Minnesota Department of Agriculture
Pesticide & Fertilizer Management Division
AFREC R2020-7
FINAL REPORT
FOR THE PERIOD APRIL 1, 2020 - JUNE 30, 2021

SWIFT CONTRACT NUMBER: 174045	PURCHASE ORDER NUMBER: 35449
PROJECT DESCRIPTION:	Utilizing On-farm Research to Revise Fertilizer Recommendations in Low Yielding Zones
REPORT DUE DATE:	July 31, 2021
PRINCIPAL INVESTIGATOR:	Matt Wiebers
VENDOR/CONTRACTOR/ORGANIZATION	Minnesota Crop Production Retailers Bill Bond
ADDRESS:	5490 101st Ave N Suite 100 Maple Grove, MN 55369
PHONE NUMBER:	(651) 260-6991
EMAIL:	bill@mcpr-cca.org

PROJECT HIGHLIGHTS

1. Covid19 and statewide travel restrictions during the project limited in-person contact with fertilizer dealers and farmers
2. An early start to the spring 2020 season limited pre-plant opportunities for fertilizer trials, but the target number of trials was still met for the project.
3. The 2020 was a record production year for many growers in Minnesota. AFREC trial participants experienced yields +20% above state averages.
4. The completion rate was 100% with regard to yield data collection for trials.

PROJECT BACKGROUND

The project partnered with service providers to identify management zones including low, medium, and high yielding areas of fields. An on-farm research approach was used to test a range of fertilizer rates in these zones. The data will be used to support possible changes to current methods used to fertilize these poor performing areas. Replicated strips and “learning block” type approaches were used in conjunction with precision agriculture technologies such as GPS based application and harvest equipment. Corn and soybeans were the crops utilized for the study.

OBJECTIVES

There were three objectives for the project. These are copied directly from the work plan.

1. To develop new and leverage existing partnerships with industry and grower groups with the capability to increase the efficiency in scaling up the number of on-farm trials
2. To collect on-farm research data from up to 24 fields statewide that will be used for evaluating fertilizer recommendations in low-yielding areas of corn, soybean, wheat, and sugar beet fields in the 2020 crop season.
3. To produce new information that will be used by Minnesota farmers to improve their fertilizer recommendations in low yielding areas in future crop seasons

The balance of the report will focus on how the objectives were accomplished, the data created in support of the objectives, and how the results have been conveyed to Minnesota service providers and growers.

ACTIVITIES

A total of 15 deliverables spanned the project. Each of the deliverables supports the overall completion of the project from start to finish in sequential order. The project deliverables were met except the AFREC meeting presentation. The in-person grower meetings were replaced with virtual / email communication of the trial results.

Deliverable Number	Task Number	Deliverable	Responsible Partner	Final status
1	1	Trial agreement	MCPR	Complete
2	2	Research protocols	P.I. and service providers	Complete
3	5	Trial prescription files	P.I. and service providers	Complete
4	5	Trial cooperator agreements	P.I. and service providers	Complete
5	NA	Quarterly Report and invoice	P.I.	Complete
6	5	Trial fertilizer as-applied maps	P.I. and service providers	Complete
7	6	Trial aerial photo maps	P.I. and service providers	Complete
8	4	Soil sample summary report	P.I. and service providers	Complete
9	NA	Quarterly Report and invoice	P.I.	Complete
10	NA	AFREC meeting presentation	P.I.	N/A
11	9	Quarterly Report and invoice	P.I.	Complete
12	NA	Individual trial yield report	P.I. and service providers	Complete
13	9	Webinars and in-person meetings with growers	P.I.	Partial (no in-person)
14	10	Web-enabled data access	P.I.	Complete
15	10	Final report	P.I.	Complete

MCPR CONTRIBUTIONS

The following comments were provided by Bill Bond, MCPR Executive Director for inclusion in the final report.

