PENNSYLVANIA SOYBEAN BOARD FINAL PROJECT REPORT

Section 1: Project Information

Fiscal Year: 2017-18

Project Title: Increasing Yields and Profitability for Mid-Atlantic Double-Crop Soybean

Project Category: Research

Project Duration: 7/1/15 – 6/30/18

Project Submitter: David Holshouser

Email Address: dholshou@vt.edu

Phone Number: 757-807-6541

Mobile Phone Number: 757-355-2972

Organization: Virginia Tech – Tidewater AREC

Office Address: 6321 Holland Rd, Suffolk, VA 23437

Section 2: Report

Expected Outcomes/Deliverables:

1. "State of the Mid-Atlantic Double-Crop Soybean Production System" publication. This publication will summarize findings of an exhaustive literature review of all available double-crop soybean information. This publication will also make recommendations for future research and technology transfer.
2. User-friendly, web-based, smartphone-compatible information management system. This system will include information from the literature review and meta-analysis. It will also include research results conducted as part of this project.
3. Annual publication of on-farm research. Electronic and hard copies will be produced.
4. Refereed scientific journal articles and Extension publications
5. Advanced production practices that increase yield and profitability of double-crop soybean. These practices will be transferred to the soybean industry in various methods and formats including, but not limited to, presentations at farmer meetings and field days, Extension publications, webcasts, and social media.

Did you meet your expected outcomes and deliverables? If yes, please explain. If not, please explain.

1. Dr. Parvej completed a thorough literature review and has drafted an article, "Double-Crop Soybean Production System in the United States", which reviewed approximately

600 journal articles. An abstract is attached. We will wait to publish this (as a refereed journal article) and the "State of the Mid-Atlantic Double-Crop Soybean Production System" publications until all of the data collected in this project is thoroughly analyzed and published. Waiting will make these much better publications.

2. We depended on continued funding from the United Soybean Board to accomplish this objective; therefore, this was not completed.
3. A 3-year publication, that includes all on-farm research since this project started is being prepared. Otherwise, the on-farm research has been published in each participating state's publication.
4. We are currently working on referred publications and hope to submit to the Agronomy Journal this summer.
5. Planting soybean early following high-moisture wheat harvest is and excellent management practice for increasing double-crop soybean yield. Other practices help, but are not nearly as important. Furthermore, early wheat harvest resulted in greater wheat yields and quality. Our research (>20 site-years) is the strongest and most comprehensive data set ever developed in the Mid-Atlantic region that supports early high-moisture wheat harvest. These results have been shared at numerous extension, industry, and professional meetings. The next step is to begin intensive dialog with buyers of wheat and soybean and with dryer manufacturers that will allow higher-moisture wheat harvest.

Background:

Nearly half of the Mid-Atlantic soybean acres are usually planted after small grain harvest. Double-crop small grain-soybean systems lead to greater total annual production and are usually more profitable than single-crop systems due to more efficient use of land, equipment, labor, and fertilizer. Double cropping improves soil quality through additional crop residue and provides an additional sink for atmospheric CO2. Winter small grain scavenges nutrients left over from the previous summer crop, preventing leaching through the sandy Coastal Plain soils. The double-crop system also encourages continuous no-till, which prevents excessive runoff of nutrients and other chemicals, especially on hilly Piedmont soils . Together, no-till double-crop small grain-soybean greatly benefits the environment and positively contributes to cleaner watersheds. To summarize, the double-crop small grain-soybean system that is common to the Mid-Atlantic region increases total production, profits, improves the environment, and contributes to a more sustainable food system.

Although the advantages of double-crop wheat-soybean systems are many, the late planting date results in 10 to 30% less yield versus full-season soybean. This is largely due to less time to accumulate sufficient leaf area for maximum yield. Mid-Atlantic Extension recommendations for double-crop soybean therefore focus on increasing early season vegetative growth. Planting later-maturing varieties in narrow rows at high plant populations as soon as possible after

wheat harvest partially accomplish this goal. However, yields still lag behind full-season soybean.

