AU TAPS
TESTING AG PERFORMANCE SOLUTIONS

Impacts of Agronomic and Economic Decisions on Crop Yield, Input Use Efficiency, and Profitability

REPORT 2025

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Alabama Agricultural Experiment Station
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Acknowledgment

The success of the 2025 Testing Agricultural Performance Solutions (TAPS) program at Auburn University, Alabama, reflects the dedication of many individuals and partners. We extend our sincere appreciation to our colleagues at the E.V. Smith Research and Extension Center, Farm Service Unit, for their commitment to the field operations of this project. We are also grateful to our colleagues at the Auburn University College of Agriculture for their continued support. Special thanks go to our collaborators at Kansas State University, Colorado State University, and the University of Florida for their guidance and for helping us align this project with the broader goals of sustainable and precision agriculture. Finally, we thank the undergraduate and graduate students, and visiting research scholars in the CSES Precision Agriculture Laboratory, field assistants, industry partners, and participating farmers for their invaluable collaboration and contributions.

Mission Statement

The mission of TAPS is to engage farmers, crop consultants, scientists, extension personnel, students, government agency personnel (e.g., NRCS and USDA), and industry representatives in a collaborative, innovative effort to advance agriculture in Alabama and beyond. By exchanging knowledge, adopting cutting-edge technologies, fostering partnerships, and implementing best management practices, TAPS aims to provide effective solutions to achieve long-term productivity, sustainability, and profitability in farm operations.

Goals and Objectives

This project aimed to demonstrate the role of crop management practices and the use of decision-support tools and solutions to increase crop yield, profitability, and input use efficiency. This project also explored the role of crop marketing strategies and crop insurance on profitability and risk management. Teams comprised of farmers and crop consultants manage plots planted with corn by choosing among various crop management practices, decision support tools, and economic strategies. It is expected that sharing the results of this project with the team members, other farmers, and practitioners, may lead to knowledge sharing and adoption of solutions that will increase profitability and environmental sustainability.

EXECUTIVE SUMMARY

The 2025 TAPS program in Alabama completed its second year at the E.V. Smith Research and Extension Center in Shorter, Alabama. The project allowed farmers, extension agents, and crop consultants in teams to design a study to manage corn crop and compare their decisions with others. Farmers located in Central and Southeast Alabama grouped in teams, representing a range of farm sizes, experience levels, and production environments participated in the 2025 TAPS program. Participants made all key management decisions, including corn hybrid, seeding rate, nitrogen source, nitrogen rate and timing, irrigation rate and timing. In addition, the teams were also invited to select crop marketing and insurance strategies. These decisions were evaluated for their effects on grain yield, profitability, and input use efficiency. Results from 2025 showed clear differences among strategies, with some teams achieving higher net returns and more efficient use of nitrogen and water than others. The program continued to serve as a platform for peer-to-peer learning, open discussion of risk and cost, and the adoption of more precise and sustainable management practices. At the end of the season, farmers, extension personnel, industry partners, sponsors, and other stakeholders met to discuss the results and share ideas.

The TAPS program acknowledges the support of the Alabama Agricultural Experiment Station at Auburn University and the funding from the Wheat and Feed Grain Committee of the Alabama Farmers Federation and the Alabama Soil and Water Conservation Committee, which made the 2025 competition possible. We also thank all private companies that contributed time, technology, and technical assistance.

The continued success and impact of this program depend on the active participation of producers and partners across the state. We look forward to building on the lessons learned in 2025 as we plan future TAPS competitions.

Sincerely,
The TAPS Team

1. PROGRAM OVERVIEW

The Testing Agricultural Performance Solutions (TAPS) program is a national initiative currently implemented by several Land-grant universities across the Midwest and Southeast USA. It was designed to demonstrate how different crop management strategies and technologies affect crop yield, input use efficiency, and profitability. The program runs as a competition among teams with each team making selections on agronomic and economic strategies, including hybrid selection, seeding rate, nitrogen source, nitrogen application rate and timing, irrigation rate and timing, crop insurance, and crop marketing strategies (Figure. 1). By comparing the outcomes of these decisions, participants were able to evaluate their own management practices and benchmark their performance against economically profitable and environmentally responsible standards. Teams also had access to a range of tools and technologies from private companies, allowing them to test these solutions in real production conditions and potentially increase their adoption at the farm level.

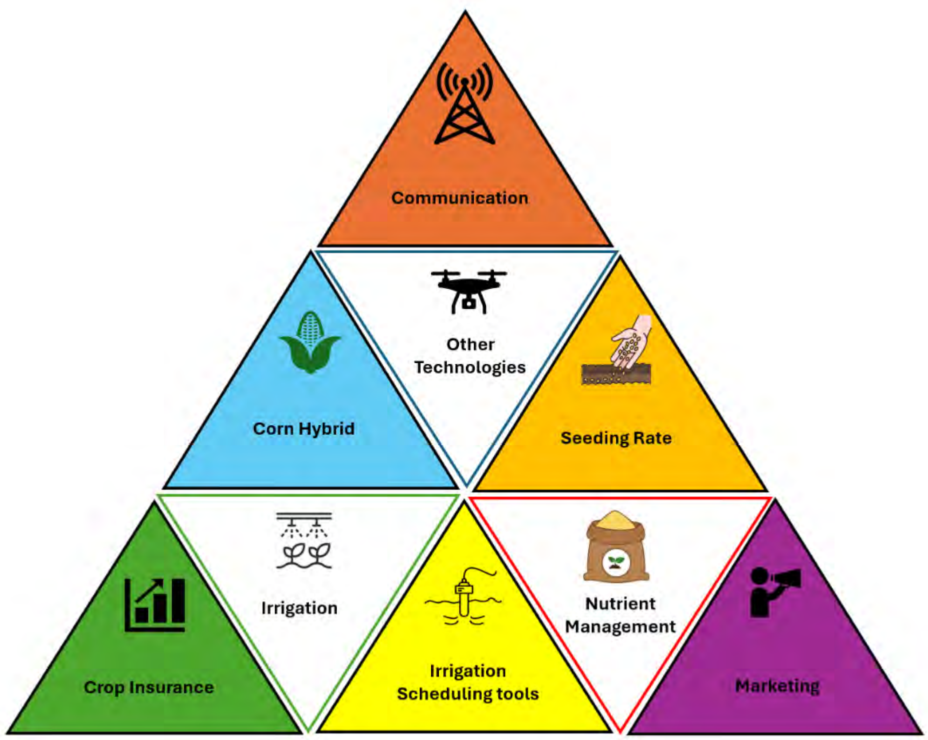

Figure 1. 2025 TAPS crop management choices.

In the second year of TAPS, Teams made all management decisions through the national TAPS portal (https://tapsnetwork.org/). Before the V10 nitrogen application, each team received an individual report summarizing all management decisions they had made from planting through the V6 nitrogen application. Photos documenting crop development, together with weekly rainfall totals, were also shared with participants.

The project was conducted at the E.V. Smith Research and Extension Center, Farm Services Unit, in Shorter, Alabama, with nine teams (Teams 1 – 9) mainly composed of farmers, and one team integrated by the regional Extension agents of the Agronomic Crops Team. The test was located at the Gin-East field of the Farm Services Unit (32°26′17″ N, 85°54′42″ W).

Each team independently managed three 0.8-acre plots (Figure 2). Because the field used for the 2025 competition had significant variability in soil and elevation, three blocks were formed, and teams' plots were randomized across each block (hereafter referred to as the TAPS Field). Block 1 was characterized by a sandy loam soil, and blocks 2 and 3 had clay to clay loam soil texture. The corn crop in the TAPS field was irrigated with a center-pivot system equipped with variable rate irrigation (VRI) technology. A control treatment, designated as Team 9, received only 0 lb N/ac and served as a benchmark for nitrogen use efficiency, providing a reference point for evaluating the environmental and economic impacts of the nitrogen management strategies used by competing teams. The three plots of team 9 did not receive irrigation throughout the growing season (control plots).

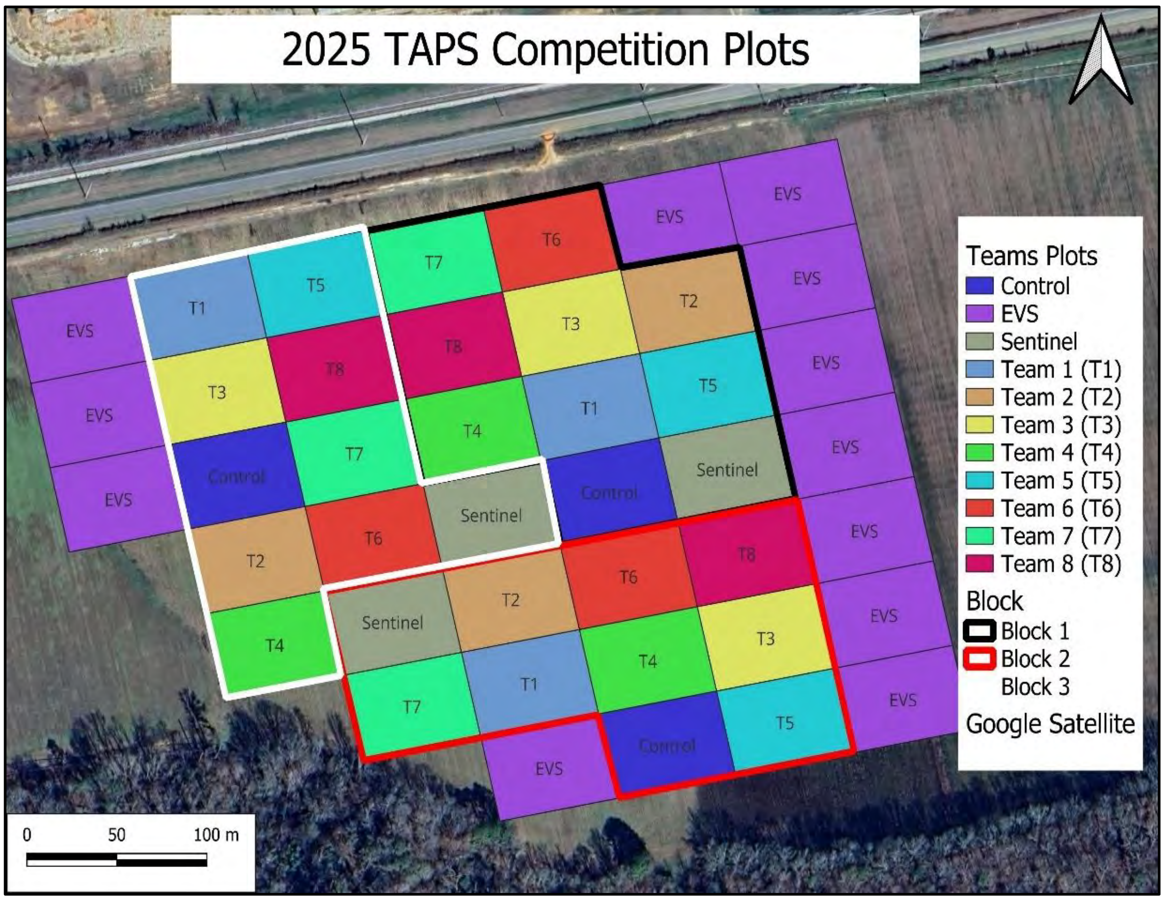

Figure 2. 2025 Plots layout. Each team was assigned three randomized plots of 0.8 acres (one plot in each block), which they independently managed according to their management choices.