The Minnesota Crop Production Retailers provided administrative support and direction for the AFREC 2020 project including all grant submissions, financial accountability through bookkeeping, invoicing, and auditing overall funds administration. In addition, MCPR provided Executive Director leadership and relationship administration with the MN Agricultural Retailer network and membership. Office space, promotional information, and publicity for the research outcomes related to this specific grant and the overall "On-Farm Research" initiative. In addition, promoting precision ag accommodation of the AFREC on farm research to suggest modeling the research within the precision ag practices of MCPR members and their grower customers. MCPR is the signatory and nonprofit organization within which these activities reside.

IMPLEMENTATION OF TRIALS

The implementation of research in 2020 expanded on an approach used in 2017,2018, and 2019 studies. The approach focused on leveraging service providers and their existing relationships with fertilizer retailers and growers to scale up the number of trials. Two documents were created in support of communication of the AFREC project needs. The first document created was the dealer research instructions, which is included as Appendix A. The second document was the grower protocol included as Appendix B. The information in these documents was used to select growers and fields suitable for the research project.

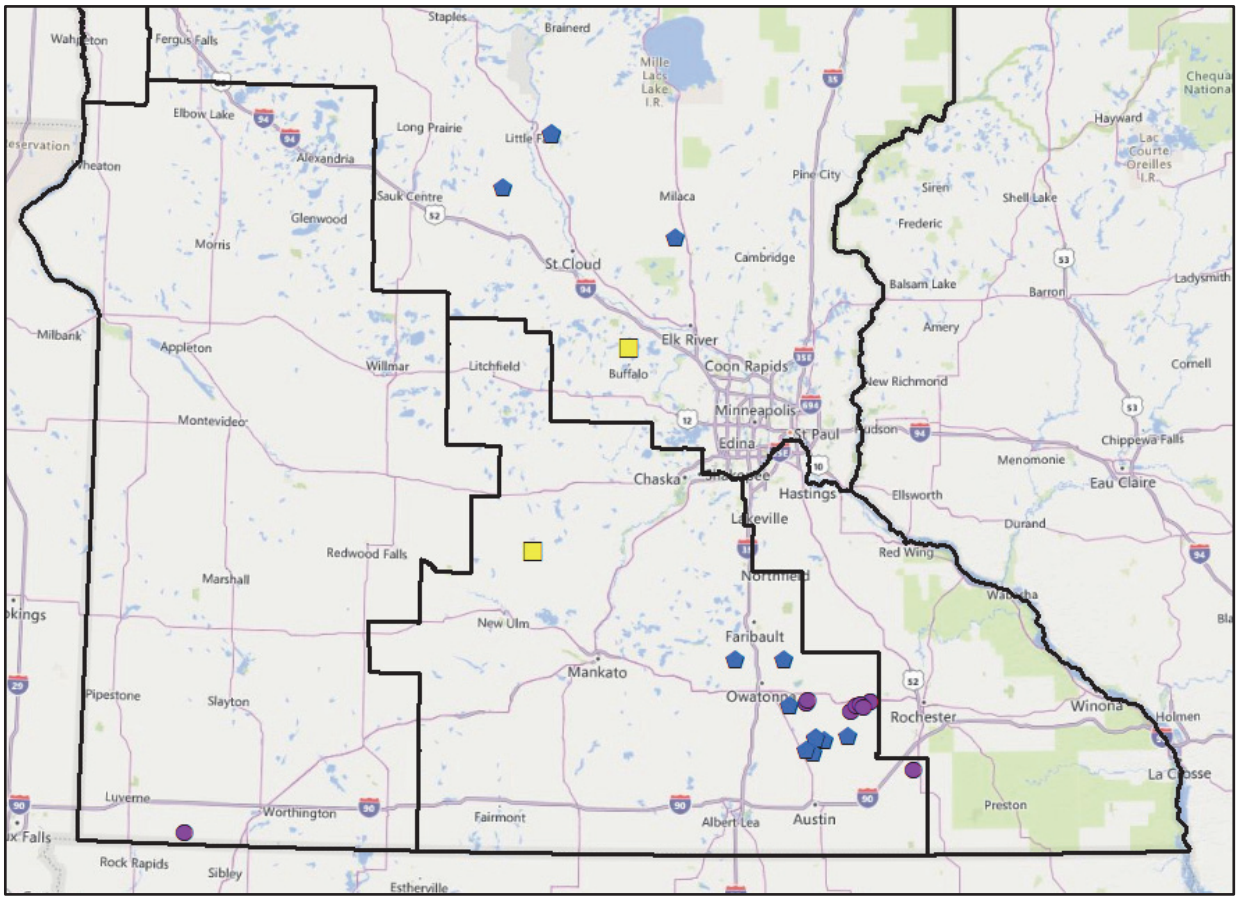
The service project and the growers committed to the project by signing a contract. This same contract has been used in 2017,2018, and 2019 to formalize the relationship and responsibilities of each partner. The service provider retains the executed copies of this agreement. Appendix C contains a copy of a blank grower agreement.