A proposal was submitted and funded by the United Soybean Board to form the Mid-Atlantic Double-Crop Soybean Initiative. This evolved in to this ongoing 3-year project, which received initial funding from USB and from Mid-Atlantic Soybean Boards. USB decided not to fund the 2nd year of this project, but the team decided to continue with activities.

Rationale/Justification:

Increasing yield and profitability of double-crop small grain-soybean systems is important because soybean is the foundation for row crop production in the Mid-Atlantic region of the U.S. Historically, over half of the soybean in this region is double-cropped after wheat and this system contributes greatly to the overall profitability of agriculture. Double cropping soybean with small grain allows the farmer to meet environmental goals and regulations through no-tillage and the use of a “harvestable cover crop”. However, soybean yield suffers due to late planting and leads to less total production. To increase soybean production and meet profitability, environmental, and sustainability goals, yields of double-crop soybean will need to increase and be more competitive with full-season systems. Such yield increases for a region can only be accomplished by a multidisciplinary multi-state effort that deliberately focuses their knowledge, ideas, and capabilities towards a common goal.

Objectives:

1. Create a database/clearinghouse of knowledge, research, and Extension recommendations for double-crop soybean production in the Mid-Atlantic. An exhaustive literature review and meta-analysis will begin on the most important aspects of double-crop soybean.
2. Create a coordinated Mid-Atlantic on-farm research structure to discover, validate, and increase the use of environmentally responsible practices that increase efficiency and profitability of double-crop soybean.
3. Research practices that lead to earlier small-grain harvest without adverse effects on yield, providing for an earlier planting date for double-crop soybean. These experiments will determine the profitability of harvesting high moisture wheat and immediately planting soybean. Main plots will be five wheat harvest / soybean planting dates beginning when wheat grain moisture approaches 20%. Subplots will consist of six soybean varieties of three relative maturities.
4. Investigate specific production practices that will feed data into the overall Mid-Atlantic effort. Such projects may be state-specific, tapping into that state’s production system and expertise.

Activities/Procedures:

1. Create a database/clearinghouse of knowledge, research, and Extension recommendations for double-crop soybean production in the Mid-Atlantic using the following steps.
    - An exhaustive review of all available double-crop soybean information is underway. From this review and analysis, we are discovering what information exists, understanding patterns and discrepancies among multiple studies, identifying the gaps in our current knowledge, and determining what is needed to move forward?
    - From the literature review, a meta-analysis of one or more aspects of double-crop soybean production will begin during the winter of 2016/2017.
    - Create a user-friendly, web-based, smartphone-compatible information management system/platform in year 3.
    - Publish a "State of the Mid-Atlantic Double-Crop Soybean Production System" report that summarize these findings and make recommendations for future research and technology transfer.
2. Create a coordinated Mid-Atlantic on-farm research structure to discover, validate, and increase the use of environmentally responsible practices that increase efficiency and profitability of double-crop soybean. Steps to accomplish this activity include:
    - Needs and interests were assessed via personal contact, surveys of farmers and the soybean industry, and from recommendations from the Mid-Atlantic Double-Crop Soybean Advisory Committee.
    - From this survey, coordinated multi-state trials based were conducted.
    - Results will be published in an annual report.
3. Research practices that lead to earlier small-grain harvest without adverse effects on yield, providing for an earlier planting date for double-crop soybean.
    - Determine the profitability of harvesting high moisture wheat and immediately planting soybean.
        - Four experiment were conducted in four states in 2015 and nine experiments were conducted in five states in 2016 (the N.C. experiment was conducted in Gates County). Plans are to conduct the experiment in Perquimans County, N.C. in 2017.
        - Treatments consist of five wheat harvest/soybean planting dates beginning when wheat seed moisture approaches 20%. Within each of these treatments, six soybean varieties representing three relative maturities will be planted.
    - Conduct other research that may speed up wheat harvest date. Such research will not likely be conducted in all states, but adapted to the local practices.
    - Initiate an extension/outreach effort to convince farmers to harvest and dry wheat or to convince buyers of the value of high-moisture wheat.

- Continue to solicit cooperation and/or participation with small grain associations and boards.

