# Impact of Planting Dates on Soybean Yield and Quality

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## Summary

To increase soybean yield potential, early planting dates have been promoted as a management practice that can improve the yield of soybeans. Early planting of soybeans can be a relative term, meaning late April/early May for some soybean producers in Kansas. Still, this study defines early planted soybeans in late March/early April. Theoretically, the earlier planting date could allow for more vegetative growth and interception of more light before blooming, increasing the yield potential. Early planting may be a viable option with the improvement of soybean seed treatments to protect seeds when emergence is slowed due to cool and wet conditions. Over the four years this study has been conducted at the Kansas River Valley Experiment Field, the early planting dates in late March/early April have shown soybean yields as either stable or increased when planting in late March/early April compared to planting in mid-to-late April and early-to-mid May. This study also indicates the increased yield potential compared to more traditional planting dates later in May.


## Objective

1. Utilizing UAV and proximal sensing for gathering biophysical and physiological data to predict soybean yield
2. Soybean quality assessment using multispectral data and machine learning models

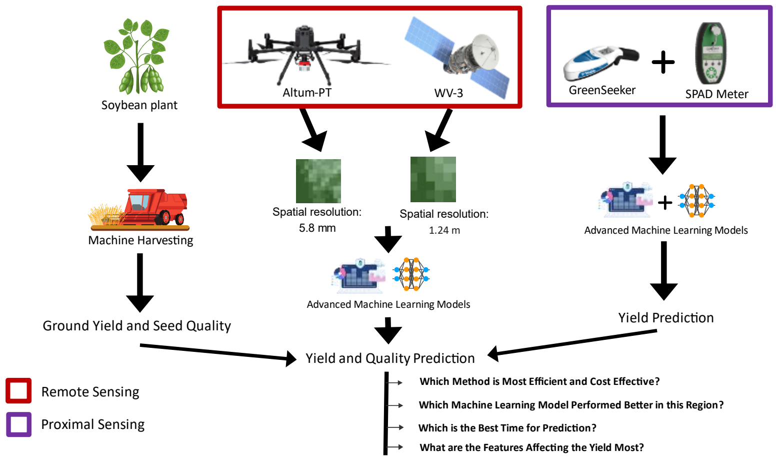



Figure 1: Pictorial illustration of the soybean project

## Method and materials

### Study Area and Experiment

Early soybean planting studies were conducted 2021-2024 at Kansas State University experiment field, Kansas River Valley (Topeka). Reports of results from individual years, 2021-2023 from Topeka and North Central Experiment Field have been published in previous Field

Research Reports (Vol. 8, Iss. 4 2022; Vol. 9, Iss. 4 2023: Vol. 10, Iss. 3 2024). Early soybean planting studies were conducted in 2024 at the Kansas State University experiment field, Kansas River Valley Experiment Field, Topeka, Kansas, USA (39°04'37.0"N 95°46'07.7" W). North Central Kansas Research Station, Scandia, Kansas, USA (39°49'41.60"N, 97°50'22.07" W). In both studies, two varieties were planted at two seeding rates (100,000 and 150,000 seeds/acre) at each of the three planting dates. The varieties at Topeka were Pioneer 37A18E (Maturity Group MG 3.7) and Pioneer 42A84E (MG 4.2), which were treated with ILeVO and Lumigen. The varieties at Scandia were Pioneer GH3883XF (Maturity Group MG 3.8) and Pioneer GH4222XF (MG 4.2), which were treated with ILeVO and Lumigen. The varieties at Topeka were Pioneer 37A18E (Maturity Group MG 3.7) and Pioneer 42A84E (MG 4.2), were treated with ILeVO and Lumigen. The experiment at Topeka in 2024 was irrigated, receiving 5.75 inches of water from July 29 to September 16. The 2024 planting dates at Topeka were March 29, April 15, and May 1. The 2024 planting dates at Scandia were April 12, May 1 and May 22. Soybeans were planted in four 30-inch row plots at 10 ft wide × 40 long. The experimental design utilized was a randomized complete block design with four replications. Yields were determined from the middle two rows of each plot to avoid influence from neighbouring plots. Yields were corrected to 13% grain moisture. Weed control was managed to have no effect on yields.