2. MANAGEMENT OPTIONS AVAILABLE TO THE TEAMS

2.1 Hybrid Selection (decision type #1) and Seeding Rate (decision type #2). Teams were required to select their corn hybrid and seeding rate. The five corn hybrids available in the competition included Dekalb 68-35 (118 RM), Dekalb 70-45 (120 RM), Croplan 5893 (118 RM), Armor 5272 (118 RM), and DynaGro 58VC65 (118 RM). Teams chose the corn hybrid from these options as well as the seeding rate of their preference.

2.2 Crop Insurance (decision #3). Prior to planting, teams were required to select a crop insurance package from the following six options:

1. Revenue Protection with Harvest Price Exclusion – Optional Unit (RPHPE-OU),
2. Revenue Protection with Harvest Price Exclusion – Enterprise Unit (RPHPE-EU),
3. Yield Protection – Enterprise Unit (YP-EU),
4. Yield Protection – Optional Units (YP-EU),
5. Revenue Protection – Enterprise Unit (RP-EU), and
6. Revenue Protection – Optional Units (RP-EU)

2.3. Nitrogen Management (decision #4). Teams were asked to select from various nitrogen management options such as nitrogen source, rate, and time of application. The maximum and total amount of nitrogen each team could apply during the 2025 growing season was 350 lbs N/ac. Five choices regarding nitrogen application source were available: liquid Ammonium Polyphosphate (APP) 11-37-0 (planting), granular NPK 19-19-19 (planting), liquid Urea Ammonium Nitrate (UAN) 28-0-0-5 (at planting and side-dress application – V6 & V10), granular Urea – 40% (side-dress – V6), and Liquid Urea Calcium Ammonium Nitrate (UCAN) 23-0-0-4 Ca (side-dress – V6 & V10). Teams were also allowed to apply nitrogen at three different times during the growing season: at planting, at the V6 growth stage, and at the V10 growth stage (side-dress application). To provide a unique insight into how effectively nitrogen inputs (source, rate, and timing of application) are utilized, indices such as Nitrogen Use Efficiency (NUE), Agronomic Efficiency of Nitrogen (AEN), Nitrogen Recovery Efficiency (NRE), Nitrogen Intensification Performance Index (NIPI), and Nitrogen Uptake (NU) were estimated. The equations for calculating these indices can be found in Appendix B. These metrics provide valuable insights into nitrogen input efficiency, crop response, and environmental sustainability. Team 9, serving as the control with 0 lbs N/ac applied, represents the baseline nitrogen uptake ($NU_{Control}$) and Yield ($Y_{Control}$) without fertilizer, making it essential for comparison with fertilized plots (Team Plots 1-8). Nitrogen Uptake (NU) measured the total nitrogen absorbed by the crop's aboveground biomass, while AEN evaluated the increase in grain yield per unit of nitrogen applied. NRE quantified the percentage of applied nitrogen recovered by the crop. NUE provided a broader perspective on grain yield per unit of nitrogen applied. NIPI assessed the relative gains in yield and nitrogen uptake between fertilized and control plots. These indices collectively emphasize the importance of efficient nitrogen management to balance productivity and sustainability in crop production.

2.4. Water Management (decision #5). The TAPS field was irrigated using a center pivot irrigation system with variable rate irrigation (VRI) capabilities. Teams were responsible for selecting their preferred tools for irrigation scheduling. The options available for soil sensors were: AquaSpy® and Sentek (distributed by Simplot Smart Farm). In addition, an irrigation scheduling phone App (Smart Irrigation CropFit App) that uses the crop evapotranspiration-based soil water balance was also available as an option among the irrigation scheduling tools (https://smartirrigationapps.org/cropfit-app/). The teams also had access to real-time weather data recorded by a weather station installed near the field, as well as an automatic rain gauge located at one of the field's boundaries, which recorded both irrigation and rainfall. From late May to late July, teams submitted their irrigation recommendations through the TAPS portal. When needed, text messages were sent as reminders. Irrigation was applied up to two times per week, with application depths of up to 1.0 inch (in), in 0.5-inch increments. If teams chose to apply more than1.0 inch of water in a single irrigation event, the rate was split in half, and the pivot was run twice consecutively. The center pivot irrigation system at the TAPS field consists of seven spans, each equipped with VRI capabilities. The VRI applies different irrigation rates using the zone control method, and specifically for this system, the minimum lateral distance with different irrigation rates is half of the span length. To understand how effectively irrigation water is utilized, two indices; Irrigation Water Use Efficiency (IWUE) and Crop Water Productivity (CWP) were used to estimate water use efficiencies. The equation for calculating these indices can be found in Appendix B. IWUE measures grain yield per inch of irrigation water applied. It evaluates how effectively irrigation water contributes to grain yield. IWUE is crucial for assessing water use in a region where irrigation management can significantly impact crop performance. CWP measures total biomass produced per inch of water (irrigation + rainfall). It focuses on total biomass rather than grain yield alone and reflects the efficiency of water use for overall crop growth.

2.5. Grain Marketing (decision #6). The TAPS teams evaluated choices related to crop marketing selection made by the participants. Three marketing options were considered: 1) Basis contract, 2) Forward contract, and 3) Hedge-to-Arrive (HTA).

2.6. Other Management Decisions. All other management decisions, (e.g., tillage practices, residue management, etc.), were determined and executed by the TAPS team and were uniformly applied to the entire TAPS field. The competition teams freely made choices, as they sought to be the most profitable, efficient, and highest-yielding Team. The TAPS team did the physical management of all plots (e.g., operation of machinery, fertilizer and irrigation application, collection of tissue samples, harvesting, etc.).

3. TIMELINE OF ACTIVITIES

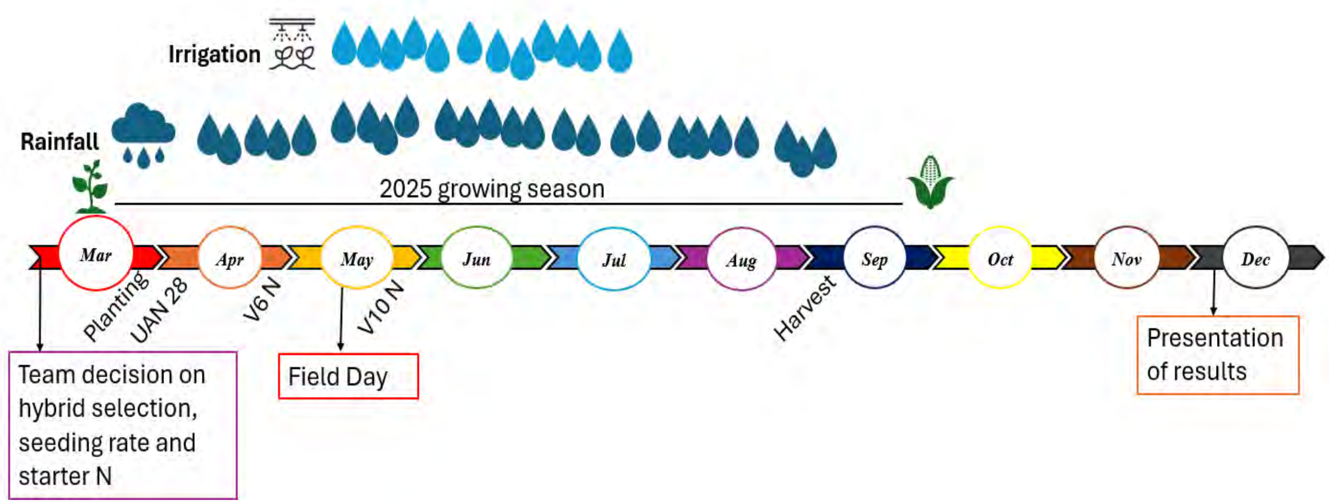

Figure 3. 2025 TAPS timeline of crop management practices and associated project activities.

4. EQUIPMENT AND TECHNOLOGY

Figure 4. Technologies and services used by Teams for decision-making.

One of the primary goals of the competition is to equip farmers, crop consultants, and extension personnel with commercial tools and solutions that improve crop management efficiency and profitability. By allowing teams to test these solutions on a small scale with minimal risk of yield loss, the competition provides a platform for evaluating their benefits, accelerating learning, and encouraging adoption.

Teams had access to advanced technologies, including irrigation scheduling tools and in-season nitrogen recommendation platforms such as Sentinel Ag (https://www.sentinelag.tech/). These tools were selected to raise awareness among participants about their practical use and to help them evaluate their financial and conservation value for their operations. Additionally, while the teams did not operate the farming equipment used to apply inputs on the plots, they were exposed to various Precision Agriculture Technologies. This provided valuable insights into the benefits of variable rate application methods and how teams can use these technologies in their farming operations. A list of technologies used for the 2025 TAPS competition can be found in Appendix A.

5. GROWING CONDITIONS

The project site is located in a humid subtropical climate, with most precipitation occurring in winter and variable rainfall during summer. Although NRCS soil survey information characterizes the predominant soil type at the site as Altavista silt loam (USDA-NRCS, 2024), soil texture analysis of samples collected from the field indicated textures ranging from sandy loam to clay. Corn was planted on March 27, 2025, and starter N was applied between March 27 and April 3. Shortly after the application of the starter fertilizer 28-0-0-5, the TAPS field received over 6 inches of rainfall on April 5 and 7, causing ponding in parts of the plots (Figure 5). Crop emergence, especially on the plots located on block 2, was severely impacted by the heavy and continuous rainfall events. Nitrogen application dates and the amount of rainfall recorded close to each nitrogen application event are presented in Figure 6. The corn reached silking in late June and showed early signs of physiological maturity by mid-August (Figure 7).

Figure 5. Ponding and surface water saturation on the TAPS field after 6.3 inches of rain (April 5-7) following starter 28-0-0-5 application on April 3.