4. Investigate specific production practices to feed data into the overall Mid-Atlantic effort. Such projects may be state-specific, tapping into that state's production system and expertise. Over time, they may expand into other states if the need exists. Key focus areas include:
   - Conduct research to optimize light capture and leaf area development.
   - Investigate soil moisture, water use, and nutrient uptake and cycling to determine effects of the small grain crop on soybean yield. Funded QSSB projects related to this area of study include:
   - Study the interaction of planting date, maturity group, and environmental conditions. From these data, develop site-specific probability models that determine the best planting date and maturity group.

Results and Discussion:

1. Dr. Parvej completed a thorough literature review and has drafted an article, "Double-Crop Soybean Production System in the United States", which reviewed approximately 600 journal articles. The abstract is attached.

   We will wait to publish this (as a refereed journal article) and the "State of the Mid-Atlantic Double-Crop Soybean Production System" publications until all of the data collected in this project is thoroughly analyzed and published. Waiting will make these much better publications.

   We depended on continued funding from the United Soybean Board to accomplish this objective; therefore, this was not completed.

2. We created an on-farm network that included research from all five states. Virginia results "Virginia On-Farm Soybean Test Plots" available at https://pubs.ext.vt.edu/CSES/cses-223/CSES-223.html. On-farm research from other states was made available as publications in each participating state.

   A 3-year publication, that includes all on-farm research since this project started is being prepared.

3. We evaluated the effect of early high moisture wheat harvest on wheat and double-crop soybean yield and quality across five Mid-Atlantic states including Pennsylvania, Maryland, Delaware, Virginia, and North Carolina during 2015 to 2017. At each location, we harvested wheat five times at 4 to 7 d intervals beginning when grain moisture approached 20% and immediately planted six soybean cultivars of three relative maturities. Wheat grain moisture tended to decrease with time, depending on weather. Wheat harvesting dates explained 63% of the variation of wheat relative yield, which decreased quadratically with delaying harvesting (Fig. 1). Wheat test weight decreased

linearly (Fig. 2) and falling number decreased curvilinearly with delayed harvesting (Fig. 3). Double-crop soybean yield decreased quadratically as planting was delayed from early June to late July (Fig. 4). However, the degree of yield loss due to late planting varied with locations. Cultivar yield differences were more dependent on environment than relative maturity. Normalized difference vegetation index (NDVI) usually peaked at the R4 stage with the maximum value of 0.90 (Fig. 5). At the R3 stage, NDVI was highly correlated with relative soybean yield and explained 72% of the variation of soybean yield (Fig. 6). Wheat yield loss with delaying harvesting was due mainly to test weight loss and double-crop yield loss with delaying planting was due mainly to the lack of time of developing optimum leaf area index of 4.0 (NDVI 0.9) by the R3 stage to maximize solar radiation interception.

In summary, planting soybean early following high-moisture wheat harvest is an excellent management practice for increasing double-crop soybean yield. Other practices help, but are not nearly as important. Furthermore, early wheat harvest resulted in greater wheat yields and quality. Our research (>20 site-years) is the strongest and most comprehensive data set ever developed in the Mid-Atlantic region that supports early high-moisture wheat harvest. These results have been shared at numerous extension, industry, and professional meetings. The next step is to begin intensive dialog with buyers of wheat and soybean and with dryer manufacturers that will allow higher-moisture wheat harvest.

4. Numerous research related to double-crop soybean was performed in all states. In Virginia, we correlated NDVI with soybean LAI. This will allow more rapid measurements of leaf area and should allow more site-specific management of double-crop soybean. We researched and are continuing to research seeding rate, relative maturity by planting date interactions, soil fertility, and the effect of straw height on soybean yield. For completed experiments, data is being analyzed and will be reported later.

Practical Application:

Soybean following winter wheat is the most prevalent double-cropping system in the United States. Double-cropping may increase profit, spread out cash flow, ensure global food security by increasing food production, and provide environmental benefits via continuous land cover. However, soybean yields less in double-cropping than full-season production systems due to delayed planting. Harvesting wheat at higher moisture (15-20%) can increase wheat yield by reducing test weight loss as increase its quality. Furthermore, double-crop soybean yield increases by allowing early planting. This practice will increase overall double-crop income. Costs may increase, especially if specialized drying is needed. Future efforts will focus on an

economic analysis and beginning a discussion with grain buyers to encourage them to purchase high-moisture wheat without dockage.