**Data Collection**

We have collected the data for four different growth stages in soybeans (early vegetative, late vegetative, early reproductive, and late reproductive stage). Collected data includes Unoccupied Aerial System (UAS), proximal sensors and crop data (leaf number, plant height, plant population).

1. **Remote Data Collection using UAS**

| **Instrument** | Altum PT |
|---|---|
| **Height** | 98.0 ft (30 m) |
| **Spectral Resolution** | 5.8 mm |
| **Thermal Resolution** | 8.5 cm |
| **Front Overlap** | 90% |
| **Side Overlap** | 90% |
| **Speed** | 3 m/s (6.71 miles/hr) |

2. **Proximal Data collection**

| **Instrument name** | Application | Distance | No per plot |
|---|---|---|---|
| **Handheld GreenSeeker by *Trimble*** | To measure point-based NDVI | 0.5m | 3 |
| **Chlorophyll Content Meter by *Apogee*** | To measure point-based leaf chlorophyll | - | 3 |
| ***ACCUPAR LP-80* Canopy Interception and Leaf Area Index** | To measure the leaf area index and PAR | - | 3 |

**Results and Discussion**

The average days to emerge for the planting dates for the four years of the study decreased from 20 days for the first planting date the end of March to just under 12 days for the third date the beginning of May (Table 1). The difference between emergence dates of the first and third planting dates was not as great difference in the planting dates, 25.6 days vs 34 days, respectively. The planting and emergence dates, days to emerge and growing degree days (GDD) for the four years and average of four years of the study are listed in Table 1.

The canopy dates between the first and last planting dates had shortened to a difference of 5.4 days (Table 1) comparing to the 34 day difference between the same planting dates. By the end of the season, the maturity dates were only 3.2 days different between the first and third planting dates. This demonstrates the ability of the soybean plant to "hurry up" through the season in response to changes in day length and not as influenced by calendar date as other crops.

There was a low level of SDS foliar symptoms observed, with the highest level being on the variety that did not have ILEVO seed treatment in 2023 (Table 1). As reported previously and again this year, there were no significant differences in the severity of Sudden Death Syndrome (SDS) between the planting dates for any years of the study.

There was over a 4 bushel per acre (bu/a) (>5%) increase with yields from the late March and mid-April planting dates over the early May planting date over the four years of the study (Table 1). For individual years, the highest yield could be either the end of March or mid-April planting dates.

The earlier maturity group (MG) (3.7) soybeans tended to canopy and mature a few days earlier than the later MG soybeans (average MG 4.1) (Table 1). Over the four years of the study, the MG 3.7 varieties matured just under 4 days before the varieties averaging MG 4.1. There was no interaction between planting date and varieties for canopy and maturity dates.

Over the four years of the study, the MG 3.7 varieties yielded almost 2 bu/a better than the MG 4.1 varieties (Table 1). This may be in part due to the lack of ILEVO seed treatment and increased SDS on the MG 4.2 in 2023, and to the specific varieties selected. There was no interaction between planting date and varieties for yield.

Seeding rate was not a significant factor for any of this data collected in this study over the four years.

There has not been a killing frost experienced during this study for the four years. In looking at a chart for first and last frost dates for Topeka, KS put out by the National Gardeners Association (not shown) gives an idea of the risk associated with having soybeans emerged earlier in the season. According to this chart, there is a 10% chance of 28$^{o}$ on April 16, and 10% chance of 32$^{o}$ on May 3. The average emergence date for the late March planting date was April 20, with the earliest being April 15. The temperatures that soybeans can survive are influenced by several factors including the soil type, moisture and residue cover, but general thought is soybeans can tolerate 28$^{o}$ for several hours.

