. It was cool and dry at planting and hot and dry through the reproductive period. Parvej et al. (2015) observed that soybean growth habit affected both main stem and branching node numbers. In this study (planted in late-April to mid-May) growth habit was the only factor that was significant for node count. In agreeance with Parvej et al. (2015), Heatherly & Smith (2004) observed determinate cultivars generally had more nodes than indeterminate varieties at R1 (plantings occurred in early to mid-April and early-May).

For node count at R8, environment, GH, and the interaction of GHxE were all significant with p-values of <0.001 (Table 3). Every environment, apart from Yadkin-2023 had significant differences between the two growth habits (Figure 3). Within each of these environments indeterminate varieties generally resulted in greater node counts at R8 than determinate varieties with differences in node counts between growth habits ranging from 0.32 nodes to 5.6 nodes (Figure 3). Similarly, Heatherly & Smith (2004) observed indeterminate cultivars had greater node counts at ST (stem termination) than determinate cultivars.

The notable increase in node count between determinate and indeterminate varieties from R1 to R8 can be credited to genetics of indeterminate varieties. Indeterminate varieties are bred to flower for a longer period of time compared to determinate varieties. As indeterminate varieties continue vegetative growth after reproductive growth begins, the indeterminate stem will continue terminal growth, growing taller and putting on additional branches, as long as lateral growth continues (Heatherly & Smith, 2004). We observed similar trends in this study, as indeterminate varieties continued to grow laterally later in the season after determinate varieties had slowed in lateral growth and additional branch production.

**Lodging**

Soybean growth habit impacted soybean lodging at R8 differently at each environment (Table 3). For lodging at R8, environment was significant with a p-value of <0.001, and the interaction of GHxE was significant with a p-value of 0.002 (Table 3). Bladen-2024, Oxford, Rowan-2024, and Washington-2024 were removed from the analysis due to all or most values for the lodging rating being zero. From the five environments within the analysis where lodging was present, there was no significant difference between the two growth habits (Figure 4).

There were notable distinctions within environments that were not significantly different. The largest difference was observed in Yadkin-2023 where indeterminates generally averaged 16.5% more lodging over determinants. Comparably, Robinson & Wilcox (1998) observed taller indeterminate isolines lodged more than the shorter determinate isolines. Heatherly & Smith (2004) noted determinate stems generally produce a thick stem tip, due to stem girth continuing growth after stem length has ceased. A thicker stem girth has the potential to be less prone to breaking or producing weaker stems, which leads to lodging. This could be a factor as to why more indeterminates lodged in this particular study. In Union-2023, the determinate varieties generally averaged 8.3% more lodging over the indeterminate varieties. Determinate varieties were 1.5 cm shorter and had two less nodes than indeterminate varieties at R8, but showed greater loading even still.

**Green Stem**

Soybean growth habit impacted soybean green stem at R8 differently at each environment (Table 3). For green stem at R8, environment was significant with a p-value of <0.001, GH was significant with a p-value of 0.0201, and the interaction of GHxE was significant with a p-value of 0.005 (Table 3). Bladen-2024 and Washington-2024 were removed from the analysis due to all or most values for the lodging rating being zero. From the seven environments within the analysis, the effect of green stem at R8 was significant in Hyde-2023, Sampson-2023, and Union-2023 (Table 3).

Across each of these significant environments, indeterminate varieties generally resulted in greater green stem than determinate varieties (Figure 5). The largest difference was noted in Sampson-2023 where indeterminates averaged 26.37% more green stem over determinate varieties. A study by Hill et al. (2006) compared green stem disorder from private and public breeding organizations to determine if cultivar genetics is a factor in the green stem disorder. The study indicates genetic variability among cultivars for green stem sensitivity is prevalent. However, it is still unknown why there is greater green stem within the indeterminate varieties of this study.

**Yield**

Soybean growth habit impacted soybean yield differently at each environment (Table 3). For soybean yield, environment and the interaction of GHxE were significant with p-values of <0.001 (Table 3). The effect of growth habit on yield was significant in Hyde-2023, Sampson-2023, Bladen-2024, and Perquimans-2024 (Table 3).

In two of the four significant environments (Sampson-2023 and Bladen-2024) determinate varieties out yielded the indeterminate varieties where yield differences between growth habits ranged from 245.5 kg/ha$^{-1}$ to 830.5 kg/ha$^{-1}$ (Figure 6). A study conducted by Pyle et al. (1982) observed in most environments determinate lines out yielded indeterminate lines, and noted to be significantly different.

In two of the four significant environments (Hyde-2023 and Perquimans-2024) indeterminate varieties out yielded the determinate varieties where yield differences between growth habits ranged from 204.4 kg/ha$^{-1}$ to 1028.9 kg/ha$^{-1}$ (Figure 6). Similarly, Robinson & Wilcox (1998) looked at the four highest yielding varieties from each growth habit and in all cases the indeterminate cultivars out yielded the determinate cultivars. Possebom et al. (2024) also noted indeterminate varieties to yield more than determinate varieties. It is important to note that Yadkin-2023 is not mentioned for yield because yield for both indeterminate and determinate varieties was 6725 kg/ha$^{-1}$ (Figure 6).

**Seed Quality**

Soybean growth habit impacted soybean damage differently at each environment (Table 3). For soybean percent damage after harvest, environment, GH, and the interaction of GHxE were significant with a p-value of <0.001 (Table 3). The effect of growth habit on damage was significant in six environments (Table 3). Within those significant environments percent damage for determinate varieties ranged from 0.94% to 11.65% and averaged 5.6% (Table 4). Percent damage for indeterminate varieties ranged from 2.82% to 13.74% and averaged 7.7% (Table 4). In all six of the significant environments, indeterminate varieties had greater percent damage (Table 4). O'Reilly et al. (2025) observed similar ranges of damage in maturity group 5 varieties in a study in North Carolina.

Soybean growth habit impacted soybean purple seed stain (PSS) differently at each environment (Table 3). For soybean percent purple seed stain after harvest, environment, GH, and the interaction of GHxE were significant with a p-value of <0.001 (Table 3). The effect of growth habit on PSS was significant in seven environments (Table 3). Percent PSS for determinate varieties ranged from 0.19% to 4.65% and averaged 1.7% (Table 4). Percent PSS for indeterminate varieties ranged from 0.23% to 11.89% and averaged 4.9% (Table 4). In all nine environments, indeterminate varieties had greater PSS than determinate varieties (Table 4). O'Reilly et al. (2025) observed ranges of PSS across environments of North Carolina very interchangeably to this study, outside of O'Reilly et al. (2025) Johnston 2022 environment.

Soybean growth habit impacted soybean protein and oil content differently at each environment (Table 3). For soybean percent protein after harvest, environment and GH, were significant with p-values of <0.001. The interaction of GHxE was significant with a p-value of 0.005 (Table 3). For soybean percent oil after harvest, environment and GH were significant with p-values <0.001. The interaction of GHxE was significant with a p-value of 0.052 (Table 3). The effect of growth habit on protein was significant in five environments, while oil was significant in all nine (Table 3) Clemente & Cahoon, 2009 state that protein and oil percentages in soybeans is influenced by environmental cues, averaging approximately 20% of the influence.

Percent protein for determinate varieties ranged from 32.74% to 36.73% and averaged 34.7%, while indeterminate varieties ranged from 32.49% to 36.75% and averaged 34.3% (Table 4). Percent PSS for indeterminate varieties ranged from 0.23% to 11.89% and averaged 4.9% (Table 4). In seven of the nine environments, determinate varieties had a greater percent protein over indeterminate. Percent oil for determinate varieties ranged from 16.79% to 18.48% and averaged 17.2%, while indeterminate varieties ranged 17.05% to 18.88% and averaged 17.7% (Table 4). In all nine environments, indeterminate varieties had a greater percent oil over determinate. It is interesting to note that while protein was higher in most of the determinate varieties, oil was higher in all of the indeterminate varieties. When looking through the span of protein and oil from the O'Reilly et al. (2025) study specifically within maturity group 5 along with the Morris et al. (2021) study specifically within the mid-April planting date, we saw similar ranges across protein and oil.