A total of 25 trials were established and analyzed for the project compared to a workplan target of 24 trials. A breakdown of the county and associated Minnesota fertilizer BMP region for each trial.

Trials by Type and Region

N Bmp Region	County Name	Trial Type		
		Nitrogen	Potassium	Sulfur
Northeast	Mille Lacs	1		
	Morrison	2		
	Stearns	1		
	Wright			1
South Central	Dodge	3	7	
	Mower		1	
	Rice	1		
	Sibley			1
	Steele	6		
Southwest and West Central	Nobles		1	
Grand Total		14	9	2

GPS coordinates for each trial location were provided as part of the GIS data files. These coordinates were used to generate the map below which show the location of each trial.



Trial Locations - Nitrogen (blue pentagons), Sulfur (yellow squares), and Potassium (purple circles).

COLLECTION OF DATA

As-applied files

A GPS record of where and when the fertilizer was applied is referred to as the "as-applied" files or map. For on-farm research this is a critical layer used post-harvest for analysis of the data to ensure that the fertilizer application occurred as planned. For 2020, five trials did not have as-applied data available because the retail fertilizer location deleted them from the machine. The completion rate for as applied was 20 of 25 trials or 80%.

As-applied status

Trial Type	As-Applied	
Nitrogen	YES	14
Potassium	NO	5
	YES	4
Sulfur	YES	2
Grand Total		25