Table 1. Effect of early planting date and variety maturity group on soybean emergence, canopy closure, maturity date and yield at Kansas River Valley Experiment Field-Topeka, 2021-2024

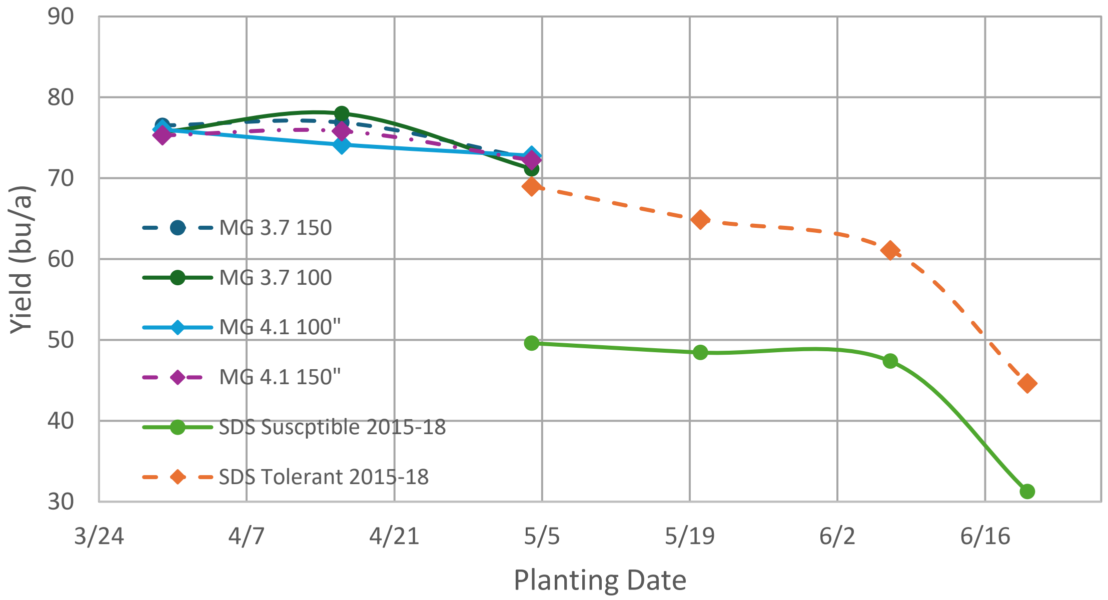
| | Planting day | emergence | days to emerge | GDD | canopy date | Maturity Date | SDS (R6) | yield |
|---|---|---|---|---|---|---|---|---|
| **pl date** | **2021** | | | | | | | |
| 1 | 30-Mar | 19-Apr | 20 | 156 | . | 263.0 | . | 72.7 |
| 2 | 15-Apr | 2-May | 17 | 174 | . | 267.3 | . | 70.6 |
| 3 | 4-May | 19-May | 15 | 180 | . | 268.4 | . | 65.7 |
| | **2022** | | | | | | | |
| 1 | 4-Apr | 25-Apr | 21 | 198 | 196.5 | 274.5 | 4.2 | 79.9 |
| 2 | 21-Apr | 4-May | 13 | 161 | 197.0 | 274.5 | 5.6 | 78.6 |
| 3 | 9-May | 16-May | 7 | 246 | 198.9 | 276.6 | 4.3 | 76.4 |
| | **2023** | | | | | | | |
| 1 | 29-Mar | 20-Apr | 22 | 280 | 188.8 | 266.6 | 24.7 | 71.2 |
| 2 | 13-Apr | 28-Apr | 15 | 167 | 187.0 | 266.8 | 23.1 | 76.3 |
| 3 | 1-May | 11-May | 10 | 188 | 191.4 | 269.2 | 11.9 | 72.9 |
| | **2024** | | | | | | | |
| 1 | 29-Mar | 15-Apr | 17 | 215 | 187.1 | 267.8 | 5.6 | 82.3 |
| 2 | 15-Apr | 29-Apr | 14 | 180 | 189.4 | 270.3 | 7.2 | 82.0 |
| 3 | 1-May | 16-May | 15 | 207 | 198.4 | 270.8 | 4.2 | 74.7 |
| **4 year Average** | | | | | | | | |
| 1 | 31-Mar | Ap 20 | 20 | 212 | 190.8 | 268.1 | 11.5 | 76.5 |
| 2 | Ap 16 | 1-May | 14.75 | 171 | 191.1 | 269.7 | 12.0 | 76.9 |
| 3 | May 4 | 16-May | 11.75 | 205 | 196.2 | 271.3 | 6.8 | 72.4 |
| | Pr>F | | | <0.0001 | <0.0001 | <0.0001 | 0.0198 | <0.0001 |
| | | | | | | | | |
| **Variety** | **MGroup** | | | | | | | |
| | **2021** | | | | canopy date | Maturity date | SDS (R6) | yield |
| 1 | 3.7 | | | | . | 265.6 | . | 71.2 |
| 2 | 4 | | | | . | 266.8 | . | 68.1 |
| | **2022** | | | | | | | |
| 1 | 3.7 | | | | 197.5 | 275.1 | 4.5 | 78.8 |
| 2 | 3.9 | | | | 197.4 | 275.7 | 4.8 | 77.8 |
| | **2023** | | | | | | | |
| 1 | 3.7 | | | | 187.3 | 264.2 | 0.5 | 74.0 |
| 2 | 4.2 | no ILEVO | | | 190.8 | 270.9 | 39.3 | 73.0 |
| | **2024** | | | | | | | |
| 1 | 3.7 | | | | 190.0 | 266.5 | 3.8 | 80.7 |
| 2 | 4.2 | | | | 193.2 | 272.8 | 7.5 | 78.6 |
| **4 year Average** | | | | | | | | |
| | 3.7 | | | | 191.6 | 267.8 | 2.9 | 76.17 |
| | 4.1 | | | | 193.8 | 271.5 | 17.2 | 74.39 |
| | Pr>F | | | | 0.001 | <0.0001 | <0.0001 | 0.03 |