**CONCLUSIONS**

This research provides important insights into the role of soybean growth habit in full-season maturity group 5 production in North Carolina. While determinate and indeterminate varieties exhibited clear physiological differences in plant height and node count, these differences did not translate into consistent yield or seed quality advantages across individual environments. Indeterminate varieties tended to continue vegetative growth later into the season, resulting in taller plants and more nodes at maturity; however, this did not reliably enhance performance under North Carolina conditions. The significant growth habit by environment interaction observed for several traits emphasizes the complexity of soybean production and highlights the need for localized data when selecting between growth habits. Ultimately, the choice between determinate and indeterminate varieties within maturity group 5 should be guided by specific environmental conditions and management goals rather than an assumption of growth habit superiority. As breeding advances continue to expand varietal options, growers in North Carolina will benefit from targeted research.

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Table 1. Location, soil type, tillage, previous crop, planting date, and harvest date for each environment.

| Environment | Longitude and Latitude (°N) | Soil Type | Tillage | Previous Crops | Planting Date | Harvest Date |
|---|---|---|---|---|---|---|
| Hyde-2023 | 35.475236, -76.020129 | Hydeland Silt loam | Conventional | Corn | 5/11/2023 | 10/26/2023 |
| Sampson-2023 | 35.16549, -78.23191 | Woodington loamy sand | Conventional | Corn | 5/13/2023 | 11/3/2023 |
| Yadkin-2023 | 36.2407866, -80.5804336 | Nathalie fine sandy loam | No-till | Corn | 5/18/2023 | 11/7/2023 |
| Union-2023 | 35.145005, -80.404450 | Goldston-Badin complex | No-till | Cotton | 5/10/2023 | 10/27/2023 |
| Perquimans-2024 | 36.26570, -76.40231 | Cape fear loam | Conventional | Sweet Corn | 4/23/2024 | 10/15/2024 |
| Washington-2024 | 35.84930, -76.65547 | Portsmouth fine sandy loam | Conventional | Corn | 4/23/2024 | 10/21/2024 |
| Bladen-2024 | 34.49435, -78.79185 | Nahunta sandy loam | Conventional | Tobacco | 4/24/2024 | 10/12/2024 |
| Granville-2024 | 36.32753, -78.65717 | Cecil sandy loam | Conventional | Corn | 4/29/2024 | 10/23/2024 |
| Rowan-2024 | 35.69026, -80.62627 | Lloyd clay loam | No-till | Corn | 4/25/2024 | 10/11/2024 |

Table 2. Variety, growth habit, relative maturity, and seed company.

| Variety | Growth Habit | Relative Maturity | Seed Company |
|---|---|---|---|
| DM55F62 | Indeterminate | 5.5 | DON MARIO |
| AG52XF0 | Indeterminate | 5.2 | Asgrow |
| AG53XF2 | Indeterminate | 5.3 | Asgrow |
| AG56XF2 | Determinate | 5.6 | Asgrow |
| AG58XF3 | Determinate | 5.8 | Asgrow |
| S51XF84 | Indeterminate | 5.1 | Dyna-Gro |
| S58XF24 | Determinate | 5.8 | Dyna-Gro |
| S54XF62 | Determinate | 5.4 | Dyna-Gro |

Table 3. Summarized ANOVA table for plant stand, height, node count, lodging, green stem, yield, damage, purple seed stain (PSS), protein, and oil combined across environments and by individual environments. NS meaning ‘Not Significant’, and the asterisk (*) meaning the environment was not included in the analysis for that variable.

| Dependent Variable | Source | Combined Analysis | Hyde-23 | Sampson-23 | Union-23 | Yadkin-23 | Bladen-24 | Granville-24 | Perquimans-24 | Rowan-24 | Washington-24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stand (plants/ha) | GH | NS | NS | NS | NS | 0.021 | NS | NS | NS | NS | NS |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | NS | - | - | - | - | - | - | - | - | - |
| Height at R1 (cm) | GH | <0.001 | <0.001 | * | <0.001 | NS | <0.001 | <0.001 | <0.001 | NS | <0.001 |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | <0.001 | - | - | - | - | - | - | - | - | - |
| Nodes at R1 | GH | <0.001 | NS | * | 0.0002 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | <0.001 | - | - | - | - | - | - | - | - | - |
| Height at R8 (cm) | GH | <0.001 | 0.002 | <0.001 | NS | 0.023 | <0.001 | 0.001 | <0.001 | 0.019 | 0.002 |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | <0.001 | - | - | - | - | - | - | - | - | - |
| Nodes at R8 | GH | <0.001 | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | <0.001 | - | - | - | - | - | - | - | - | - |
| Lodging (%) | GH | NS | NS | NS | 0.023 | 0.002 | * | * | NS | * | * |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | 0.002 | - | - | - | - | - | - | - | - | - |
| Green Stem (%) | GH | 0.0201 | 0.004 | 0.004 | 0.02 | NS | * | NS | NS | NS | * |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | 0.005 | - | - | - | - | - | - | - | - | - |
| Yield (kg/ha) | GH | 0.729 | 0.004 | 0.016 | NS | NS | 0.038 | NS | 0.002 | NS | NS |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | <0.001 | - | - | - | - | - | - | - | - | - |

Table 3 (*continued*). Summarized ANOVA table for plant stand, height, node count, lodging, green stem, yield, damage, purple seed stain (PSS), protein, and oil combined across environments and by individual environments. NS meaning 'Not Significant', and the asterisk (*) meaning the environment was not included in the analysis for that variable.

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Damage (%) | GH | <0.001 | <0.001 | <0.001 | <0.001 | 0.004 | NS | 0.049 | NS | NS | 0.043 |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | <0.001 | - | - | - | - | - | -- | - | - | - |
| PSS (%) | GH | <0.001 | NS | 0.011 | <0.001 | NS | <0.001 | <0.001 | <0.001 | 0.002 | 0.02 |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | <0.001 | - | - | - | - | - | - | - | - | - |
| Protein | GH | <0.001 | 0.006 | NS | NS | <0.001 | 0.002 | 0.03 | 0.001 | NS | NS |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | 0.005 | - | - | - | - | - | - | - | - | - |
| Oil | GH | <0.001 | 0.007 | 0.001 | 0.027 | <0.001 | <0.001 | <0.001 | <0.001 | 0.058 | 0.001 |
| | E | <0.001 | - | - | - | - | - | - | - | - | - |
| | GHxE | 0.052 | - | - | - | - | - | - | - | - | - |

Table 4. Summary of damage, purple seed stain (PSS), protein and oil for determinate and indeterminate growth habits. For each variable, means followed by the same letter are not significantly different at $p \leq 0.10$ based on Tukey's Honestly Significant Difference (HSD).