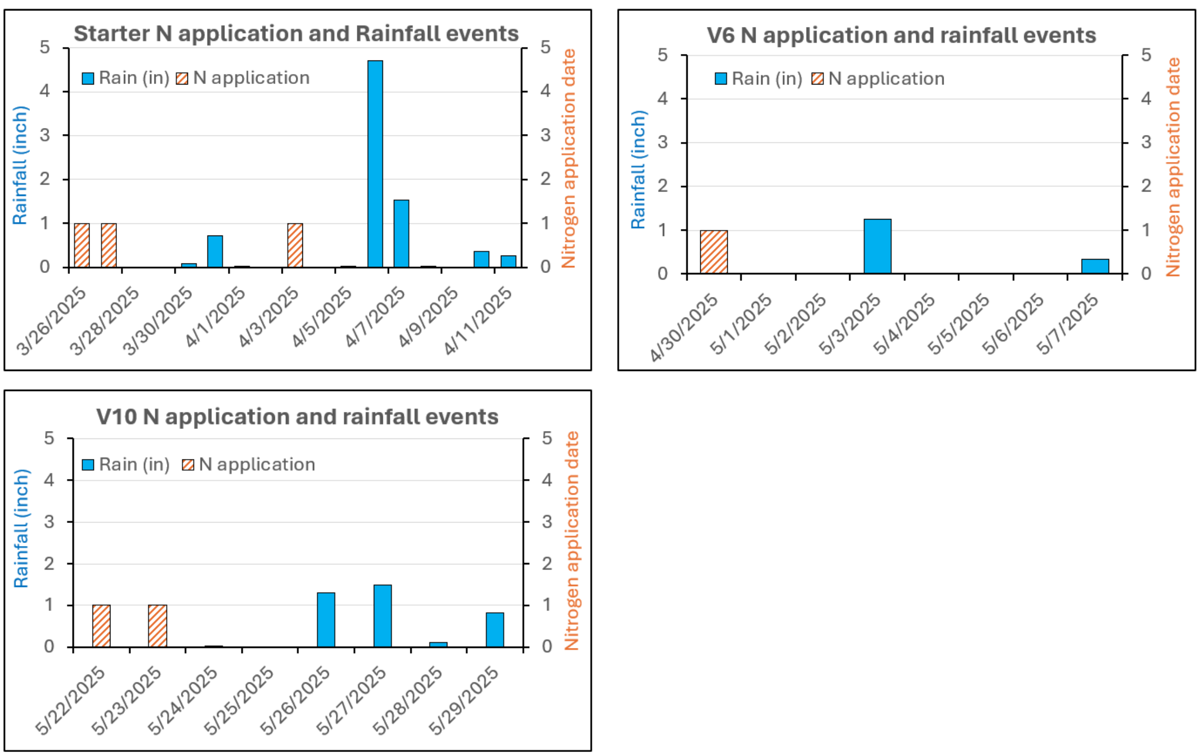

Figure 6. Rainfall events during the weeks when nitrogen was applied to the crop at planting, V6, and V10 growth stages. Note: the hatched bars on the graphs only represent the dates when nitrogen was applied.

The rainfall recorded from planting to harvest was 34.5 inches; however, the rainfall was not evenly distributed to meet the corn water requirement throughout the growing period. The historic records of rainfall from April to August for this location are 22.5 inches, which suggests the 2025 growing season registered rainfall above the historic values. Heavy and frequent rainfall was recorded in April and May (6.9 and 10.5 inches, respectively). Sparse rainfall events were recorded in June (5.6 inches) and July (2.4 inches), suggesting the need for irrigation to supplement the daily crop water needs. During the first 15 days in July, the sparse rainfall recorded was 0.9 inches; however, during the second half of the month, the cumulative rainfall recorded was 2.4 inches. The ambient temperature, minimum and maximum temperatures, increased from May to August. In May, the maximum ambient temperature recorded was 93°F, and in August it was 98°F.

To ensure adequate potassium for early crop development, a rate of 200 lbs of potash (0-0-60) per acre was applied across the test area during field preparation. Between planting and the V10 growth stage, sulfur was introduced as part of the nitrogen fertilization strategy. It was applied through the use of UAN (28-0-0-5S) and granular urea, with sulfur contributing approximately 10% of the total nitrogen applied as urea. This approach supported nitrogen and sulfur synergy, crucial for plant protein synthesis and metabolic functions. Zinc was applied (equivalent to 0.5 lbs. of actual zinc) during the herbicide application to mitigate potential micronutrient deficiencies. Fungicide was applied with a drone on June 2 to the plots of teams that selected that option.

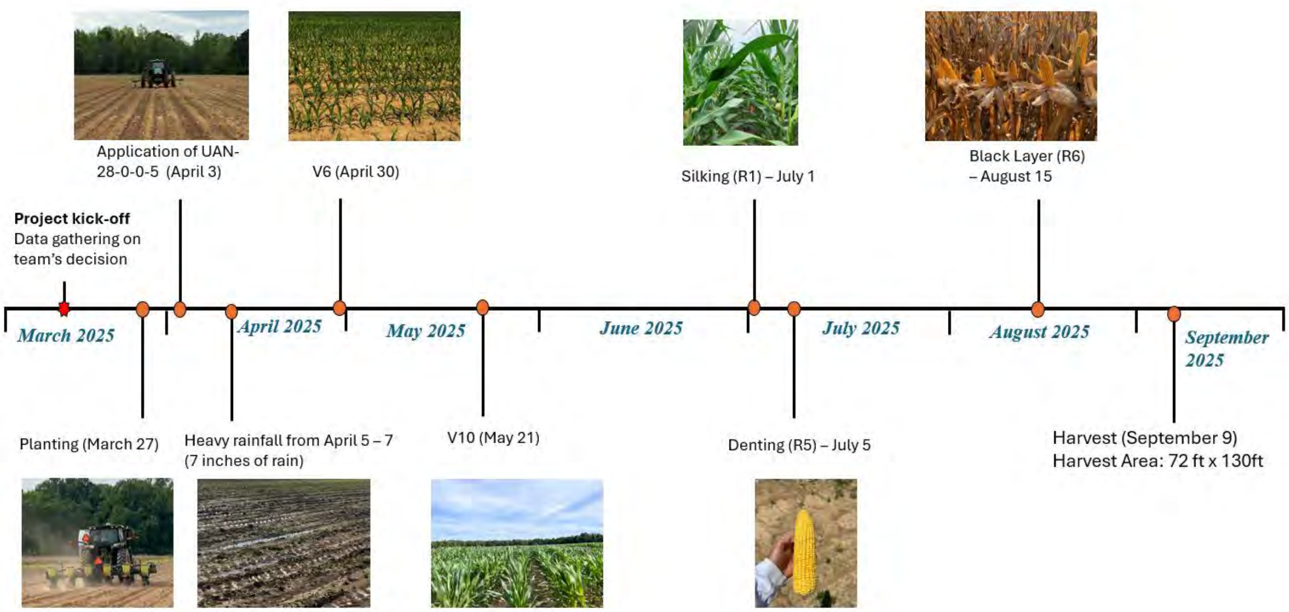

Figure 7. Sequence and dates of the major corn growth stages and events recorded from the TAPS plots from planting to harvest.

6. PARTICIPANTS

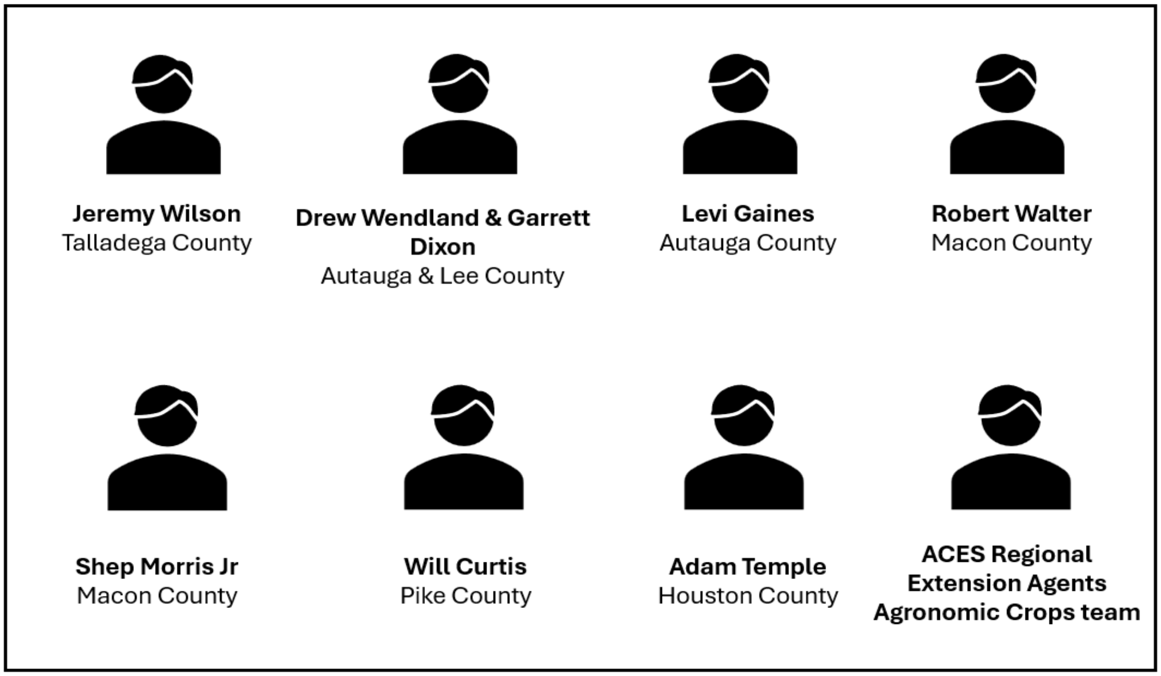

Figure 8. Participants for the 2025 AU-TAPS competitions in Alabama.

7. FUNDING AND PARTNERS

Figure 9. 2025 TAPS funding and partners. Funding to implement and execute the project, as well as contributions including seed, technology, equipment installation, access to novel tools, and time, were received.

8. DECISIONS MADE BY THE 2025 TAPS TEAMS

The teams were responsible for making pre-planting and in-season crop management and economic decisions. All decisions were submitted through the TAPS portal. The decisions and resulting outcomes are summarized below.

8.1 Competition Data

In winter 2025 and early spring, soil sampling on the TAPS field was done by SouthGen Solutions agtech company (https://www.southgen.org/) to assess soil nutrient levels and make plans for macro-nutrient application. Variable rate application of Lime, DAP 18-46-0, and MOP 0-0-60 was done before planting. This information was provided to the teams before planting. Leaf tissue samples were collected during the growing season and at harvest to measure nitrogen in the tissue and the grain.

8.2 Agronomic Decisions

Teams were responsible for making six crop management and economic decisions through the TAPS portal. Occasionally, the TAPS coordinating team communicated with the participants when the team's recommendations needed clarification. The agronomic decisions made by the teams are summarized in Table 1.

Hybrid Selection (decision type #1) and Seeding Rate (decision type #2). Although five different corn hybrids from four major seed companies were offered to the teams, only two different hybrids were chosen by the teams for the competition. Eight teams (1, 2, 4, 5, 6, 7, 8, and 9), including the control, selected the same hybrid, DKC68-35 (Table 1). Only one team chose the DKC70-45 hybrid. The seeding rates selected by the teams ranged from 29,000 to 35,000 seeds/acre. All the plots were planted on March 27, 2025.

Table 1. Summary of selected agronomic inputs selected by the various 2025 TAPS Teams.

Team ID	Corn Hybrid	Seeding Rate (1,000/ac)	Nitrogen Fertilization*							Irrigation (in)
			March 26 (NPK)	March 27&28 (APP)	April 3 (UAN)	April 30 (UAN)	May 22 (UAN)	May 23 (UCAN23)	Total N	
			---------- (Lbs.N/ac) ----------							
1	DKC68-35	34	0	26	0	225	0	0	251	1.03
2	DKC68-35	35	0	20	0	105	21	0	146	9.24
3	DKC70-45	32	0	26	0	134	0	104	264	7.80
4	DKC68-35	33	0	0	89	60	0	78	227	5.40
5	DKC68-35	34	0	21	0	50	179	0	250	0.13
6	DKC68-35	34	57	0	0	210	89	0	356	4.60
7	DKC68-35	29	0	0	45	*120	60	0	225	9.70
8	DKC68-35	33	0	0	59	200	39	0	298	10.10
9**	DKC68-35	34	0	0	0	0	0	0	0	0.75

APP – Ammonium Polyphosphate applied at planting; UAN – Urea Ammonium Nitrate; NPK – 19-19-19; Urea – 40%N. Note: The corn crop was planted on April 18, 2024.
*Team 7 applied 120 N lbs/ac at V6 with granular urea (40-0-0)
** Control treatment with no nitrogen or water application.