Combining this data with a previous study (Vol 5, Iss. 6 2019) conducted 2015-2018 at the same location that looked at soybean planting date from early May into mid-June may give a more complete picture of the effect of soybean planting date on yield. A MG 3.7 variety tolerant to SDS and with ILeVO seed treatment averaged almost the same yield when planted May 4 as the varieties planted in this study planted May 4. The yield of subsequent planting dates every two to three weeks later continued to decline, with a sharp decline in yield when planted after the first week of June (Fig. 2). The SDS susceptible variety in this study did not show an increased yield response when planted earlier than the first week of June due to the yield limiting effect of increased SDS with the earlier planting dates.

Based on these data, growing soybeans in East Central Kansas under irrigation show the best yield potential when planted mid-April or earlier. Selection of a variety with good tolerance to SDS and a good seed treatment package would be necessary to ensure good stands with the slower emergence through the cooler soils. Dryland soybean production offers other challenges, such as lack of rainfall later in the season, which may limit yield response to the earlier planting dates.

With the improvement of varieties and seed treatments there is an opportunity to increase soybean production with earlier planting dates when the soil conditions are favorable than when soybeans have been traditionally planted. If moisture is not a limiting factor during the season, lengthening the growing season allows for increased yield potential of soybeans. Also, it may spread out the risk of suffering through planting delays if a rainy period starts in May.

Figure 2: Effect of Planting Date on Soybean Yield under Irrigation, KRV 2015-18, 2021-24