Section 3: Additional Documents

(tables, figures, photos)

Abstract: Soybean [*Glycine max* (L.) Merr.] following winter wheat (*Triticum aestivum* L.) is the most prevalent double cropping system in the United States. Double cropping increases cash flow and profits and ensures global food security by increasing food production. However, double-crop soybean yields 10 to 40% less than full-season production system due to several factors. Maintaining wheat stubble height ≤30-cm during harvesting minimizes any negative effect of wheat residue under no-tillage system. Late planting shortens the soybean growing season, offers less time to develop optimum leaf area, and reduces yield. Harvesting wheat at high moisture (200 g H_2O kg^{-1} grain) or using early maturing wheat cultivar with comparable yield potential can allow 7 to 10 d early soybean planting. Planting double-crop soybean in narrow rows at high seeding rates ensures quick attainment of optimum leaf area index (LAI) of 3.5 to 4.0 by R2 to R4 stages to maximize solar radiation intercept and canopy photosynthesis. Small amount of starter N may also help obtain optimum LAI quickly by enhancing early vegetative growth. Double-crop soybean is leaf damage or defoliation than full-season soybean.

Figure 1. Wheat yield response to harvest date as represented by the day after first harvest in experiments conducted in Pennsylvania (PA), Maryland (MD), Delaware (DE), Virginia (VA), and North Carolina (NC).