| Dependent Variable | Growth Habit | Hyde-23 | Sampson-23 | Union-23 | Yadkin-23 | Bladen-24 | Granville-24 | Perquimans-24 | Rowan-24 | Washington-24 |
|---|---|---|---|---|---|---|---|---|---|---|
| Damage | Determinate | $3.5^{CD}$ | $7.4^{ABC}$ | $1.2^{E}$ | $0.9^{E}$ | $11.7^{A}$ | $8.3^{AB}$ | $3.4^{CD}$ | $6.1^{ABCD}$ | $8.0^{AB}$ |
| | Indeterminate | $9.7^{AB}$ | $13.7^{A}$ | $4.7^{BCD}$ | $2.8^{DE}$ | $11.2^{A}$ | $12.1^{A}$ | $3.4^{CD}$ | $7.7^{ABC}$ | $4.6^{BCD}$ |
| PSS | Determinate | $0.7^{D}$ | $0.2^{D}$ | $0.6^{D}$ | $0.2^{D}$ | $2.6^{CD}$ | $4.7^{BC}$ | $1.3^{D}$ | $3.4^{D}$ | $1.4^{D}$ |
| | Indeterminate | $0.9^{D}$ | $2.0^{D}$ | $7.9^{AB}$ | $0.2^{D}$ | $8.0^{AB}$ | $11.9^{A}$ | $4.2^{C}$ | $5.4^{BC}$ | $3.2^{CD}$ |
| Protein | Determinate | $35.8^{B}$ | $36.7^{A}$ | $34.2^{CDE}$ | $33.6^{EF}$ | $35.7^{B}$ | $34.9^{BCD}$ | $34.9^{BC}$ | $32.7^{FG}$ | $33.7^{DEF}$ |
| | Indeterminate | $34.9^{BC}$ | $36.8^{A}$ | $34.1^{CDE}$ | $32.8^{FG}$ | $34.8^{CD}$ | $34.1^{CDE}$ | $34.2^{CDE}$ | $32.5^{G}$ | $34.2^{CDE}$ |
| Oil | Determinate | $16.9^{IH}$ | $16.5^{I}$ | $17.2^{EFGH}$ | $17.3^{EFG}$ | $16.8^{HI}$ | $17.1^{FGH}$ | $17.1^{GH}$ | $18.5^{B}$ | $17.2^{FGH}$ |
| | Indeterminate | $17.2^{FGH}$ | $17.0^{GH}$ | $17.7^{CDEF}$ | $18.1^{BC}$ | $17.4^{EFG}$ | $17.8^{CDE}$ | $17.9^{CD}$ | $18.9^{A}$ | $17.6^{DEFG}$ |

Figure 1. Impact of environment on soybean stand. Means followed by the same letter are not significantly different at p ≤ 0.10 based on Tukey's Honestly Significant Difference (HSD).

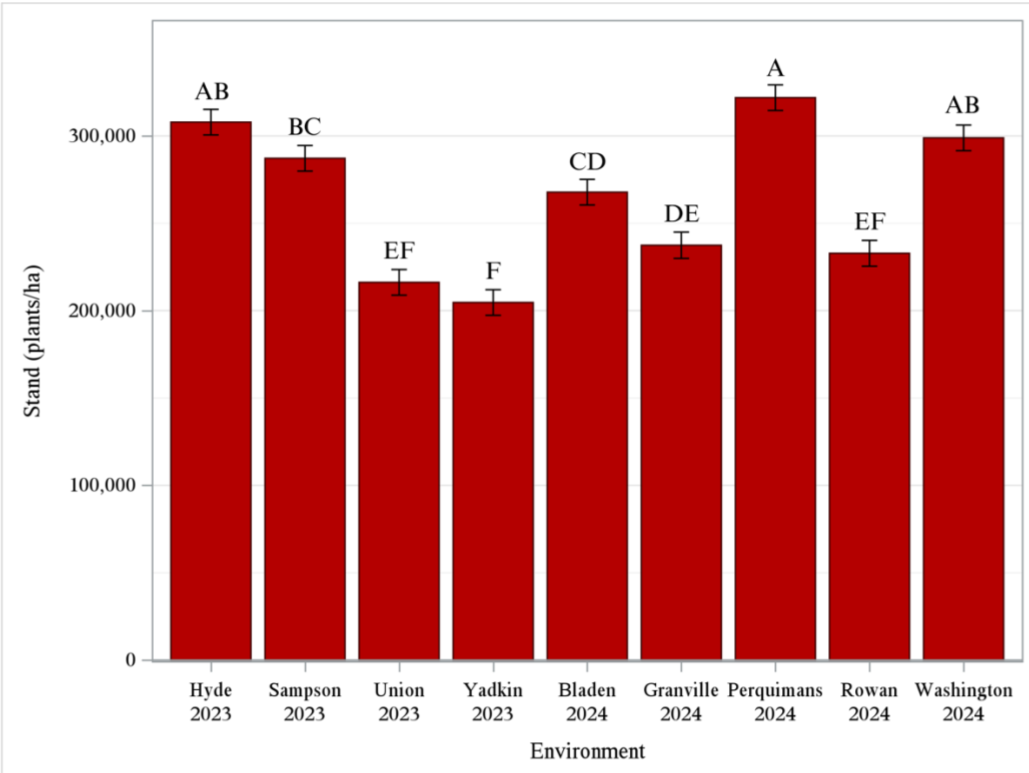



Figure 2. Impact of soybean growth habit on soybean height at R1 and R8. Means followed by the same letter are not significantly different at p ≤ 0.10 based on Tukey's Honestly Significant Difference (HSD).

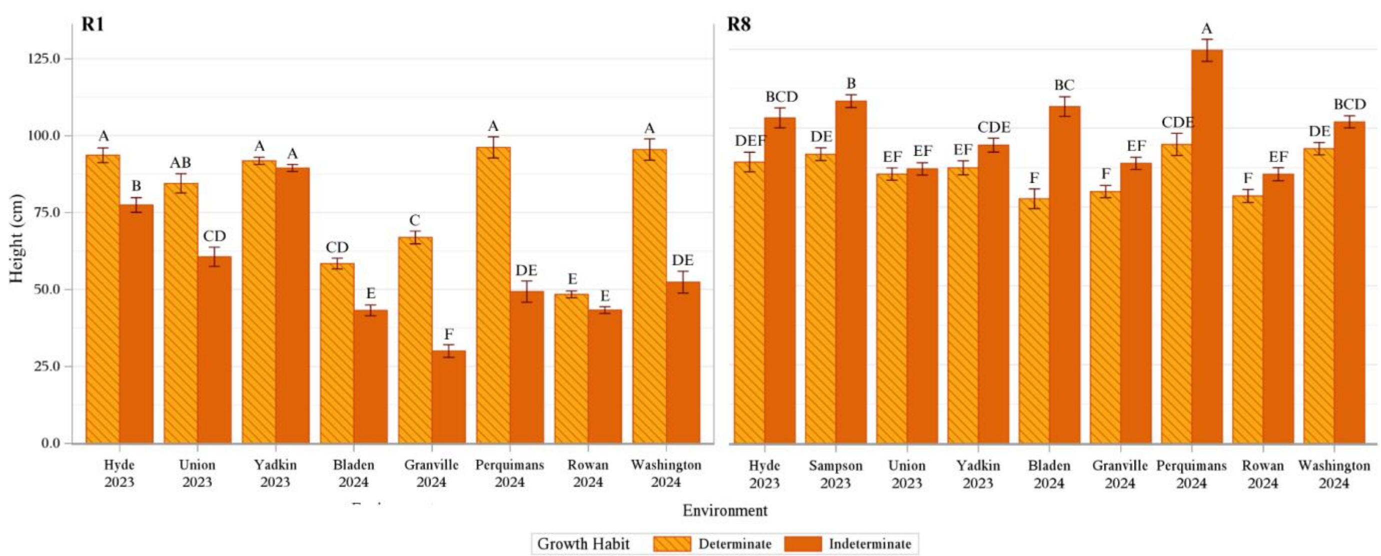


Figure 3. Impact of soybean growth habit on soybean node count at R1 and R8. Means followed by the same letter are not significantly different at p ≤ 0.10 based on Tukey's Honestly Significant Difference (HSD).