Crop Insurance (decision #3). Teams were invited to choose among six crop insurance packages with the objective of learning farmers' preferences for insurance and the role of their choice on risk management. Teams 1, 2, 4, and 6 chose Yield Protection with the Enterprise Unit (50% coverage). Teams 3, 5, 7, and 8 selected Revenue Protection, specifying coverage levels between 70% to 75%.

Nitrogen Management (decision #4). The total nitrogen fertilizer applied by the teams, excluding the control (Team 9), ranged from 146 to 356 lbs N/ac (Table 1). Based on the distribution of nitrogen among the three application timings, starter N, on average, represented 17% of each team's seasonal N rate, with individual teams' starter N ranging from 8.4 to 39.2% of their total N at planting. Most teams applied between 10 and 20% of their nitrogen at planting, whereas one team (team 4) front-loaded nearly 40% of its total N at planting. Side-dress applications at the V6 growth stage accounted for the largest share of nitrogen, averaging about 55% of the total N and ranging from 20 to almost 90% of the total nitrogen applied across teams. Team 1 applied nearly all of its nitrogen at V6 and did not apply N at V10. Final applications at the V10 growth stage contributed, on average, 28% of the seasonal N rate, with individual teams ranging from no N applied at V10 to about 72% of their total N rate at V10 (Table 1). Teams 1, 2, 3, and 5 chose the liquid fertilizer APP 11-37-0 as their starter source at planting, which was applied with an in-furrow applicator during planting. However, due to an equipment breakdown, we were unable to finish applying the 11-37-0 and completed the remaining N application with UAN 28. The starter 28-0-0-5 application was delayed due to equipment malfunction and was later applied on April 3 with a 360 Y-DROP application system. Teams 6 selected granular NPK 19-19-19 as their starter N source, which was applied a day prior to planting (March 26). The control plots (Team 9) did not receive any N application. All teams applied nitrogen at the V6 growth stage using UAN 28% except team 7, which applied N with granular urea (40-0-0) (Table 1). The third nitrogen application, made at the V10 growth stage, was applied as UAN 28% and UCAN 23%. The overall summary of nitrogen management decisions is presented in Table 1.

Biomass samples were collected on May 9 (V6), June 12 (VT), and on August 18 (black layer). These samples were analyzed for N concentration, and the data were used to estimate crop nitrogen uptake. Because teams differed in nitrogen source, rate, and timing, multiple pieces of equipment were required for N applications. Liquid 11-37-0 at planting was applied with an LMC 6-row coulter applicator mounted on the planter. At V6, the coulter applicator was upgraded with the 360 Y-DROP® side-dress implement to improve placement and efficiency of liquid N. Granular urea applications were made with a 54-ft Chandler fertilizer spreader, and the UAN 28% and UCAN 23% application at V10 was applied with a 60-ft John Deere R4030 sprayer equipped with 42-in drops. A detailed list of precision agriculture technologies used for all input applications is provided in Appendix A.

Water Management (decision #5). Due to the high and frequent rainfall events after planting, irrigation only began on May 23, 2025, and ended on July 18, 2025. Corn reached physiological maturity around the first week of August 2025. When irrigation was prescribed by the teams during weeks with significant rainfall, either irrigation was not applied, or the irrigation rate was adjusted based on the rainfall amount. Seasonal irrigation totals ranged from 0.13 to 10.1 inches (Table 1). Among the irrigation scheduling tools available, Teams 3, 4, 6, and 8 selected the Smart Irrigation CropFit App while Teams 1, 2, and 7 selected the AquaSpy® sensor, and Team 5 chose the Sentek soil sensor. The TAPS coordinating team recognizes the need for additional training on the use of irrigation scheduling tools to ensure that farmers and consultants fully leverage these tools and adjust irrigation according to the crop needs and soil water holding capacity. Figure 10 illustrates the various irrigation rates prescribed by the teams and applied using the variable-rate irrigation system. Figure 11 provides a weekly comparison of how each team irrigated their plots with respect to the weekly crop evapotranspiration, rainfall, and cumulative soil water depletion on the top 24 inches. The cumulative crop evapotranspiration value was extracted from the SI CropFit App, and the cumulative soil water depletion reported corresponds to the of the sandy loam soil (Cahaba sandy loam) that represented the conditions of the plots located on block 1. A preliminary analysis of the irrigation values suggests that many teams might have irrigated following their knowledge of the weekly crop water demand; however, at times, it seemed those teams did not consider either the previous rainfall registered at the site or the soil water holding characteristics or soil water depletion and therefore, over-irrigation was observed. For example, during the week of May 18-24, teams 3 and 8 significantly over-applied water. The soil water deficit on the top 24" was 0.6 inches; however, those teams applied 1.5 inches that week. Other important examples of over-irrigation were observed during the weeks of June 20-27 and June 27-July 4. Even though the soil water deficit was low, teams 2, 3, 6, 7, and 8 applied high rates of irrigation when compared to the soil water deficit and crop evapotranspiration. The results suggest the need to increase the training on irrigation scheduling and the use of irrigation scheduling tools.

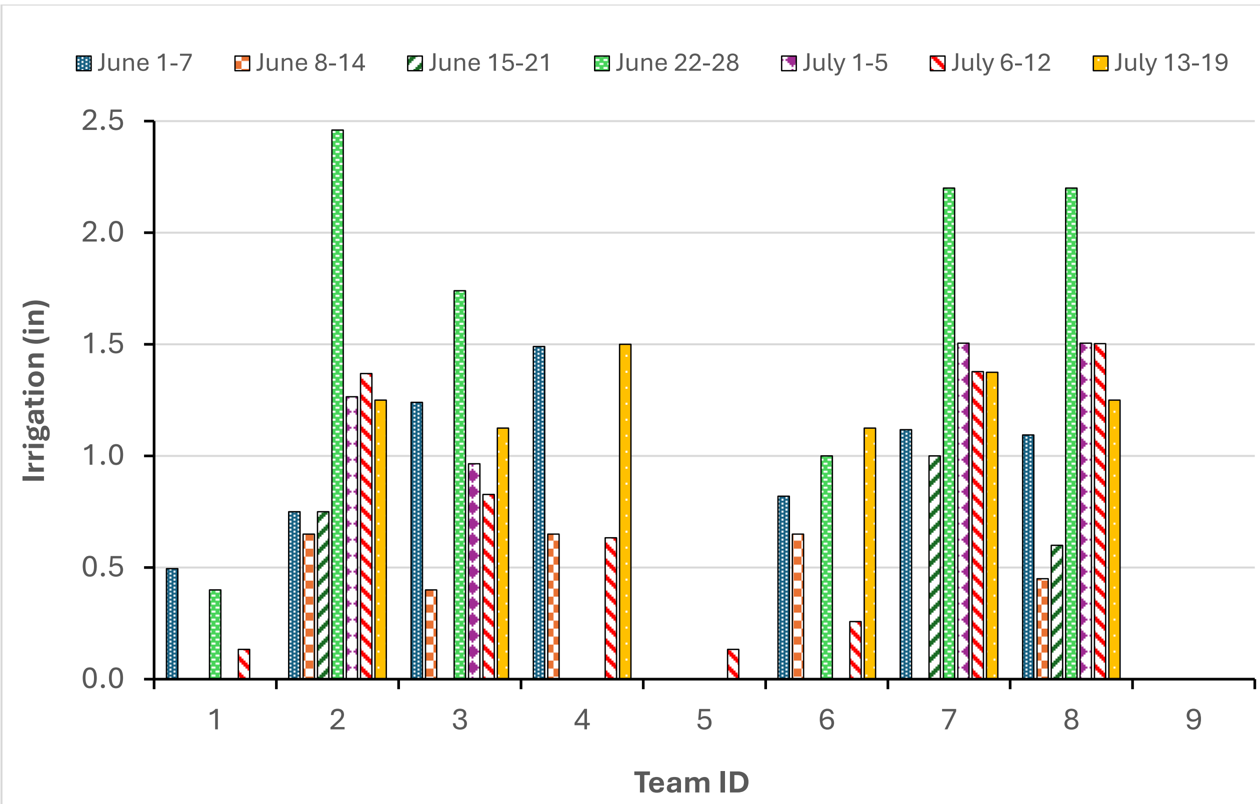

Figure 10. Weekly irrigation rates prescribed by the Teams in the competition.