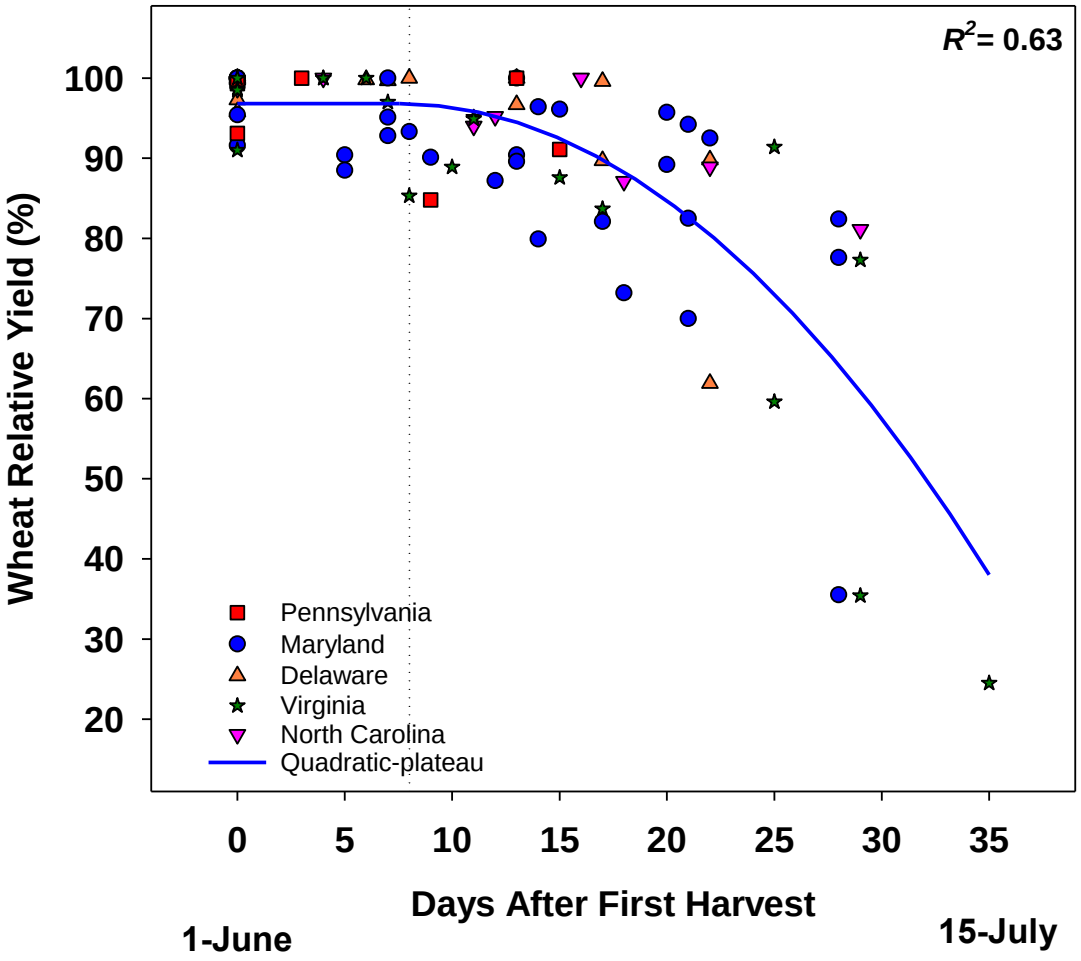


Figure 2. Wheat test weight response to harvest date as represented by the day after first harvest in experiments in Pennsylvania (PA), Maryland (MD), Delaware (DE), Virginia (VA), and North Carolina (NC).