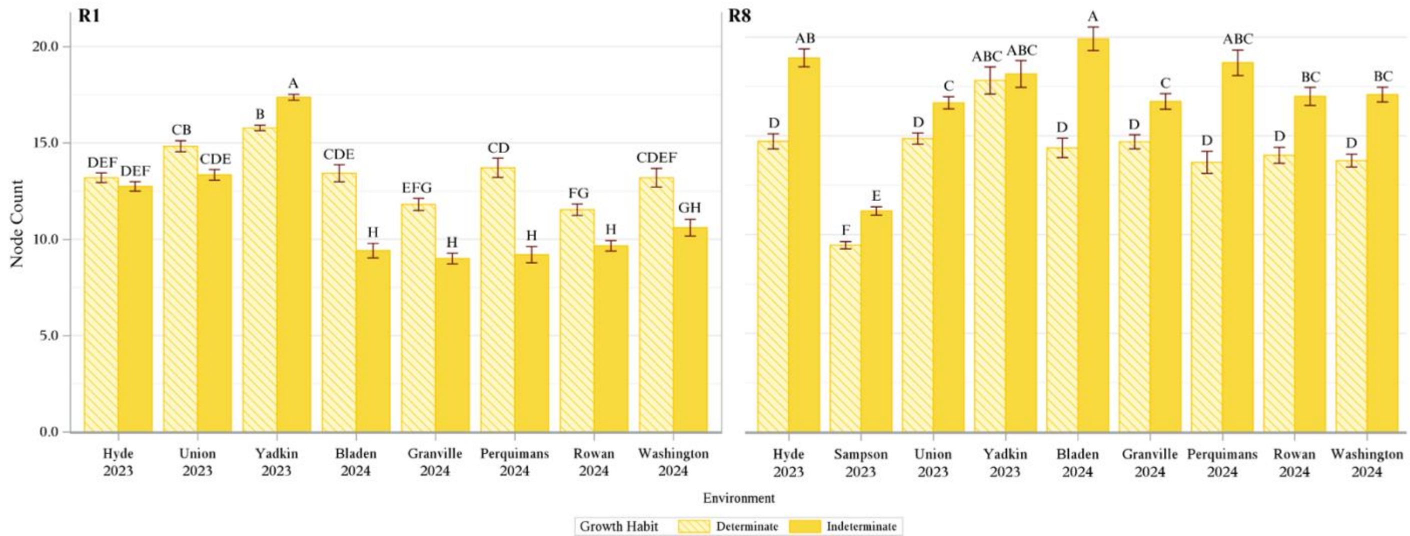



Figure 4. Impact of soybean growth habit on soybean lodging at R8. Means followed by the same letter are not significantly different at p ≤ 0.10 based on Tukey's Honestly Significant Difference (HSD).

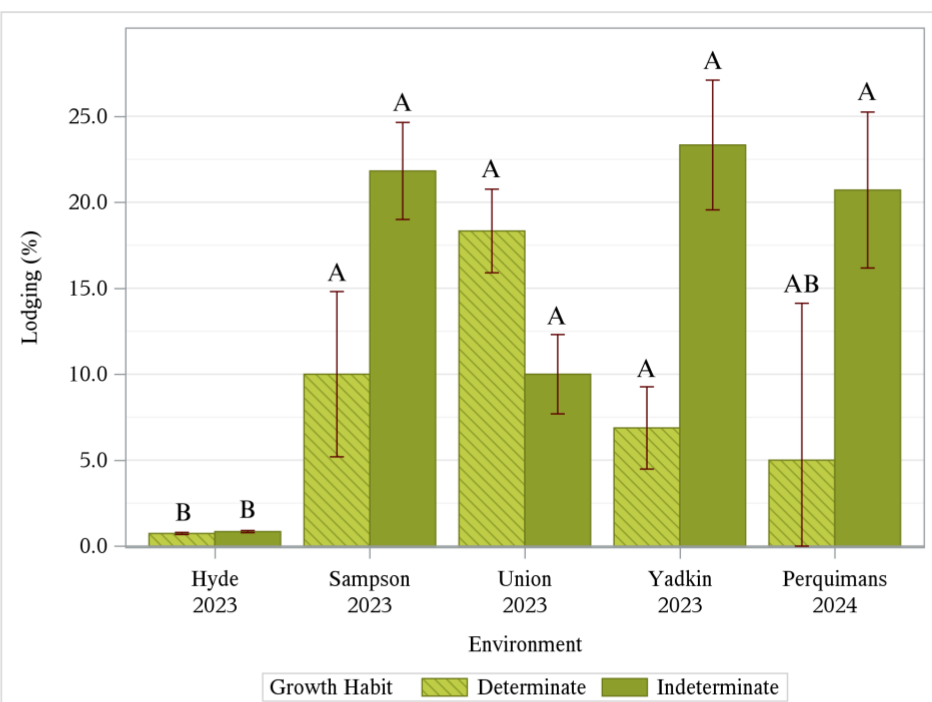


Figure 5. Impact of soybean growth habit on soybean green stem at R8. Means followed by the same letter are not significantly different at p ≤ 0.10 based on Tukey's Honestly Significant Difference (HSD).

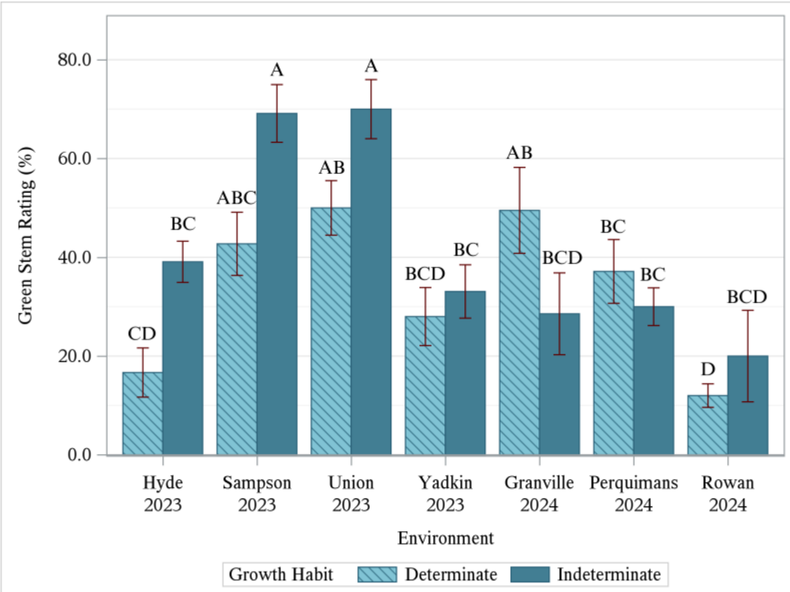
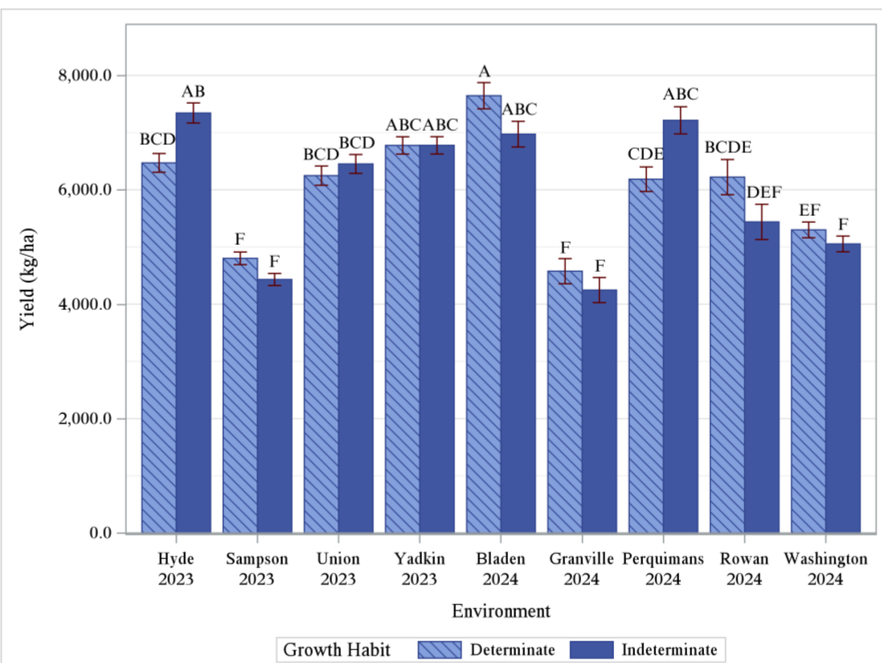



Figure 6. Impact of soybean growth habit on soybean yield. Means followed by the same letter are not significantly different at p ≤ 0.10 based on Tukey's Honestly Significant Difference (HSD).