In addition, our research shows that soybeans planted during April have performed well in terms of yield in both Topeka and Scandia (Figure 3, 5). Among them, in Topeka, we have a significant increase in yield during the mid-planning date, around mid-April (Figure 2). Regarding protein distribution on both sides, we observed that planting date does not affect protein percentage in soybeans. The relationship between protein distribution and weather variables is complex. While some research suggests that high temperatures can increase protein content in certain crops, particularly during grain filling, other studies indicate that heat stress can negatively impact protein content, depending on the crop, the timing and severity of the stress, and other factors (Jacobsen et al., 2020). Also, using descriptive statistics, we have observed that late planting (Early May) has decreased the protein percentage in Topeka (Figure 4). Based on these data, growing soybeans in East Central Kansas under irrigation show the best yield potential when planted in mid-April or earlier. This can be due to temperature, which negatively affects the crop protein percentage. In Topeka, late planting in early May decreased protein percentage, which could be attributed to higher temperatures during the grain-filling period. Warmer conditions accelerate plant development, shortening the grain-filling duration and reducing nitrogen assimilation into the grain. On the other hand, in Scandia, late planting (late May) has increased the protein percentage in crops. In Scandia, however, late planting in late May increased protein percentage (Figure 6). Selection of a variety with good tolerance to SDS and a good seed treatment package would be necessary to ensure good stands with the slower emergence through the cooler soils. With the improvement of varieties and seed treatments, soybean production can be increased with earlier planting dates when the soil conditions are favourable than when soybeans have been traditionally planted. If moisture is not a limiting factor during the season, lengthening the growing season allows for increased yield potential of soybeans. Also, it may spread out the risk of suffering through planting delays if a rainy period starts in May.