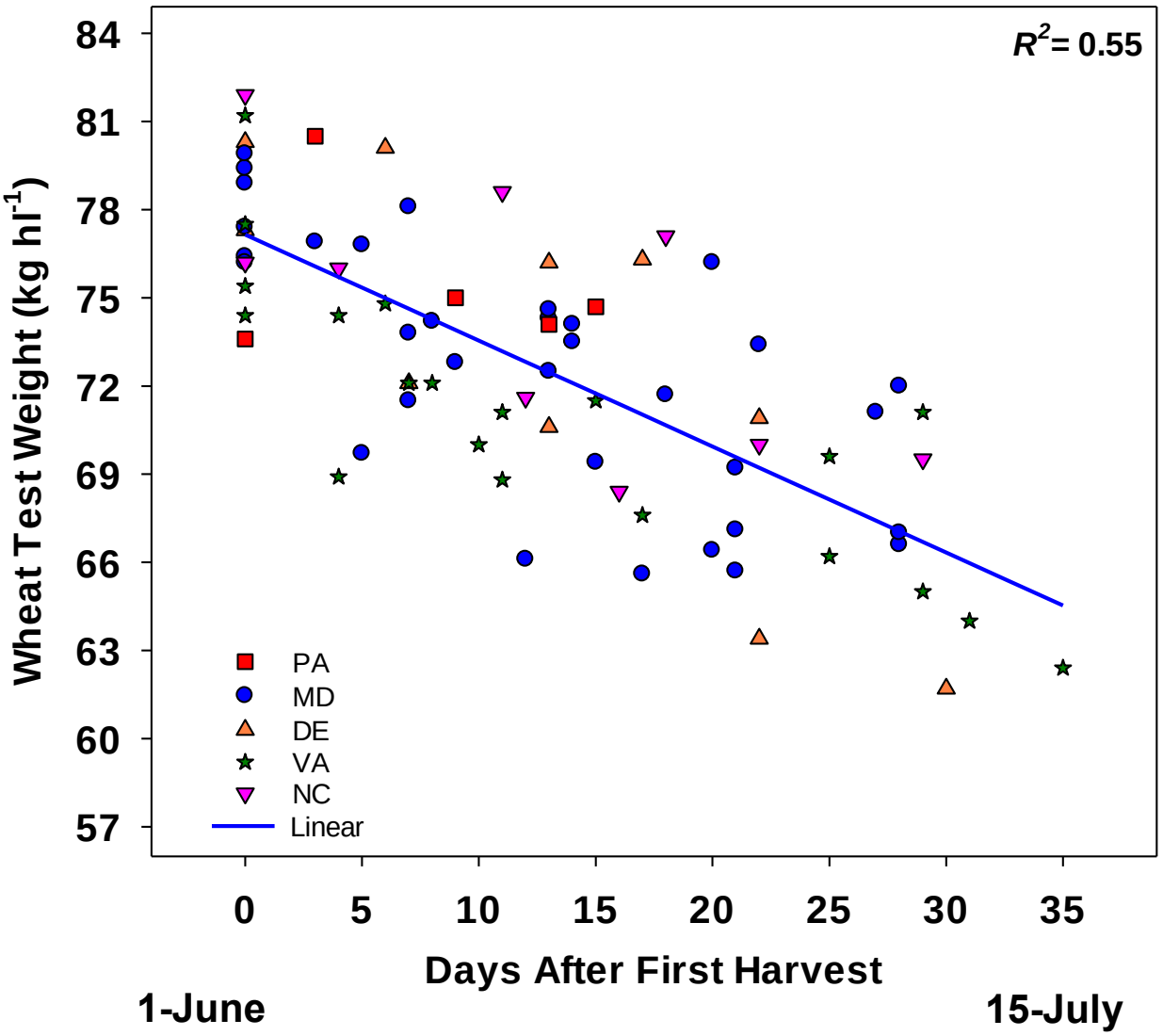


Figure 3. Wheat falling grain number response to harvest date as represented by the day after first harvest in experiments conducted in Pennsylvania (PA), Maryland (MD), Delaware (DE), Virginia (VA), and North Carolina (NC).

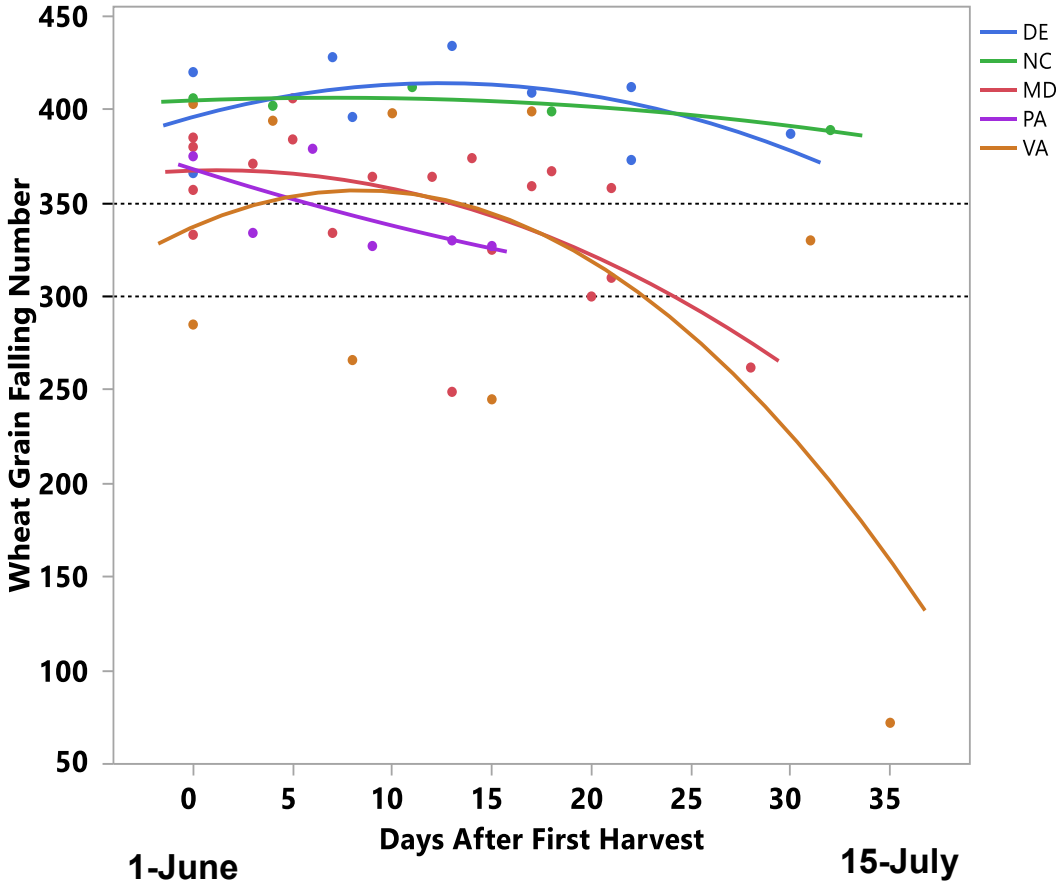


Figure 4. Relative yield of double-crop soybean as a response to planting date from experiments in Pennsylvania (PA), Maryland (MD), Delaware (DE), Virginia (VA), and North Carolina (NC).