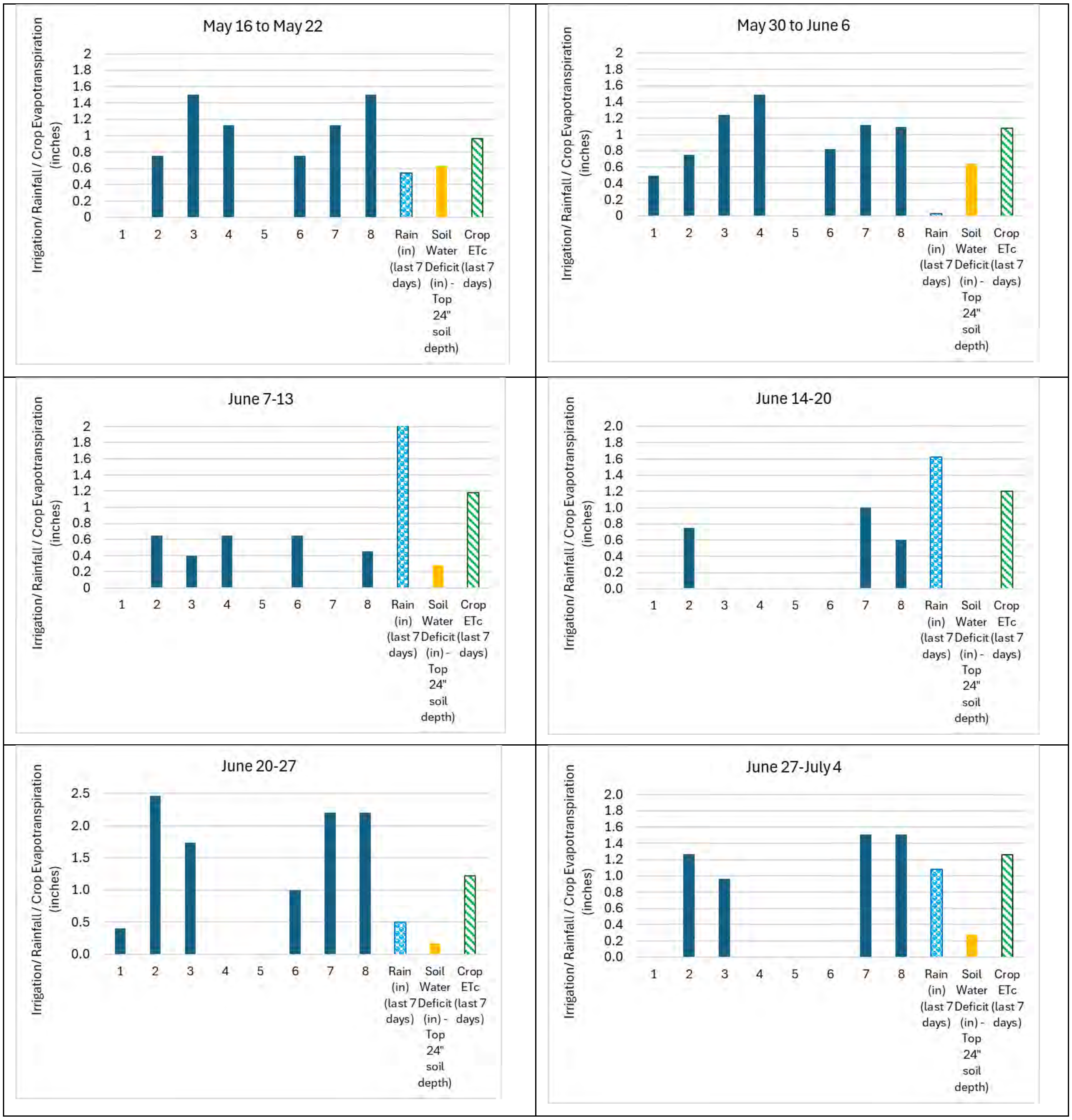

Figure 11. Examples of how the different teams managed irrigation/week with respect to soil water depletion and crop evapotranspiration. Note: Graphs also include the weekly rainfall, cumulative last seven days of soil water depletion on the top 24 inches, and the seven-day cumulative crop evapotranspiration.

9. RESULTS

9.1 Grain Yield

The heavy and frequent rainfall events right after the corn was planted, along with the poor drainage conditions in some parts of the field, might have impacted corn emergence, root development, and root respiration. Additionally, some of the nitrogen applied at planting might have been lost through runoff after more than six inches of rainfall were recorded only a few days after the application. These issues with planting and the frequent rainfall events recorded throughout most of the vegetative period might have impacted the final yield (0.2-acre plot harvest area). Even though each team managed three plots located across the field, the 2025 yield values in this report correspond to the average yield of the best two plots. Overall, the average corn grain yield among the TAPS teams ranged from about 80 bu/ac in the non-fertilized control (Team 9) to approximately 180 bu/ac for the highest-yielding teams (Figure 12). For the fertilized treatments (Teams 1–8), total nitrogen rates ranged from 146 to 356 lbs N/ac, and irrigation depth varied from almost no supplemental water (≈0.1 in) to about 10 in (Table 1). As in the previous year, these yield results should be interpreted with caution, especially if the yield among teams is compared. It is important to remember that the crop management strategies selected by the teams differed in corn hybrid, seeding rate, irrigation strategy, nitrogen source, rate, and timing of application, as well as the possible impact of rainfall after the application of nitrogen (Figure 6).

Preliminary analyses suggest that nitrogen management (rate and timing) explained a larger share of the variability in grain yield than irrigation, although irrigation still contributed to yield differences among teams. The within-field soil variability and some terrain differences might have also influenced the response of the crop to irrigation, as each team had three plots at three different locations across the field. Among the teams, yields were relatively clustered despite large differences in N and irrigation. Teams 1, 2, and 8 achieved the highest yields, between 175 – 180 bu/ac average, with total N rates of 251, 146, and 298 lbs N/ac and irrigation depths of about 1.0, 9.2, and 10.1 in, respectively (Figure 12; Table 1). Teams 3, 4, 6, and 7 produced intermediate yields between 160 and 175 bu/ac while applying between 225 and 356 lbs N/ac and 4.6 – 9.7 in of irrigation. Except for the control team 9, team 5 recorded the lowest yield among the teams (155 bu/ac) despite a relatively high N rate (250 lbs N/ac) and minimal irrigation (0.13 in). These patterns indicate that higher N and water inputs did not always translate into higher yield during the 2025 growing conditions.

Because all teams except Team 3 planted the hybrid DKC68-35 at relatively similar seeding rates (except the 29,000 seeds/ac), some comparisons among those teams are possible. For example, Teams 2 and 6 both planted DKC68-35 at 35,000 and 34,000 seeds/ac, respectively, yet Team 2 achieved one of the highest yields (180 bu/ac) with only 146 lbs N/ac and 9.24 in of irrigation, whereas Team 6 applied 356 lbs N/ac and 4.60 in of irrigation but obtained a slightly lower yield (≈160 bu/ac). Similarly, Teams 2 and 8 reached comparable high yields even though Team 8 applied more than twice the nitrogen (298 vs. 146 lbs N/ac) and slightly more irrigation. These comparisons highlight substantial opportunities to improve nitrogen use efficiency without sacrificing yield. Differences in the timing of nitrogen applications further illustrate this point. Teams varied widely in how they partitioned N among starter, V6, and V10 applications, with some teams applying almost 90% of their N at the V6 side-dress stage and no N at V10, and others applying more than 70% of their N at V10. Nitrogen applications occurred around different rainfall patterns (Figure 6), which may have influenced N availability and losses.

Overall, the 2025 results show that most teams were able to achieve yields above 150 bu/ac with a wide range of nitrogen and irrigation combinations.

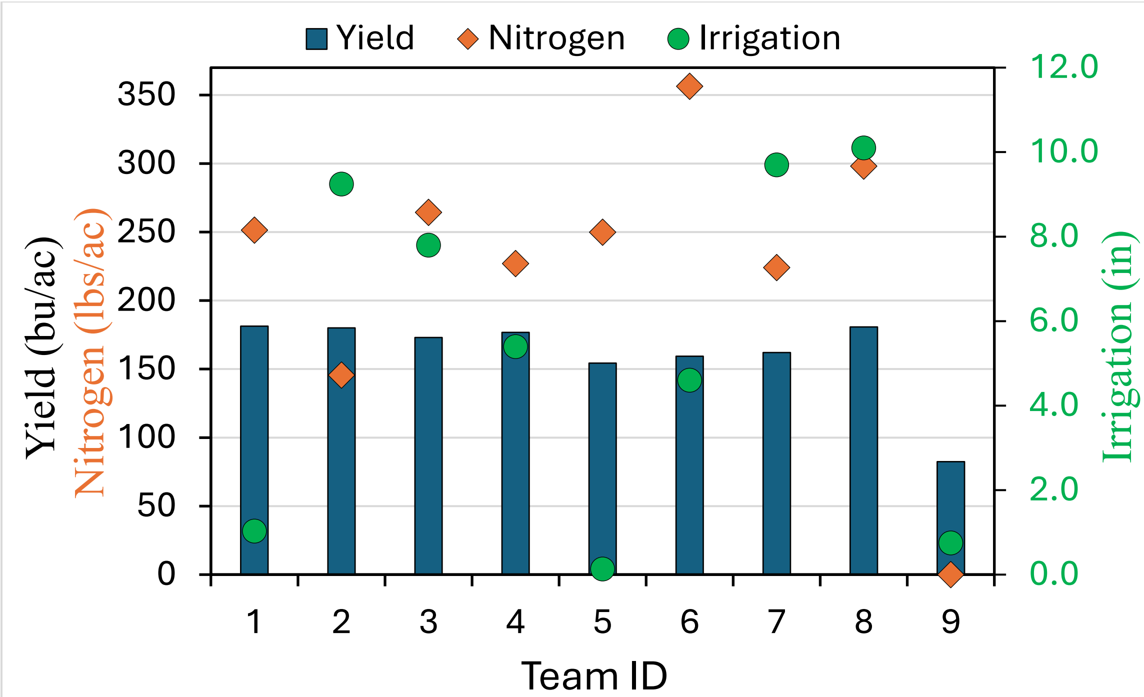

Figure 12. Grain yield differences among the 2025 TAPS teams and their total nitrogen and irrigation management decisions. Note: Plots of Team 9 did not receive neither nitrogen nor irrigation.

9.2 Input Use Efficiency

The Nitrogen Intensification Performance Index (NIPI; Lo et al., 2019) was used to quantify the effect of nitrogen on grain yield relative to the control (Team 9), which received no nitrogen and only 0.75 in of irrigation water (Table 3). Among the teams, NIPI values ranged from 0.16 to 0.41 (Figure 13, Table 3). Team 2 achieved the highest NIPI (0.41) while applying the lowest total N rate (146 lbs N/ac), indicating a strong grain yield response relative to the control per unit of N added. Teams 1 and 4 also showed relatively high NIPI values (0.28), followed by Teams 3, 7, and 8 (0.25 – 0.26). In contrast, Team 6, which applied the highest total N rate (356 lbs N/ac), recorded the lowest NIPI (0.16), indicating that heavy N inputs did not necessarily translate into proportionally higher yield. Agronomic Efficiency of nitrogen (AE), which expresses the yield increase per pound of applied N, showed similar patterns. The AE values varied from 13.5 to 41.4 lbs grain/lb N (Table 3). Team 2 again ranked first, with an AE of 41.4 lbs grain/lb N, well above the competition average. Teams 4 and 1 had the next highest AE values (25.5 and 24.6 lbs grain/lb N), while Teams 3, 7, and 8 formed an intermediate group (21–23 lbs grain/lb N). Teams 5 and 6, which applied relatively high N rates, recorded the lowest AE (18.5 and 13.5 lbs grain/lb N), highlighting diminishing returns to additional nitrogen under the 2025 growing conditions.

When nitrogen use was evaluated using Nitrogen Use Efficiency (NUE; yield obtained per unit of N applied), Team 2 again emerged as the top performer, with an NUE of 73.1 lbs grain/lb N (Table 3). The next highest NUE values were observed for Teams 4, 7, and 1 (45.9, 43.3, and 43.0 lbs grain/lb N, respectively), all of which applied moderate N rates. Teams 3, 5, and 8 exhibited intermediate NUE (36 – 40 lbs grain/lb N), whereas Team 6 had the lowest NUE (26.5 lbs grain/lb N). Nitrogen Recovery Efficiency (NRE), which reflects the percentage of applied N recovered in aboveground biomass at harvest, showed a similar ranking: Team 2 had the highest NRE (52.7%), followed by Teams 3 and 4 (36.6 and 35.8%), while Team 6 showed the lowest NRE (21.1%). These indices together indicate that combining relatively low N rates with timely applications (as in Team 2) resulted in both higher grain production per unit N and greater N uptake.