# CHAPTER 2

## Collaborating across the NC Soybean Sector to develop a dynamic webpage housing arising problems from the field

**ABSTRACT**

Soybean production in North Carolina is supported by a network of knowledgeable field-based professionals, including Extension agents, crop consultants, and agronomists, who regularly diagnose and manage in-field issues. Despite the wealth of information exchanged through these interactions, much of it is never formally documented or shared for broader educational use. To address this gap, Beans Gone Wild (BGW) was launched as a collaborative, statewide initiative to centralize and publicly catalog real-time soybean production issues. Developed with input from Extension specialists, the NC Plant Disease and Insect Clinic (PDIC), and industry partners, BGW features an interactive map and searchable problem library supported by research-based references. Following its beta year in 2023, BGW expanded its contributor base and outreach efforts in 2024, resulting in a 56% increase in reported issues and significant growth in user engagement. By linking field-based observations with science-backed resources, BGW empowers farmers, consultants, educators, and students to make informed, timely decisions, and has inspired national adaptations such as Bean Binoculars.

**NOMENCLATURE**

Soybean, Beans Gone Wild, dynamic, interface

**KEYWORDS**

Soybean, tool, collaboration, agents, specialists, consultants, Extension, catalog

**BACKGROUND**

North Carolina has a diverse set of talented field-based experts helping growers troubleshoot soybean problems that arise in the field. These individuals, such as Extension Agents, Crop Consultants, and Industry Agronomists, help growers work through these encountered problems in a variety of ways that include boots-on-the-ground visits, phone calls, text messages, and emails. Often additional follow-up is needed through submission of plants or soil samples to the NC Plant Disease and Insect Clinic (NC PDIC): a North Carolina State University diagnostic clinic, the NCDA: specifically the soil testing sector of the N.C. Department of Agriculture and Consumer Services, or a private lab, ultimately allowing a data-driven follow up with the clientele on the encountered issues and recommendations to avoid the problem in the future. Each of these encounters often results in photos, videos, site descriptions, management practices, and recommendations that could benefit the broader regional soybean production community. However, due to time constraints this information never makes it from the field, email inboxes or our phones into a format that could educationally benefit other growers and agricultural stakeholders. The objective of this effort is to resolve this conundrum by developing a publicly available database cataloging soybean issues that arise across North Carolina that will ultimately help crop consultants, Extension agents, and farmers make more informed management decisions.

Beans Gone Wild (BGW) is a collaborative project across the North Carolina soybean sector to publicly catalog encountered issues in the field to provide broad educational benefit to growers, Extension agents, and other North Carolina agricultural stakeholders. The development of a dynamic map collaboratively populated with soybean problems as they arise in the field in real-time, would be a novel contribution to improve our understanding of annual variability and the influence on soybean production in North Carolina (Recent Problems - Beans Gone Wild, n.d.).

BGW leverages a comprehensive array of research-backed electronic resources to support informed decision-making in agricultural management. Each problem submitted to the platform is paired with one to three carefully selected references that offer guidance on the issue's diagnosis, management, or specialized recommendations. The majority of these references are sourced from Extension publications produced by North Carolina State University, known for their scientific rigor and regional relevance. However, the platform also incorporates high-quality resources from other accredited land-grant universities across the United States. This broad scope reflects a key principle underlying the project: no single person or institution holds all the answers. To provide a more robust and holistic tool, we recognize the value of expanding our collaborative networks and diversifying our sources of information.

Centralizing such an extensive library of reliable content in one user-friendly platform enhances accessibility and utility across a wide range of audiences. High school and college students, for instance, can use the tool to support research projects, class assignments, or independent learning in plant sciences and agronomy. New Extension agents may turn to the platform for practical training and as a supplemental resource when addressing unfamiliar issues in the field. Crop consultants can benefit from the platform's ability to track and compare recurring problems in specific geographic areas, helping them identify patterns and tailor their scouting efforts. Meanwhile, farmers can use the tool as a decision-support system, referencing the latest research to guide their crop management strategies and respond to field observations.

In essence, BGW serves as a dynamic and evolving hub of soybean knowledge. Designed not only to solve immediate problems, but to foster learning, collaboration, and data-informed practices across the entire agricultural community.

BGW is just one of many digital resources within the agricultural community dedicated to supporting the industry through education, innovation, and accessibility. Across the country, a number of well-established websites and platforms serve similar functions, offering valuable tools and insights to farmers, researchers, and agronomists. Among these are the Soybean

Research and Information Network (SRIN), the Crop Protection Network (CPN), Science for Success, and Bean Binoculars, to new a few.

Each of these platforms functions as a hub of information, housing a wide array of guides, tools, data sets, and research-based recommendations that cater to the needs of those working in agriculture. For instance, the SRIN (Soybean Research and Information Network - SRIN, n.d.) homepage features prominent links to key partner initiatives such as Science for Success, GROW, and the Crop Protection Network, along with a dedicated resource library. This interconnected structure reflects the collaborative nature of these platforms, where cross-referencing and linking across websites make it easier for users to discover and access relevant content efficiently. These collaborative research groups worked together to launch Bean Binoculars. Which serves as a national adaptation of BGW, incorporating many of BGW's core features and design elements. In fact, several aspects of BGW were studied and integrated into Bean Binoculars during its development, underscoring the influence and impact of localized tools on broader, national-scale resources.

Ultimately, the strength of these platforms lies not just in their individual offerings, but in how they work together to build a cohesive, accessible network of information for the agricultural industry. This system of resources ensures that stakeholders at every level whether researchers, Extension agents, or growers can access the most up to date and relevant knowledge for profitable soybean production.

Another cutting-edge digital tool is SoyStage, an online tool that predicts soybean developmental stages. You are able to view phenology maps based on historical weather data, or predict phenology for the current growing season. SoyStage predicts first flower, beginning seed fill, and physiological maturity for maturity groups 3 through 6. These predictions are based upon weather data from the past 30 years (dos Santos et al., 2019). Similarly to BGW, there is an interactive map, however this map displays predicted dates.

In addition to BGW, North Carolina farmers benefit from a range of high-quality online resources, with the North Carolina State University Soybean Extension Portal (Soybeans | NC State Extension, n.d.) standing out as a centralized hub for soybean management. This platform provides research-based tools such as the Soybean Production Guide, the Soybean Yield Contest, and up-to-date information on disease, insect, and weed control. Interactive features like calculators, educational videos, and decision aids. Including BeanPACK and the Official Variety Testing (OVT) Program. Which offer tailored recommendations and field-tested data to support informed decision-making. Designed to be accessible to all users, these resources highlight the state's strong agricultural support system and the value of investing in digital, research-driven tools for crop management.

The objective for publishing this management guide is to inform Extension personnel and crop consultants on innovative and effective mechanisms to report real-time production issues from the field and elevate the research-based information that is associated with resolving those issues.

## MATERIALS AND METHODS

### Team Building and Development

The development of BGW was a direct response to the desire of the North Carolina Soybean Producers Association to see more collaboration across those individuals supporting North Carolina soybean farmers. BGW was launched with a carefully selected core team of 13 dedicated individuals, drawing on a diverse range of expertise across the North Carolina soybean sector. This group included Extension specialists and agents, crop consultants, the NC PDIC, Extension IT, and Jeff Chandler from the North Carolina Soybean Producers Association (NCSPA). At the heart of this initiative was a foundational belief in statewide collaboration, a recognition that agricultural innovation relies on the input of those working directly with growers and crops across the state.