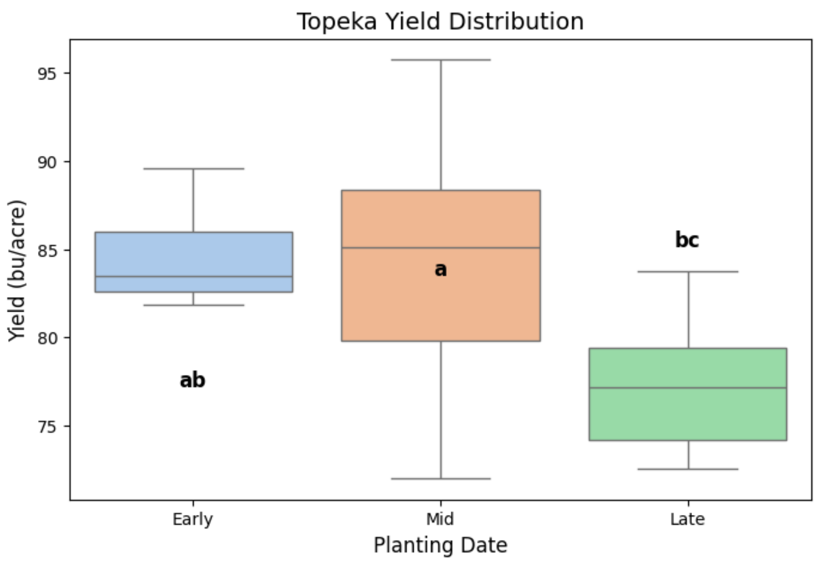



*Figure 3: Yield distribution in Topeka*

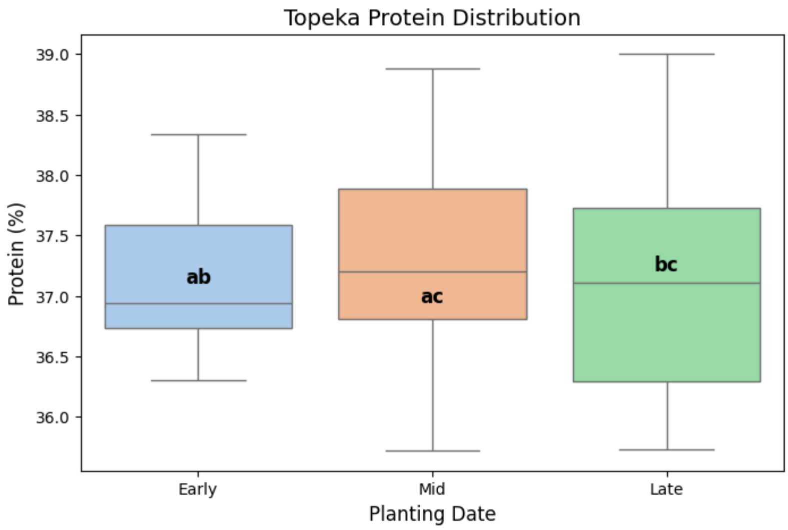



*Figure 4: Protein distribution in Topeka*

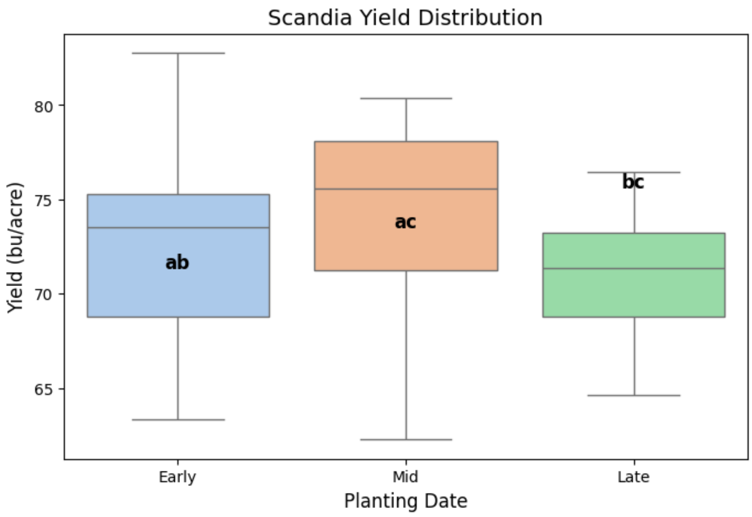



*Figure 5: Yield distribution in Scandia*

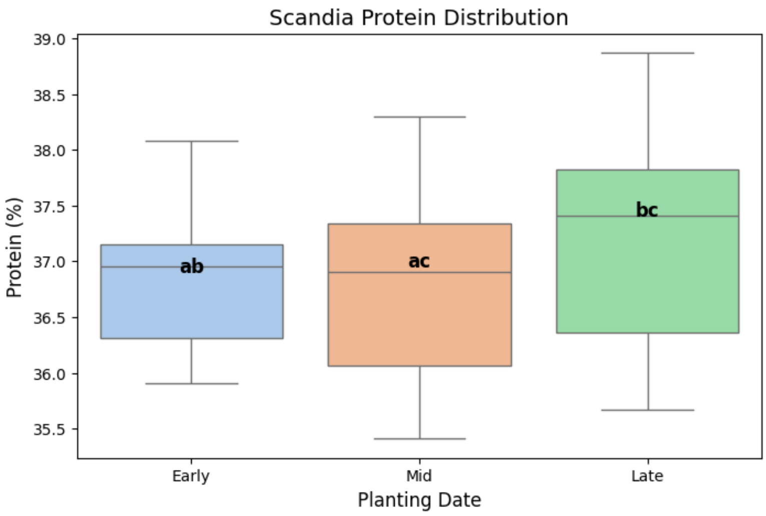



*Figure 6: Protein distribution in Scandia*

We have also performed a correlation matrix and put a significant level (at 5%). Based on our research, we found that, in Topeka, the correlation heatmap indicates a significant positive correlation between yield and NDVI values obtained from the GreenSeeker sensor and with seeding rate and plant population (Figure 7). These findings suggest that NDVI can be a reliable crop yield predictor. In contrast, in Scandia, yield exhibits a significant negative correlation with leaf protein content (Figure 8). Additionally, protein significantly correlates with LAI, crop moisture, and yield, which indicates potential interactions between canopy development, physiological traits, and grain quality. NDVI values from GrrenSekker show significant positive results for plant height, population, and leaf number. These results underscore the importance of remote sensing and physiological indicators in assessing crop performance.