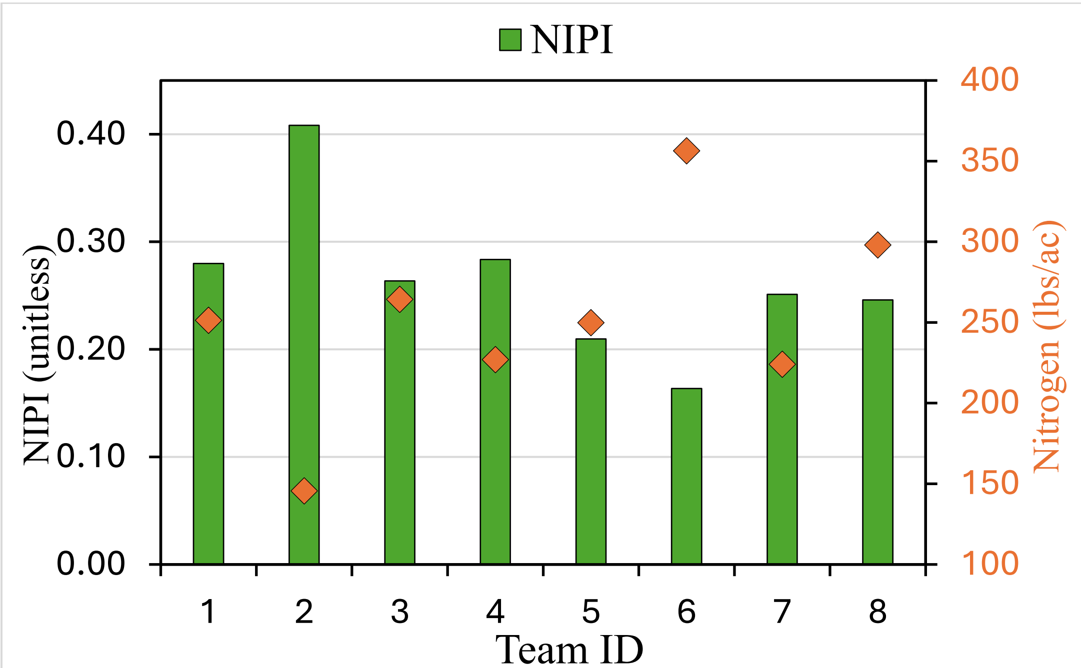

Figure 13. Team differences in the Nitrogen Intensification Performance Index (NIPI) and the total nitrogen rates

Water-related indices further emphasized the trade-offs between irrigation and efficiency. Irrigation Water Use Efficiency (IWUE) varied widely among teams, from 442 to 8,054 lbs grain per inch of irrigation (Table 3). Team 5, which applied 249.9 lbs N/ac but only 0.13 in of irrigation water, achieved by far the highest IWUE (8,054.3 lbs/ac/in). Teams 1, 4, and 6 also exhibited relatively high IWUE (3,059; 1,073; and 1,046 lbs/ac/in, respectively), reflecting moderate to high yields with relatively low irrigation amounts. In contrast, Teams 2, 7, and 8 applied 9 – 10 in of irrigation and therefore had much lower IWUE values despite achieving competitive yields. Crop Water Productivity (CWP), which considers yield per unit of total water supply (irrigation plus rainfall), showed less variation than IWUE but still distinguished the most water-efficient strategies. The highest CWP was observed for Team 1 (305.1 lbs/ac/in), followed by Teams 5, 4, and 3 (267.5, 261.6, and 253.3 lbs/ac/in, respectively). Teams 2, 3, and 8 formed an intermediate group (242 – 244 lbs/ac/in), while Team 7 had the lowest CWP among the fertilized treatments (219.9 lbs/ac/in).

This year's competition results indicate that Team 2 achieved the best overall nitrogen efficiency across multiple indices (NIPI, AE, NUE, and NRE) by combining the lowest N rate with competitive yields. Teams 1, 4, and 5 also performed strongly in at least one major efficiency metric, particularly in terms of water use (IWUE and CWP). In contrast, strategies that relied on very high N rates and substantial irrigation (e.g., Team 6) tended to have lower efficiencies, emphasizing the potential to maintain high yields while substantially improving both nitrogen and water use efficiency through more moderate and better-timed input applications.

Table 2. Summary of results from the 2025 TAPS competition

Team ID	Stover N Uptake (lbs/ac)	Grain N Uptake (lbs/ac)	Total N** Uptake (lbs/ac)	Test** Weight (lbs/bu)	Grain yield* (Bu/ac)	Gross Revenue ($/ac)	Marginal Cost ($/ac)	Net Return ($/ac)
Team 1	31.8	113.2	145.0	59.1	181.4	712.82	394.82	318.01
Team 2	31.5	111.7	143.2	57.6	180.1	702.43	398.74	303.69
Team 3	33.2	130.0	163.2	60.9	173.0	674.70	488.89	185.81
Team 4	32.8	115.0	147.8	58.5	176.8	698.52	369.84	328.68
Team 5	35.2	104.6	139.8	58.4	154.3	609.45	361.04	248.41
Team 6	38.1	103.6	141.6	58.8	159.4	621.82	469.67	152.15
Team 7	34.4	106.7	141.0	58.3	162.1	652.83	358.04	294.78
Team 8	15.7	121.8	137.5	58.9	180.7	749.91	420.75	329.16
Team 9	21.9	42.9	64.9	56.7	82.4	321.36	150.18	171.18

* Yield reported at 15.5% grain moisture content
**AEN – Agronomic Efficiency of Nitrogen; NRE – Nitrogen Recovery Efficiency; IWUE – Irrigation Water Use Efficiency; NIPI – Nitrogen Intensification Performance Index.

Table 3. Team differences in the efficiency of nitrogen, irrigation, and total water use.

Team ID	Total N (lbs/ac)	Irrigation (in)	NHI* (%)	NUE* (lbs/lbs)	AE* (lbs/lbs)	PE* (lbs/lbs)	NRE* (%)	NIPI* (unitless)	IWUE* (lbs/in)	CWP* (lbs/in)
Team 1	251.4	1.03	78.0	43.0	24.6	78.5	31.2	0.28	3058.7	305.1
Team 2	145.7	9.24	78.2	73.1	41.4	79.1	52.7	0.41	566.1	243.9
Team 3	264.4	7.80	79.7	40.4	22.9	63.2	36.6	0.26	652.1	253.3
Team 4	227.0	5.40	77.3	45.9	25.5	72.1	35.8	0.28	1073.0	261.6
Team 5	249.9	0.13	75.2	37.0	18.5	64.4	29.3	0.21	8054.3	267.5
Team 6	356.4	4.60	73.1	26.5	13.5	64.3	21.1	0.16	1046.1	241.9
Team 7	224.1	9.70	75.5	43.3	22.7	67.5	33.3	0.25	442.3	219.9
Team 8	298.1	10.10	88.5	36.4	20.9	89.2	23.8	0.25	525.7	244.0
Team 9	0.0	0.75	66.3	0.0	0.0	0.0	0.0	0.00	0.0	0

*NUE – Nitrogen Use Efficiency; CWP – Crop Water Productivity. Biomass, yield, and N uptake values are based on samples collected at harvest. Note: the yield on this table is reported in Lbs./acre as these values were used to the efficiency indices presented in this table. ** Grain moisture at 15.5%

10. ECONOMIC DECISIONS

Teams carefully selected Multi-Peril Crop Insurance (MPCI) policies to align with their risk management strategies. The options included Revenue Protection (RP), Revenue Protection with Harvest Price Exclusion (RP-HPE), and Yield Protection (YP), all of which were offered only as Enterprise Units. RP policies offered protection against lost revenue due to a decline in price and/or USDA RMA-covered yield loss, with coverage levels ranging from 50% to 85% of the defined Actual Production History (APH) yield, in increments of 5%. Additionally, RP guaranteed the higher of the projected or harvest price as part of the revenue guarantee. YP policies focused solely on protection against USDA RMA-covered yield loss, with coverage levels between 50% and 85%, and price protection ranging from 55% to 100% of the projected price. Catastrophic coverage (CAT) was also available under YP, covering 50% of the APH yield and 55% of the projected price.

Among the competitors, only one team prioritized minimizing cost by selecting YP at the CAT level, priced at just $0.655 per acre. Three of the teams chose 50% coverage at a cost of $2.53 per acre. Four teams opted for RP, balancing moderate coverage with cost. Two of the teams that selected RP chose 70% coverage at a cost of $6.76 per acre, while the other two teams chose RP at 75% coverage and a cost of $9.61 per acre. Higher coverage, while at a higher premium, does ensure more comprehensive protection against price and yield variability, showcasing a preference for higher financial security. The premium costs of the chosen policies were included in the team's marginal costs, and any indemnities were factored into their revenues.

Overall, the diverse selection of policy options reflects a range of risk management strategies aimed at balancing costs and yield or revenue protection (Table 4).

Table 4. Crop Insurance Premiums by Coverage Level and Policy Type.

Coverage Level	RP (Revenue Protection)	RP-HPE (Revenue Price - Harvest Price Exclusion)	YP (Yield Protection)
CAT	-	-	$ 0.66
50%	$ 3.14	$ 2.85	$ 2.53
55%	$ 3.80	$ 3.38	$ 2.91
60%	$ 4.59	$ 4.02	$ 3.38
65%	$ 5.56	$ 4.77	$ 3.95
70%	$ 6.76	$ 5.70	$ 4.68
75%	$ 9.61	$ 7.97	$ 6.54
80%	$ 16.75	$ 13.61	$ 11.18
85%	$ 30.31	$ 24.26	$ 20.14

*All coverage options, except CAT, are shown based on a 100% projected price. Only Enterprise Units were offered.

The Teams had access to soil analysis reports and were required to make strategic agronomic decisions such as:

Corn Hybrid Selection: Teams selected hybrids from options listed in Table 5, which ranged in cost from $285.00/bag (Armor 1474) to $314.00/bag (Dekalb 68-35). Their choices influenced not only seed costs but also yield potential and disease resistance.

Seeding Rates: Decisions on seeding density directly impacted total seed costs and yield outcomes, with the per-seed cost detailed in Table 5.

Table 5. Corn Hybrid Costs.

Corn Hybrid	Per Bag (80K seeds)	Per 1,000 Seeds
Armor 1474	$285.00	$3.56
Croplan 5893	$305.00	$3.81
Delkab 68-35	$314.00	$3.92
Delkab 70-45	$306.00	$3.82
DynaGro 58VC65	$298.00	$3.73

Nitrogen Fertilizer Management: Teams selected from options 11-37-0 (liquid) at $710/ton, 19-19-19-5 (granular - 5% Sulfur) at $585/ton, 28-0-0-5 (liquid - 5% Sulfur) at $335/ton, 40-0-0-6 (granular - 6% Sulfur) at $490/ton, UCAN-23 (liquid fertilizer solution containing 23% nitrogen, 4% calcium (Ca)) at $375/ton as shown in Table 6. Decisions were made carefully considering both the cost per pound of nitrogen and the timing of application to optimize nitrogen efficiency and maximize the yield response while controlling costs.

Table 6. Nitrogen Fertilizer Costs.

Starter Nitrogen Fertilizer	Per Ton	Per Gallon	$/lb.
11-37-0 (liquid)	$710.00	$4.26	
19-19-19-5 (granular - 5% Sulfur)	$585.00		$0.29
28-0-0-5 (liquid - 5% Sulfur)	$335.00	$1.84	
40-0-0-6 (granular - 6% Sulfur)	$490.00		$0.25
UCAN-23 (liquid fertilizer solution containing 23% nitrogen, 4% calcium (Ca))	$375.00	$2.15	

Irrigation Management: Teams determined irrigation requirements using irrigation scheduling tools and weather conditions, while accounting for the operational cost of $9.00 per inch of water applied (Table 7). Additional management options—including fungicide application ($10.15/acre), Sentinel fertigation

($8.00/acre), and laboratory N-content analysis ($15.00 per sample), were also made available to the teams (Table 7).