From the beginning, the project leaders understood that building a strong, effective team would require early and intentional planning. We didn't just recruit people, but handpicked them based on their skills, their roles in the agricultural industry, and their capacity to contribute unique insights to the beta-testing phase in 2023. These individuals were experts in their respective areas and actively engaged with farmers and in the field, offering real-time observations and feedback.

**Tool Ideation**

Prior to developing the tool, we hosted numerous Zoom meetings to brainstorm ideas and ensure that everyone's voice was heard. We knew the tool needed to be publicly available, visually appealing, and issues were formatted in an educational format. We had the initial idea for the tool to be an interactive map of North Carolina with issues populated on the map each week automatically. However, feedback from the team was clear that we did not want to jeopardize the credibility of the information being displayed to the public through automatic uploading to the map. Therefore, it was determined that every issue submitted would be confirmed by an NC State extension specialist or the NC PDIC before being uploaded and public facing. The team also determined there should be a problem library, where all issues can be stored even after they phase off of the interactive map. Problems here are in chronological order from oldest to newest uploads, and they can be sorted by month, county, and/or disorder.

This collaborative approach was essential in shaping what the tool would eventually become. Discussions covered everything from feature design to operational logistics, with team members providing perspectives that reflected their different professional backgrounds and day-to-day challenges. Despite these differences, the team shared a collective commitment to the project's success. Through discussion we planned to include as many soybean issues as possible, which we called disorders. The decided upon categories include abiotic, animal feeding, disease, herbicide injury, insect, nematodes, and nutritional. The strength of this team lies in its diversity, dedication, and shared vision to improve soybean management across the state.

**Tool Front and Back End Development**

The web application was developed using the Django web framework, which provided a solid foundation for both the back-end data management and front-end visualization components. Django's built-in Admin interface was leveraged as the primary data entry mechanism, allowing authorized agricultural specialists to efficiently document soybean issues. This implementation included specialized model fields to capture critical agronomic data such as disorder type, GPS coordinates, scouted date, and other relevant information. The GPS coordinates were used to add markers to the map. They were based off of our Extension County Centers in order to protect the privacy of farmers. PostgreSQL was used as the database to store data in a queryable format.

For the mapping component, Leaflet.js was integrated to visualize the collected soybean problem data across North Carolina. The application employs Django's view functions to retrieve and process the data from the models, which is then passed to the Leaflet.js front-end. Custom markers representing different soybean issues are dynamically rendered on the map, with color-coding indicating disorder type and popup information displaying detailed problem descriptions and photos. The application incorporates responsive design principles, allowing agricultural stakeholders to access critical information about soybean problems via various devices while in the field, significantly enhancing the state's ability to monitor and respond to emerging agricultural threats.

Following a successful beta testing year in 2023, it became clear that expanding contributor recruitment would enhance the value of the tool by increasing the number and diversity of issues reported. A larger contributor base across North Carolina would provide a more accurate, real-time snapshot of soybean production conditions at various times throughout the growing season. As a result, the number of contributors grew significantly, from just 12 in 2023 to 134 in 2024. This dramatic increase was made possible by tapping into Extension agents and crop consultants across the state.

**Uploading Problems from the Field to the Tool**

While the number of contributors changed, the core methods of issue submission remained consistent across both years. In 2023, contributors could report issues directly from the field via text message or phone call to the project manager, Google Form, or email. However, some improvements were made in 2024 based on feedback from the previous year. Notably, Extension IT helped set up a dedicated BGW email address, replacing the use of a personal email for the project manager. The Google Form was also refined to be more intuitive and user-friendly in the field, with the primary goal of simplifying the submission process. Contributors could also send in issues to the NC PDIC if they were unsure of the problem. The tool manager had access to NC PDIC soybean submissions, and sifted through issues each week.

No matter the method of submission, there was a set list of aspects the project manager required in order to upload the issue. These included your contact information, as communication between manager and contributor was usually necessary, however names or farms were never posted alongside issues. The date the issue was scouted, along with the growth stage. We required the county it was scouted in, but did not go to farm or field level to protect growers. The disorder that the issue fell under, as well as the specific name of the issue. Details about the problem if known such as planting date, maturity group, weather issues, pesticides sprayed, etc. As well as one to three photos of the issue at hand. We specified to take broad photos of the field and up-close photos of individual plants or leaves. Contributors were responsible for providing this information in the email or text/call methods, while the Google Form had each of these requirements listed in an easy to select format. The project manager made contact with contributors to receive missing information whenever needed.

**Team Communication**

In 2023, we supported engagement by sending a weekly reminder email every Wednesday from the time the first issue was submitted in mid-April through mid-November. In 2024, the team improved upon this system using the new BGW email address to send out two regular communications each week: a Tuesday reminder email encouraging submissions and a Friday recap email summarizing that week's activity on the tool. The recap email included the number of issues reported, the types of disorders observed, and often featured a highlight. The highlight would include a particularly interesting case, complete with a photo or two.

**Social Media Use and Promotion of the tool**

To further promote the tool and increase public awareness, a social media campaign was launched in 2024. This included the creation of Instagram and X (formerly Twitter) accounts, both under the same username for easy access. To keep users engaged, we introduced Wild Bean Wednesday #WBW, a weekly feature that shared soybean-related content every Wednesday. Posts ranged from fun facts and trivia questions to photos of real field issues, videos, and relevant articles. This campaign helped extend the tool's reach while building a broader community of interest around soybean health and diagnostics.

Opportunities arose in 2023 and 2024 to promote the tool at numerous statewide events. Including research field days, winter meetings, and conferences such as the NC Commodity conference and the NC Agricultural Consultants Association conference. Presentations would include a QR that proceeded directly to the tool. This assisted in direct traffic visits to the tool.

**Metric Tracking**

Metrics were followed by utilizing Google Analytics. Extension IT aided in allowing the project leads access to this site and guiding us in how to interpret this data. The analytics were recorded multiple times a year for specific aspects such as users and views for a certain month or if briefs were presented. Google Analytics allows us to track information from a single day, span of months, a year, or observe data across 2023 and 2024.

## RESULTS AND DISCUSSION

**Contribution Summary**

Contributors had three primary methods for uploading issues to the tool: a Google Form, phone call or text, and email. Across both years, the majority of submissions came through calls, texts, emails, or the NC State PDIC, rather than the Google Form (Figure 1). In 2023 and 2024, the Google Form accounted for 28% of all submissions. When analyzing individual submission methods, text and phone call consistently emerged as the most commonly used across both years (Figure 1). Overall, there was a notable increase in the number of total issues reported: from 57 entries between April and October 2023 to 89 entries between May and October 2024. This upward trend highlights both the growing engagement with the tool and the increased contributor base in 2024.

One key reason for the increase in issue entries in 2024 was the expanded contributor base. In 2023, the contributor group was intentionally kept small, with specialists making up the largest share (5 contributors), while agents and the NC PDIC had the fewest, with only 2 contributors each (Figure 2). However, in 2024, a significant number of Extension agents and crop consultants were added to the roster. As a result, Extension agents became the largest contributor group with 91 individuals, while the number of NC PDIC contributors remained consistent at 2 (Figure 2). Crop consultants had a significant increase in contributors from 3 in 2023 to 34 in 2024. This shift in team composition played a major role in driving the increase in submitted issues.

Although the total number of issues reported increased significantly from 2023 to 2024, the overall trend in disorder types remained consistent between the two years. Reported issues fell into several main categories: abiotic stress, animal feeding, disease, herbicide injury, insect, nematodes, and nutritional disorders. In both years, insect-related issues were the most frequently reported, with disease-related issues consistently following as the second most common (Figure 3). Conversely, nematode-related issues remained among the least reported in both years, reflecting a consistent pattern of lower visibility or detection for that disorder type (Figure 3).

**Impact**

From the launch of BGW in April 2023 through December 2023, the tool attracted a total of 911 users (Figure 4) and recorded 4,743 unique page views (Figure 5). This suggests that many users were returning to the site multiple times. The average engagement time per user was 1 minute and 42 seconds, indicating a reasonable level of interaction per visit. Of the total page views, 702 were direct visits to the tool and 143 came from organic searches for BGW, making these the top two sources of traffic (Figure 5).