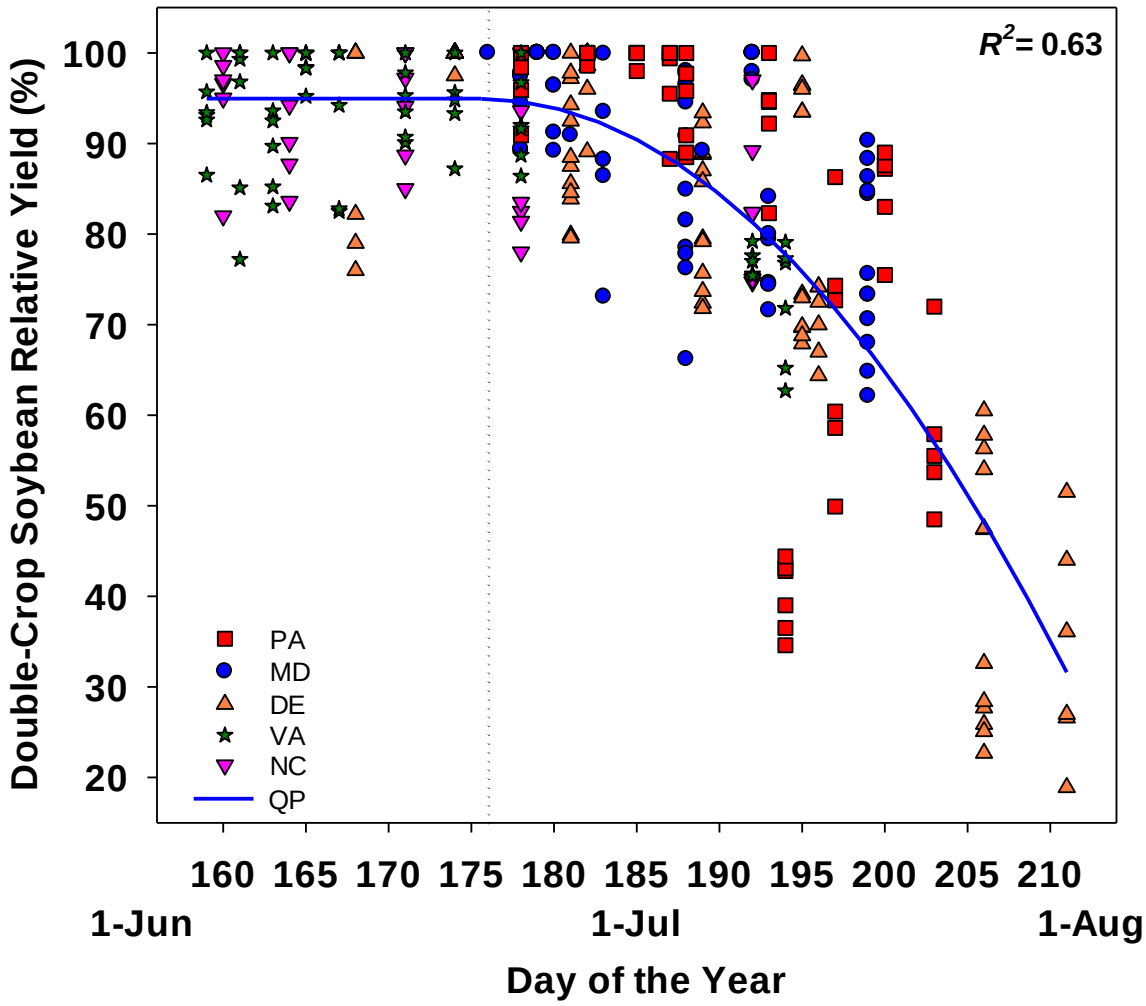


Figure 5. Normalized difference vegetation index (NDVI) over time, as represented by reproductive stage, to planting date of double-crop soybean.