Table 7. Other input costs.

Other Inputs	Unit	Cost
Irrigation operations	in	$9.00
Fungicide appl	acre	$10.15
Sentinel Fertigation	acre	$8.00
Laboratory analysis N-Content	sample	$15.00
AquaSpy Sensor	acre	$1.70
Sentek Sensor	acre	$2.00
Trellis Sensor	acre	$1.45
SmartIrrigation CropFit App (University of Georgia)	App	$0.00

10.1 Net Returns

Profitability refers to the ability of a business or activity to generate financial gain. In the context of crop production, it measures how efficiently a farm converts its costs (such as seeds, fertilizers, irrigation, and labor) into income from selling the crops. We do not calculate profitability for this competition because we have not estimated total cost of production. Instead, we focus on net returns, which represents the amount of revenue that can be allocated to additional costs that are not estimated. Net return is thus calculated as:

$$\text{Net Return} = \text{Gross Revenue} - \text{Marginal Cost}$$

A higher net return indicates that the farm has more residual revenue remaining to allocate to other costs of production not included in the marginal cost calculation.

The Marginal Cost is calculated by summing all input costs per acre that are related to the team decisions. This includes expenses for crop insurance, seeding, fertilizer, irrigation, and sprayer applications. In this context, only costs that can differ between teams are computed as follows:

$$\text{Marginal Cost} = \text{Sum of all team decision input costs (per acre)}$$

The Gross Revenue is determined by adding the revenue from crop sales per acre to any additional sources of revenue, such as crop insurance indemnity payments, if applicable:

$$\text{Gross Revenue} = \text{Revenue from Crop Sale (per acre)} + \text{Crop Insurance Indemnity (if applicable)}$$

Revenue from crop sales was determined based on the marketing decisions of the teams discussed in the next section. The performance of teams is depicted in terms of Gross Revenue and Marginal Cost in Figure 14 and Net Returns in Figure 15, highlighting the degree of variation in results.

Team 8 stands out as one of the top performers, achieving the highest gross revenue ($749.91 per acre) and the highest net return among all teams, totaling $329.16. Despite having a moderate marginal cost ($420.75), its high level of revenue results in excellent profitability. Team 4 also performs exceptionally well, combining high gross revenue ($698.52 per acre) with one of the lowest marginal costs ($369.84). This balance produces a strong net return, totaling $328.68. Team 1 delivers solid performance, generating a gross revenue of $712.82 with a marginal cost of $394.82, resulting in a net return of $318.01. Similarly, Team 2, with gross revenue of $702.43 and a marginal cost of $398.74, achieves a competitive net return of $303.69. Team 7, despite receiving a small crop insurance indemnity, produces a gross revenue of $652.83 and maintains a relatively low marginal cost ($358.04), resulting in a net return of $294.78. Team 5, despite receiving a small crop insurance indemnity, generates a gross revenue of $609.45 and reports a net return of $248.41. Team 3, despite having reasonable gross revenue ($674.70), faces the highest marginal cost ($488.89), reducing its net return to $185.81. Team 9, with the lowest gross revenue ($321.36) and the lowest marginal cost ($150.18), achieves a net return of $171.18. Team 6, even with gross revenue of $621.82, exhibits one of the highest marginal costs ($469.67), resulting in the lowest overall net return, $152.15.

These findings underscore the importance of optimizing input costs to maximize net return and, ultimately, profitability in crop production.

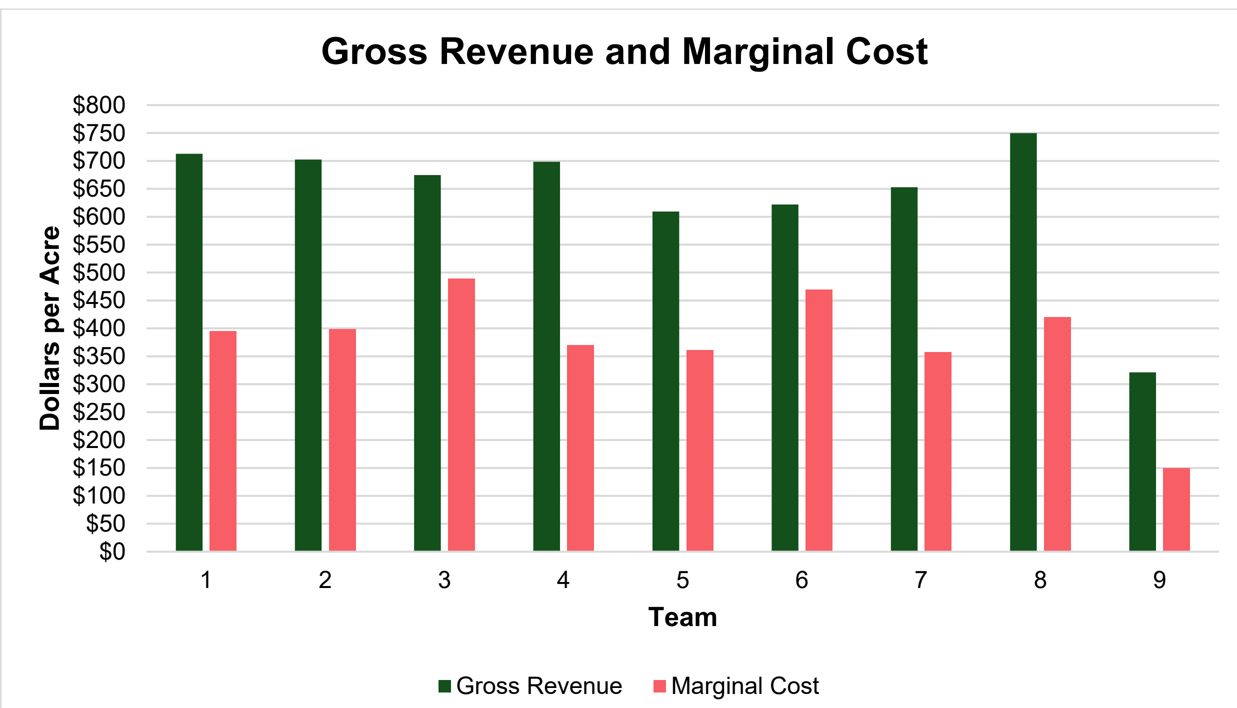

Figure 14. Gross Revenue and Marginal Cost.

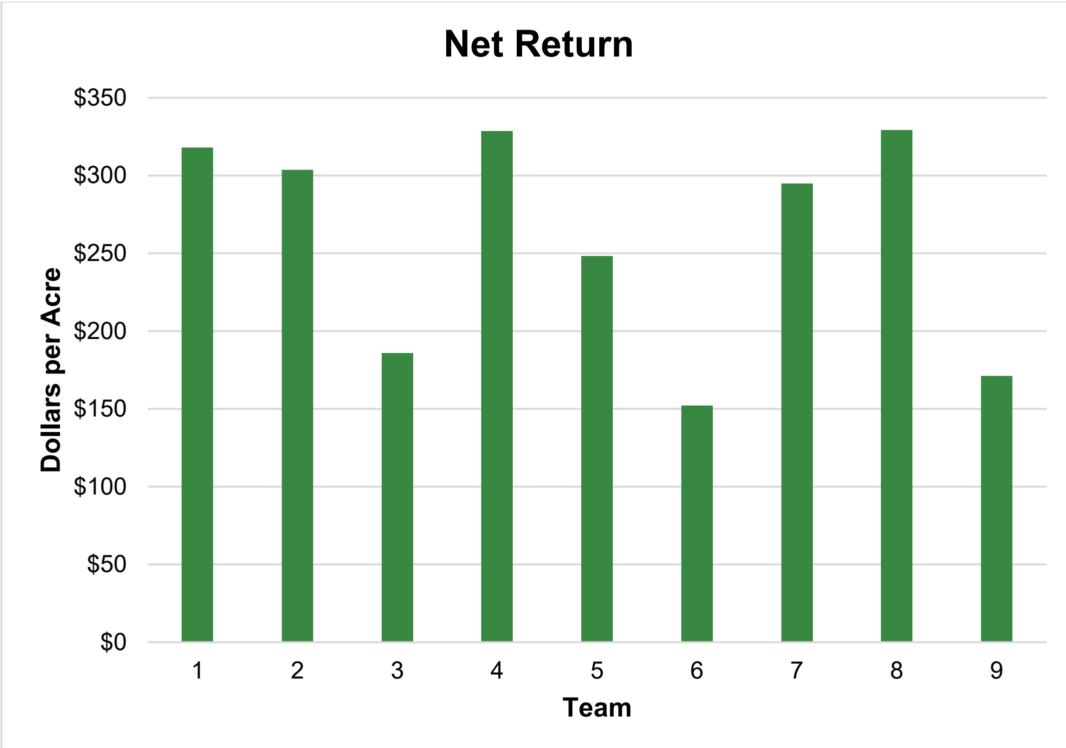

Figure 15. Net Return.

10.2 Marketing

The calculated yields were simulated over 1,000 acres. Teams were able to pre-harvest market (forward contracts, hedge-to-arrive contracts, or basis contracts) and sell grain on the harvest date. During the 2025 competition, five teams relied solely on at-harvest sales and three teams used pre-harvest marketing. Team 8 led the way with 64% of marketed grain booked pre-harvest, with teams 1 and 4 both at 11%, as shown in the figure below.

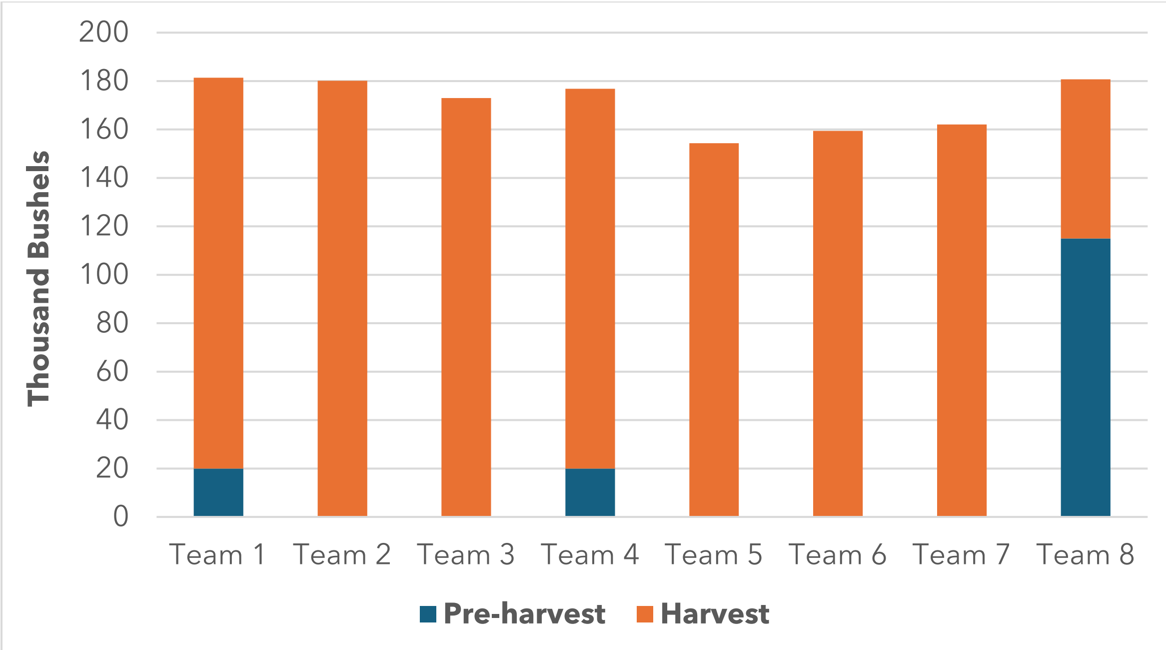

Figure 16: Quantity of Corn Marketed Pre-harvest vs. At-harvest by Team

The marketing strategies varied across the teams, as team 1 marketed an equal portion each month from May through August, team 4 contracted all of its grain in March, and team 8 booked a portion in March and a portion in June. The teams used all three pre-harvest marketing tools available, but 84% of pre-harvest market sales were through forward contracts as shown in Figure 17 below.