In 2024, from May through December, user engagement continued to grow. The site recorded 1,254 users (Figure 4) and 4,426 unique page views (Figure 5). Similar to the previous year, this indicates repeat visits and sustained interest in the tool. The average engagement time per user in 2024 was 1 minute and 15 seconds. Among the page views, 759 were direct visits and 452 were organic searches for BGW, again ranking as the top two sources of traffic (Figure 5). The increase in organic search traffic from 2023 to 2024 suggests that users were actively seeking out the tool, likely remembering it by name. Notably, in 2024 there were 1,217 new users and 160 returning users, further demonstrating both growing awareness and continued engagement with the platform.

As part of the 2024 outreach efforts, BGW launched social media accounts on Instagram and X (formerly Twitter) to increase attention and engagement. On Instagram, the account gained 79 followers and shared 11 posts throughout the year. The most-liked post, featuring Dr. Rachel Vann speaking in the field about an Extension trial, received 25 likes, while the most-viewed post, a video about a NC State soybean school, reached 977 views. On X, the account gathered 27 followers and published 52 posts, including Wild Bean Wednesday #WBW content and reposts from relevant sources and other followers. The most popular post, a video of the NCSU soybean team planting, earned 8 likes and 537 views, making it the most engaging content on that platform. These efforts helped broaden awareness of the project and kept users informed and connected throughout the season.

One of the driving goals behind the creation of BGW was to elevate and centralize access to high-quality electronic resources. By leveraging trusted materials from NC State University and other land-grant institutions, the tool provided users with consistent, research-based information to support timely diagnostics and decision-making in the field. Over the course of 2023 and 2024, a total of 72 resources were featured through the platform. Of these, 62 originated from NC State, reflecting the university's strong foundation in Extension and research. The remaining 10 resources came from other accredited land-grant universities, further broadening the scope and credibility of the content provided. By integrating these materials into one accessible location, BGW not only promoted reliable information but also helped reinforce the value of Extension services and university-based research in real-world agricultural practices.

Across 2023 and 2024, the top three most viewed issues uploaded to BGW reflected strong user interest in nutritional and abiotic disorders (Figure 6). Two of these top performing entries were nutritional issues, potassium deficiency and zinc toxicity, while the third was an abiotic issue, slime mold. The potassium deficiency post got the most attention in 2023, with 120 views, and remained a topic of interest in 2024 with 54 additional views, highlighting ongoing concern around nutrient-related disorders in soybean production. Zinc toxicity, on the other hand, showed a growing interest over time, rising from 53 views in 2023 to 87 views in 2024, suggesting increased user engagement with less commonly discussed nutrient imbalances. The slime mold issue, an eye-catching abiotic condition, drew 62 views in 2023 and 83 in 2024, making it one of the most consistently viewed entries. These numbers demonstrate not only the relevance of the tool's content but also how visually distinct or diagnostically challenging issues tend to attract repeated user engagement over time.

**Future of the Tool**

Toward the end of 2023, growing interest emerged around the idea of expanding BGW beyond soybeans to include additional crops. While the concept was well-received, the core team met to discuss the feasibility and timing of such an expansion. After careful consideration, it was decided that 2024 would serve as a final, focused year dedicated solely to soybeans. This approach allowed for the continued growth of the contributor network and the solidification of the tool's foundation before branching out to other crops.

The project is now entering an exciting new phase under the leadership of Dr. Daisy Ahumada, the corn, cotton, and tobacco. The tool has been rebranded as Root Cause Reports and will now encompass corn in addition to soybeans. While the scope of crops has expanded, the user interface, issue submission process, and format of posted entries will remain familiar, maintaining consistency for contributors and users alike. We are actively collaborating with Dr. Ahumada and her team to ensure a smooth and successful transition, providing continued support as the tool evolves.

In parallel, 2024 also marked the launch of Bean Binoculars, a national soybean issue reporting platform led by Dr. Haleigh Ortmeier-Clarke in partnership with the Crop Protection Network (CPN). BGW played a foundational role in the development of Bean Binoculars. We're excited to see the ongoing growth and impact of both Root Cause Reports and Bean Binoculars, and we remain committed to supporting these tools as they continue to advance agricultural diagnostics and field-based reporting.

**Implications for Soybean Management**

With such a broad span of topics that ranges across almost every aspect of soybean production it was crucial to have elevated electronic resources that are relevant and reliable. The problem library houses every issue ever uploaded to BGW, with each issue having corresponding resources. This type of stored, user-friendly information located in one place can be crucial to stakeholders in the North Carolina soybean sector.

While every growing season is different, crop consultants can utilize this data by preparing for certain problems at specific growth stages that have recurred in recent years. Students can reference this information in projects and papers, while professors could designate certain issues to students as a research assignment. Farmers and Extension agents could find it valuable for hands-on training or detecting patterns.

**CONCLUSION**

The BGW platform has become an effective and innovative tool for capturing and disseminating real-time soybean production challenges across North Carolina. By bridging the gap between field diagnostics and educational outreach, it enables faster, more informed responses to crop issues while also fostering a collaborative and connected agricultural community. The tool's growing usage, contributor engagement, and online traffic emphasize the need for accessible, research-backed digital resources. As it continues to evolve, BGW holds strong potential not only to shape soybean management practices in North Carolina, but to influence national efforts in crop diagnostics and Extension engagement. By centralizing field insights and elevating research-backed recommendations, BGW strengthens the state's agricultural resilience through innovation, education, and collaboration.

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Figure 1. Method of submission by year.

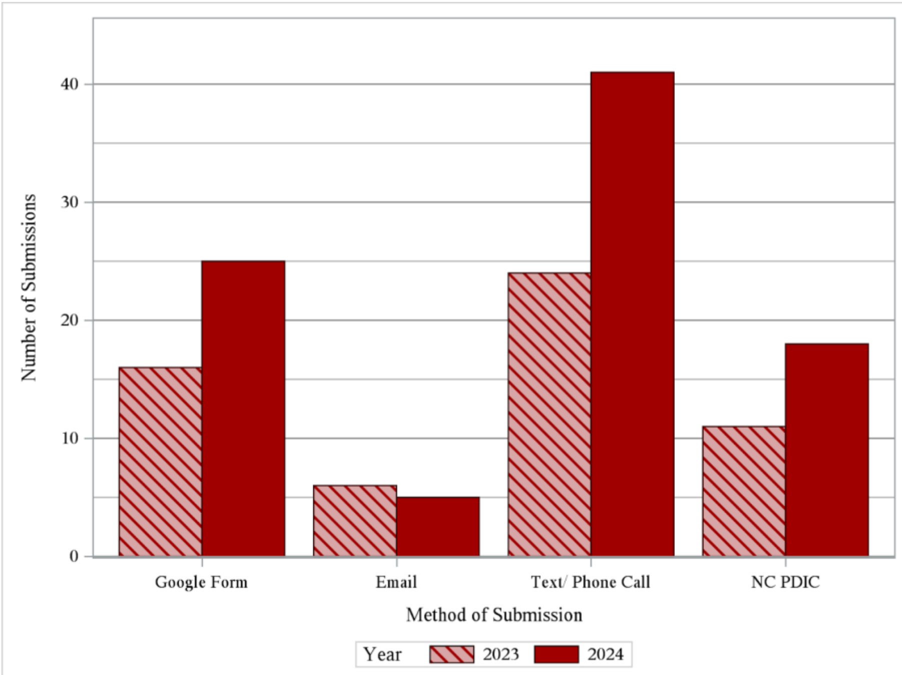


Figure 2. Type of contributor by year.