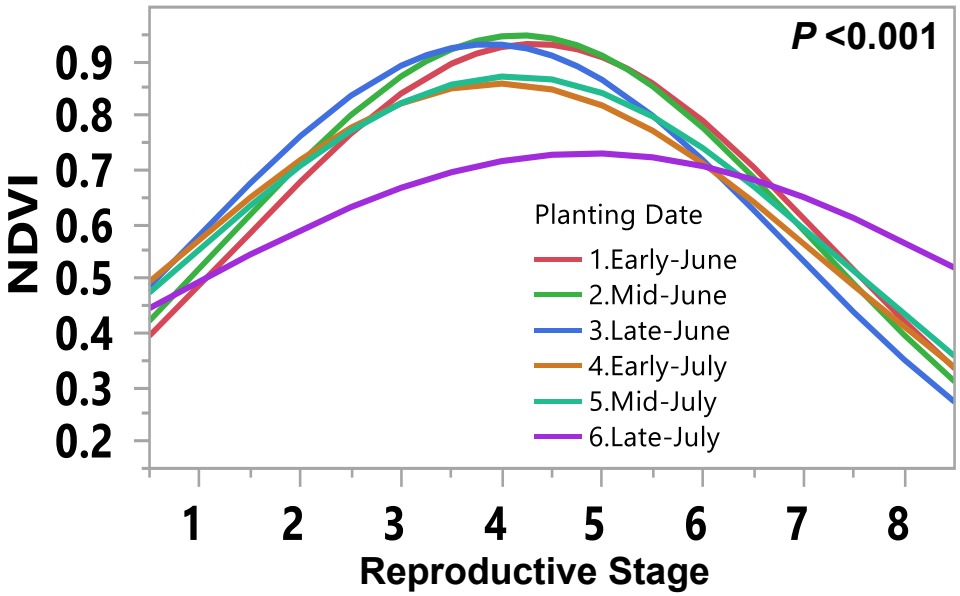
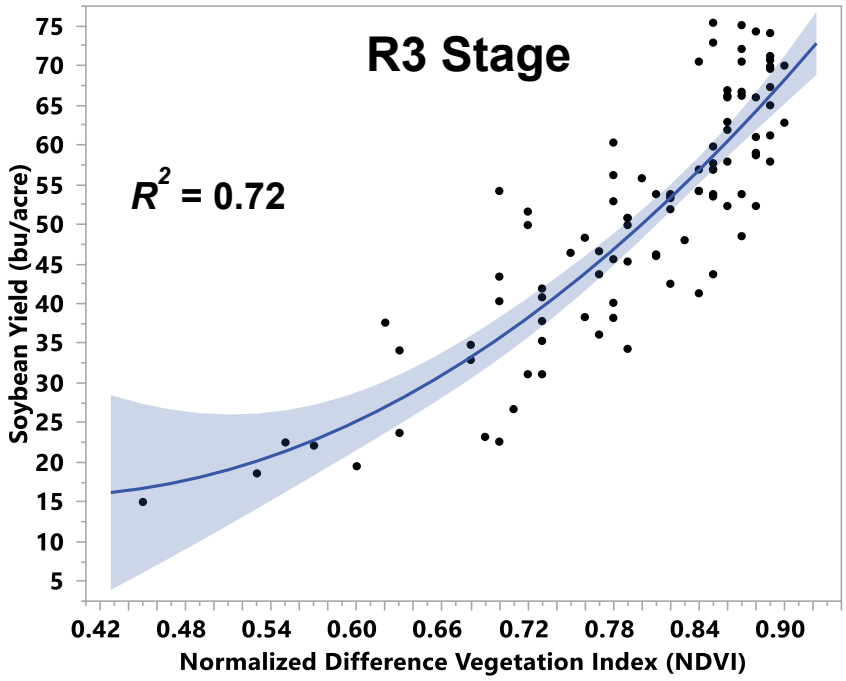


Fig. 6


R3 Stage
R^2 = 0.72
Soybean Yield (bu/acre)
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0.42
0.48
0.54
0.60
0.66
0.72
0.78
0.84
0.90
Normalized Difference Vegetation Index (NDVI)

Section 4: Legal Agreement:

I certify that the use of any check-off funds awarded as a result of this proposal will comply with the provisions set forth in the Soybean Promotion, Research, and Consumer Information Act, and the related Order and regulations. Check-off funds awarded as a result of this proposal will not be used to influence or advocate for legislation or policy.

☑ I accept the terms of this agreement *