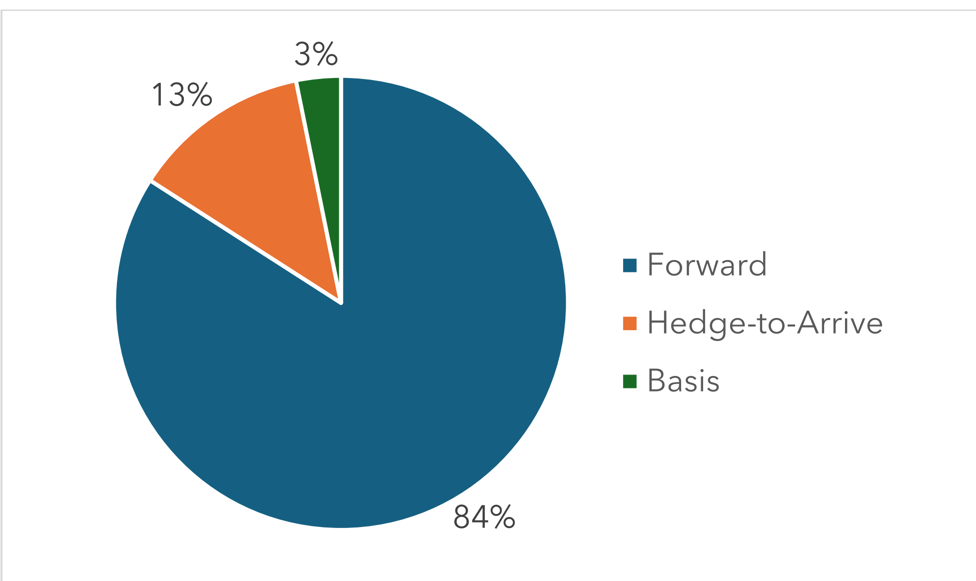

Figure 17: Pre-harvest Marketed Corn by Contract Type

Corn prices generally decreased throughout the growing season in 2025. Basis weakened from $0.00 at the start of the competition to -$0.30 at harvest. The harvest price was $3.90 per bushel on September 9th, 2025, as shown in Figure 18.

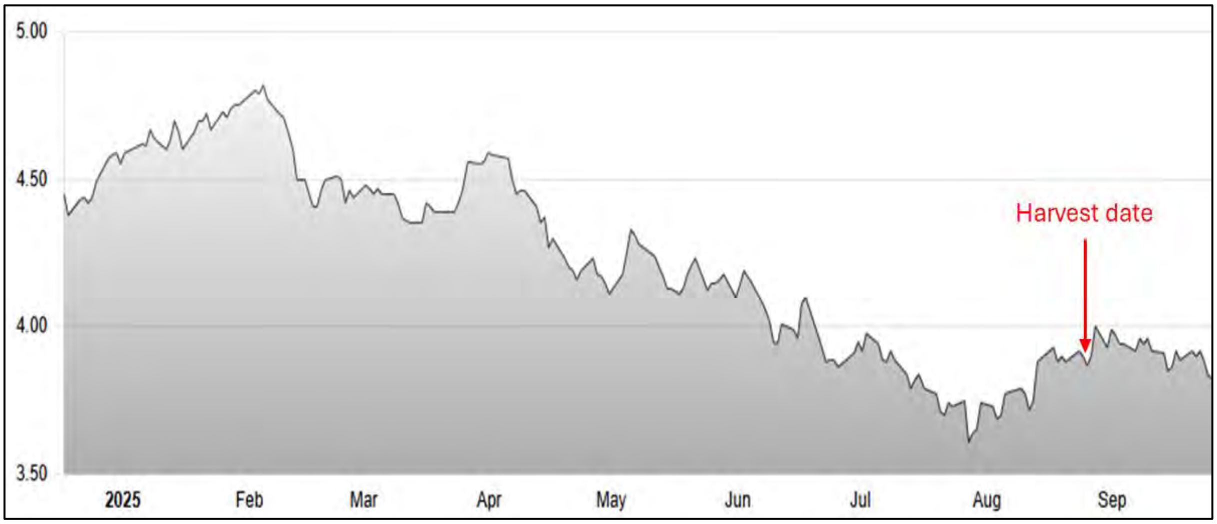

Figure 18: 2025 Corn Prices. **(**Source: Agrex Inc, Montgomery)

The total revenue was calculated using the sum of the revenues from pre-harvest marketed corn and at-harvest sales minus the $50 booking fee per pre-harvest transaction. This total revenue value was divided by the total production to obtain the average price received. As shown in the table below, the three teams that marketed grain pre-harvest received the three highest average prices. Team 8 led the way at a $4.15 per bu. average price, because of the significant proportion of their grain that was priced before harvest.

Table 8: Average Corn Price (per bu.) Received by Team

Team	Average Price
1	$3.93
2	$3.90
3	$3.90
4	$3.95
5	$3.90
6	$3.90
7	$3.90
8	$4.15

This year, pre-harvest marketing boosted teams' revenue. In comparison to if they had sold all their grain at harvest, teams 1, 4, and 8 increased their revenues by $4,550, $8,900, and $45,400, respectively, due to their pre-harvest marketing decisions.

CONCLUSION

The second year of the TAPS project in Alabama continued to provide valuable opportunities to work alongside farmers, crop consultants, and industry partners in testing diverse crop management strategies, economic decisions, and precision agriculture technologies. Building on lessons from 2024 (the inaugural year), the 2025 competition refined protocols for nitrogen and irrigation management, expanded the set of tools evaluated, and generated a richer dataset to better understand yield, profitability, and input-use efficiency across a range of agronomic decisions. The insights gained this year, particularly regarding the potential to maintain competitive yields with more moderate nitrogen rates and irrigation, will guide improvements for future TAPS competitions and on-farm decision making. As we look ahead, our focus remains on using the growing body of TAPS data to identify best practices and to encourage the adoption of innovative, science-based technologies that enhance both farm profitability and environmental sustainability. We invite ideas for new tools, management concepts, or decision-support systems that could be tested in upcoming competitions and welcome continued feedback from participants and collaborators.

We extend our sincere appreciation to the farmers and crop consultants who entered the 2025 competition, and to the staff of the E.V. Smith Research and Extension Center, Farm Services Unit, for their dedicated support in establishing and managing the trials. We are equally grateful to the private companies that contributed technology, products, and services, and to the students, undergraduate, graduate, and visiting scholars, whose efforts in the field and laboratory were essential to the project's success. The achievements of the 2025 TAPS season would not have been possible without your commitment and collaboration.

FUNDING

The TAPS program was established through the commitment and support of our participants, partners, and sponsors (Figures 8 and 9). The 2025 competitions were funded by grants from the Wheat and Feed Grain Committee of ALFA and the Alabama Soil and Water Conservation Committee. Partial funding was also provided by the USDA-NRCS Conservation Innovation Grant under award number USDA-NR243A750011G036.

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APPENDIX

Appendix A

Table 9. List of technologies used for the 2025 TAPS competition.

Agronomic Practice	Equipment /Technology	Representative
Planting	John Deere 1700 six-row planter	SunSouth
	Planter retrofitted with Precision Planting Technology	
	* vSet Select	
	* vDrive	Vantage South
	* Delta Force	
	* Smart Firmer	
	20|20 Display	
Nitrogen application	LMC coulter for liquid application	
	Chandler spreader, 54 feet wide	
	InCommand 1200 (Ag Leader) display	InformedAG
	360 Y-Drop	Vantage South
	John Deere, 4640 display-Gen4 (side-dress liquid application)	
	TeeJeet rate controller	
	John Deere R4030 sprayer, 60 feet	SunSouth
	John Deere 2630 display-Gen3	
	In-season nitrogen recommendations and fertigation	Sentinel Fertigation
Irrigation	Valley Center Pivot Irrigation System with VRI - Zone control	Reid Bros Irrigation
Irrigation Scheduling	AquaSpy sensor	TriGreen
	Trellis soil water tension sensor	Trellis
	Senstek sensor	Simplot
	SmartIrrigation CropFit App	UGA
Crop Scouting	Drone imagery	SouthGen
Harvest	John Deere six-row grain combine	SunSouth

Appendix B

Equations for the estimation of efficiency variables:

$$\text{N Uptake (lbs/ac)} = \frac{N_{Conc.}\ (\%) \times \text{Biomass (lbs/ac)}}{100}$$

$$\text{NUE (lbs/lbs)} = \frac{\text{Yield (lbs/ac)}}{\text{TN (lbs/ac)}}$$

$$\text{NRE (\%)} = \frac{NU_{Fert}\ \text{(lbs/ac)} - NU_{Control}\ \text{(lbs/ac)}}{\text{TN (lbs/ac)}} \times 100$$

$$\text{AEN (lbs/lbs)} = \frac{Y_{Fert}\ \text{(lbs/ac)} - Y_{Control}\ \text{(lbs/ac)}}{\text{TN (lbs/ac)}}$$

$$\text{NIPI} = \frac{((Y_{Fert} - Y_{Control}) \div Y_{Control})}{(ANU_{Control} + TN) \div ANU_{Control}}$$

$$\text{IWUE (lbs/in)} = \frac{\text{Yield (lbs/ac)}}{\text{Total Irrigation (in)}}$$

$$\text{CWP (lbs/in)} = \frac{\text{Total Biomass (lbs/ac)}}{\text{Irrigation (in) + Rainfall (in)}}$$

Where;
$Y_{Fert.}$ = Yield with fertilizer.
$Y_{Control}$ = Yield without fertilizer
$N_{Conc.}$ = Nitrogen concentration in the aboveground biomass
TN = Total nitrogen applied by the team.
NU_{Fert} = Nitrogen uptake in the aboveground biomass with fertilizer
$NU_{Control}$ = Nitrogen uptake in the aboveground biomass without fertilizer
ANU = Aboveground nitrogen uptake in pounds/acre.
$ANU_{control}$ = Aboveground nitrogen uptake in pounds/acre estimated for the control treatment.