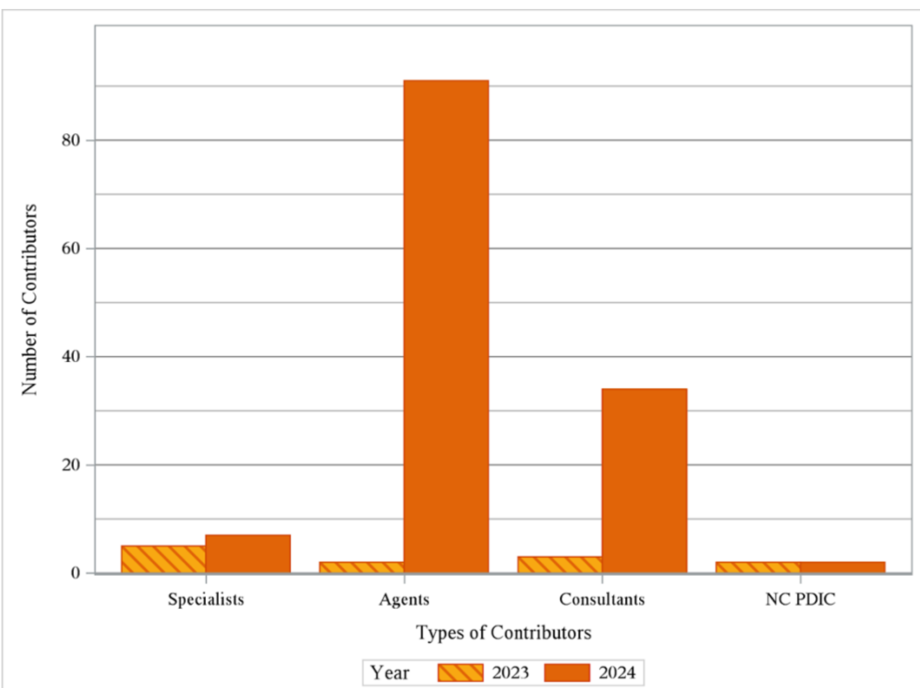

Figure 3. Type of problem by year.

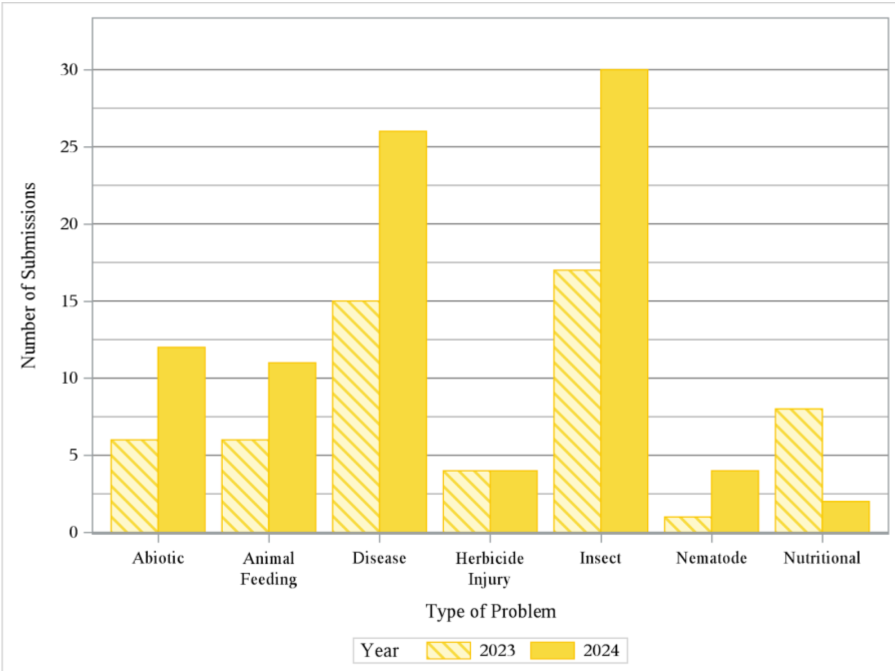


Figure 4. Number of page views by year.

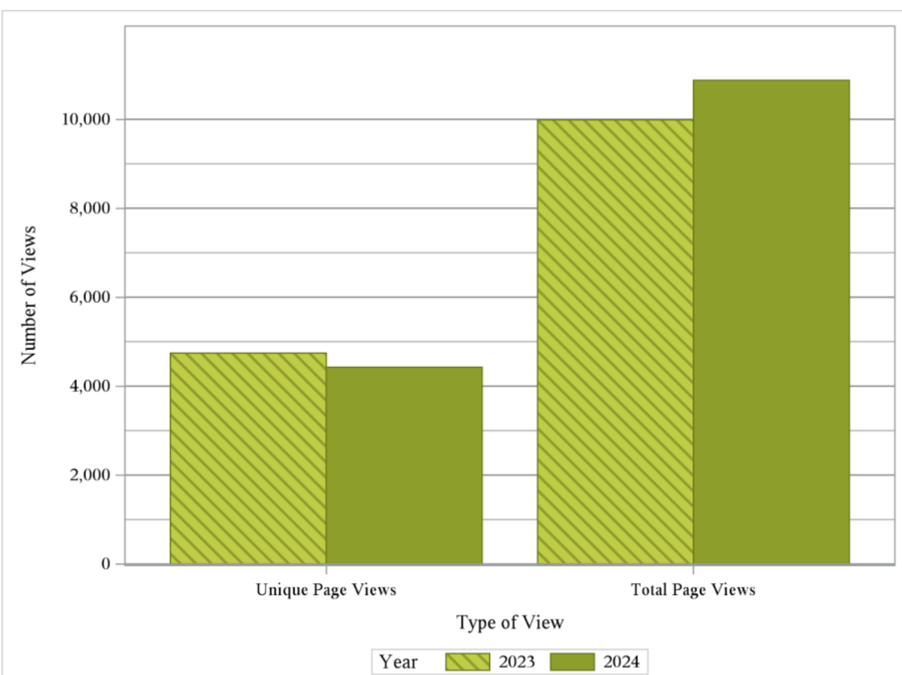

Figure 5. Number of searches by year.

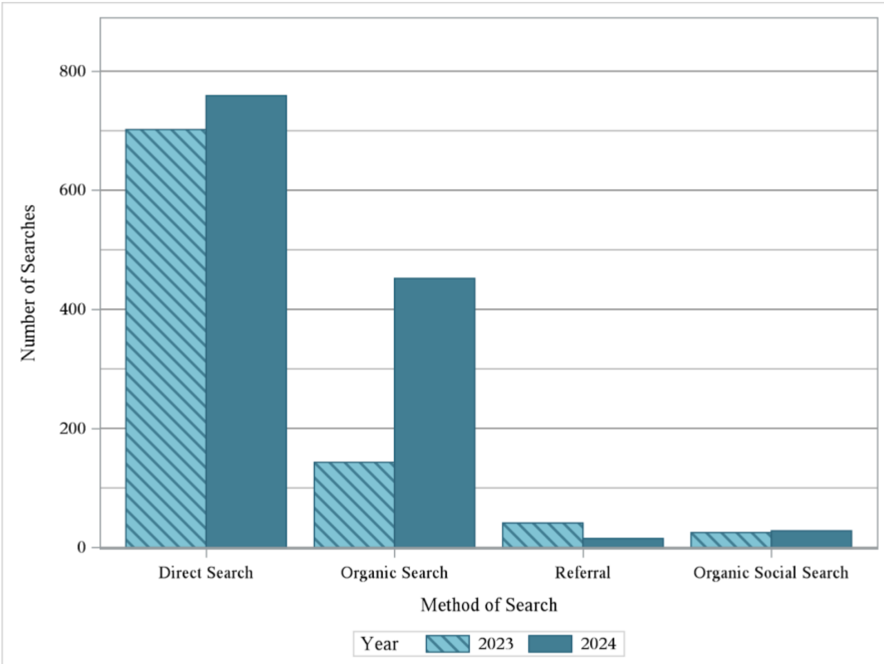


Figure 6. Top three most viewed problems.