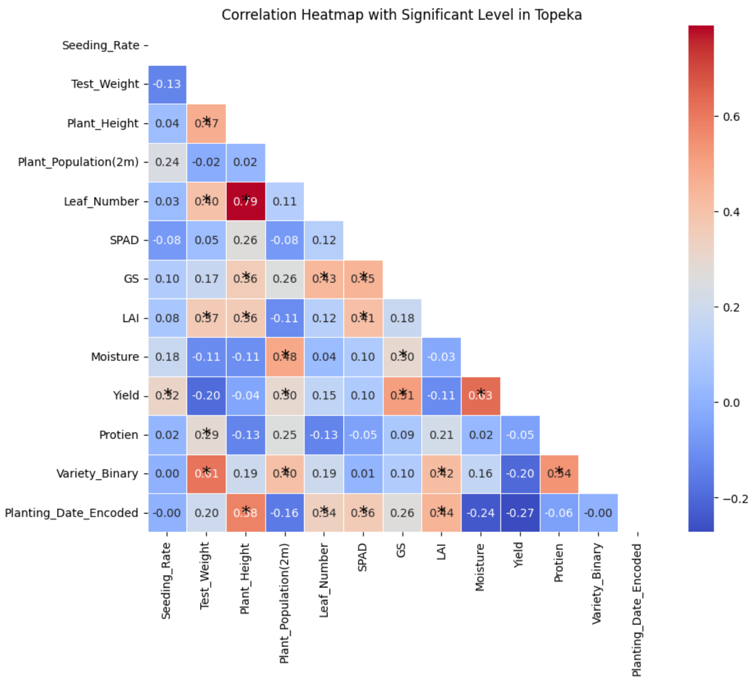



*Figure 2: Correlation Heatmap with Significant Level in Topeka*

We have also implemented machine learning models by combining both datasets. We are still working on the project and have not yet acquired the necessary remote sensing and climate data, impacting the results. We applied the AdaBoost and XGBoost models and obtained R-squared values of 0.30 for AdaBoost and 0.25 for XGBoost. While these analysis require further investigation and this research is underway to make further conclusions

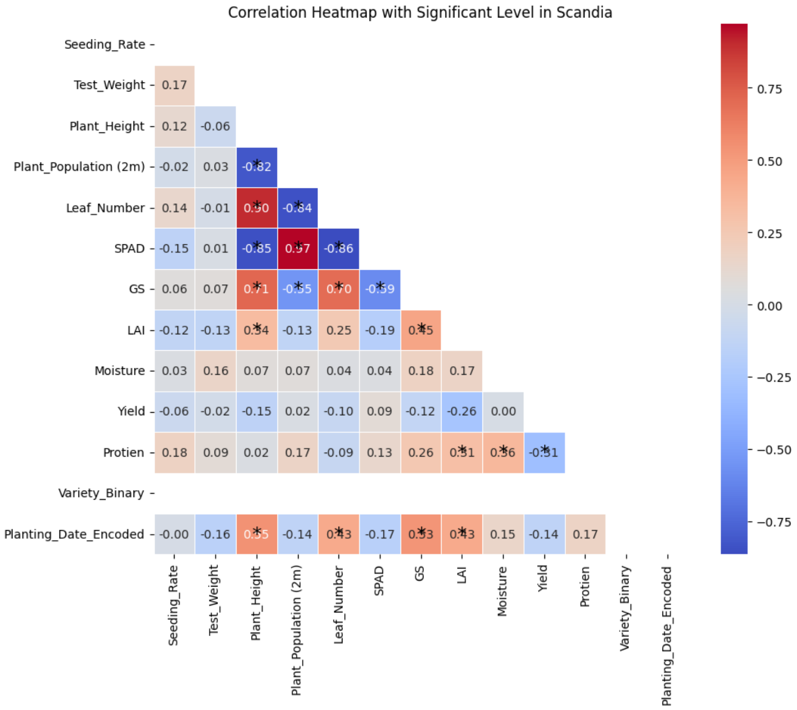



*Figure 8: Correlation Heatmap with Significant Level in Scandia*

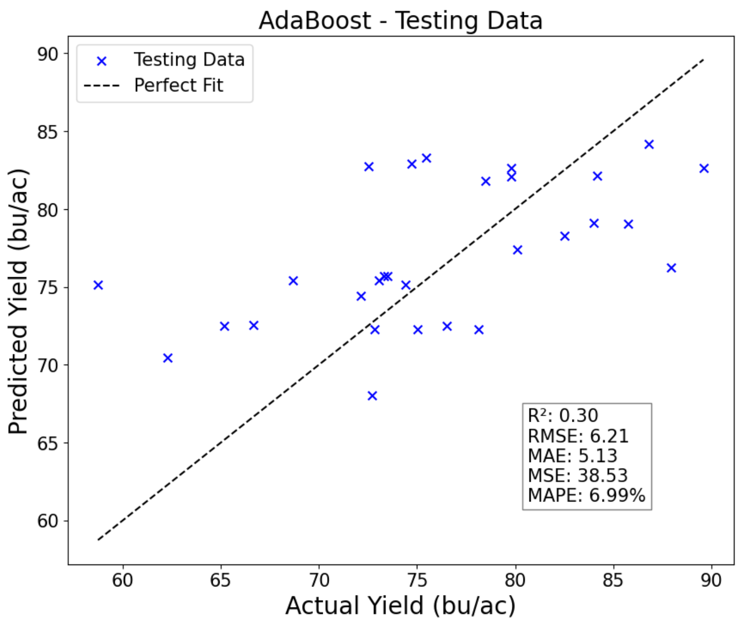



*Figure 9: Error metrics visualization for both the field*

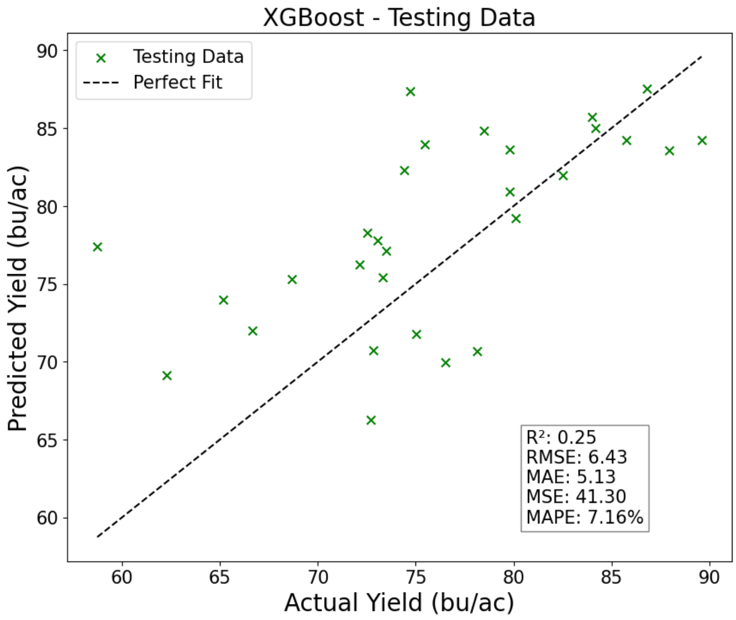



*Figure 10: Error metrics visualization for both the field*

**Importance for Soybean growers and farmers**

Accurate prediction of soybean yield is essential for assessing the potential variability in yield due to climate change, a critical concern for growers and farmers in Kansas. Such predictive capability allows for informed adjustments in crop production strategies and timely interventions to mitigate risks. This study aims to provide key insights for soybean producers, addressing fundamental questions such as: Which method, remote or proximal sensing, is more efficient and cost-effective for soybean yield prediction? What is the most suitable machine learning model for specific datasets and site conditions? When is the optimal time for yield prediction? Which features—weather, agronomic, and biophysical factors—influence yield? Through this research, we seek to equip soybean growers with actionable information to enhance decision-making and improve yield sustainability in the face of climatic challenges. However, this study is under research. We are working on gathering the remote sensing variables and climatic variables.

**References**

Jacobsen, J. S., Jackson, G. D., & Lorbeer, S. (2005). *Nitrogen management for hard wheat protein enhancement*. Montana State University Extension. https://landresources.montana.edu/soilfertility/documents/PDF/pub/NWhtProtEB0206.pdf