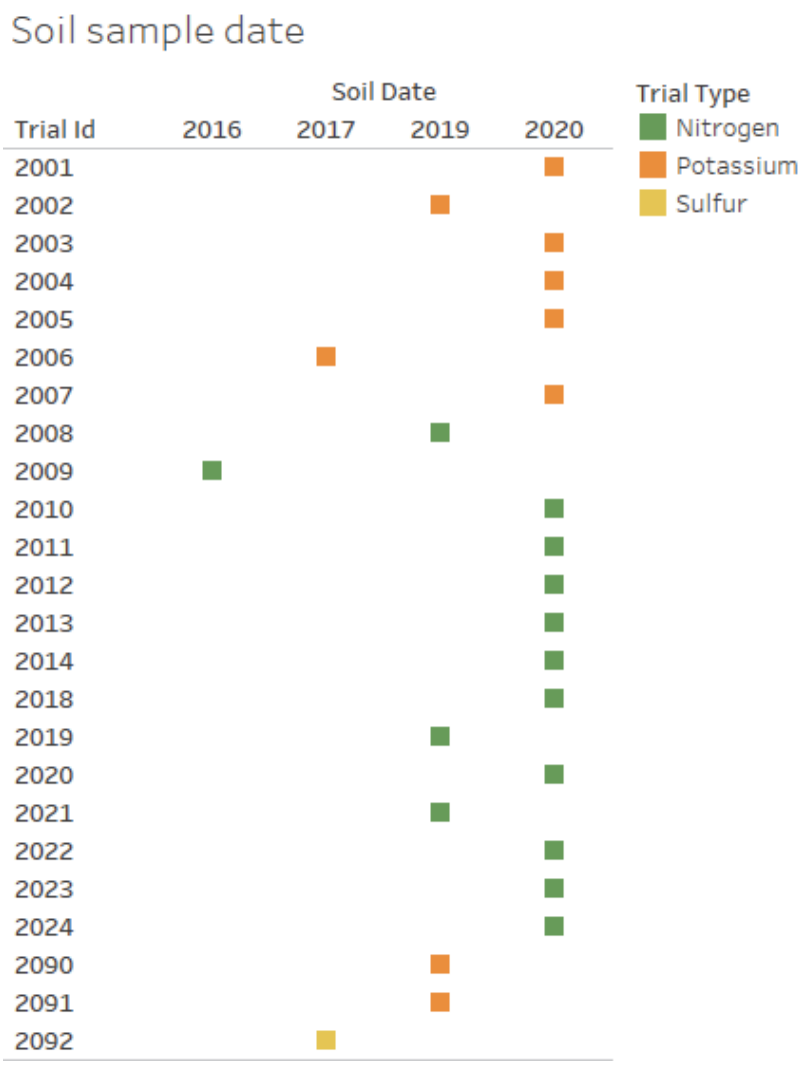
In-Season Imagery

Collection of in-season imagery for on-farm trials is another important layer of data. Many on-farm trials are placed in portions of fields that are not accessible during the growing season. Secondly, the manpower and time cost of visiting each trial can quickly become an expensive aspect to the project. Remote sensing has proven to be a low-cost method to evaluate the health of the crop in season. For the 2020 project, satellite imagery was collected during the month of August for 100% of trials. In-season imagery is used in the analysis of every trial to evaluate the impact of weather or man-made issues.

Soil Samples

Soil samples were collected to help understand the existing fertility levels in the trial area. The samples were collected from the location of each trial at a standard 0-7" core depth. The soil was analyzed by MVTL labs in New Ulm, MN. The measurements included P,K, CEC, and ph. A second 0-24" core depth was collected and analyzed to measure the mobile nutrients Nitrate and Sulfate-Sulfur. The lab results of the soil sample analysis are included as part of the individual trial data. The process for collecting soil samples is included as Appendix D.

- Fifteen trials were sampled during the 2020 season.
- Six trials had recent soil samples from 2019 and were not sampled
- The remaining four trials were not available for soil samples due to field access issues or tillage immediately following the combine harvest. In this case prior soil samples were used from 2018 or earlier. No samples were collected after tillage operations in the fall.



Field ID	Date Sampled
2001	7/30/2020
2002	6/5/2019
2003	7/30/2020
2004	7/30/2020
2005	7/30/2020
2006	7/12/2017
2007	7/30/2020
2008	6/18/2019
2009	5/20/2016
2010	7/30/2020
2011	11/17/2020
2012	11/17/2020
2013	11/17/2020
2014	11/17/2020
2017	N/A
2018	10/20/2020
2019	5/28/2019
2020	7/30/2020
2021	5/28/2019
2022	7/30/2020
2023	10/20/2020
2024	7/30/2020
2090	7/13/2019
2091	7/13/2019
2092	11/3/2017

GPS yield monitor data

Yield monitors were used to collect harvest data for each trial. All 25 trials – 100% -- submitted yield data for analysis. The harvest dates range from September 26th through November 7th with 50% of the trials harvested by October 18th. The GPS yield monitor files began to arrive from the service provider on December 23 about 6 weeks following the harvest of the last field. Additional yield monitor files continued to arrive through the month of January and February 2021.

ANALYSIS AND RESULTS

The workplan outlined a planned harvest data collection period within 30 days of harvest or December 15th, whichever is sooner. The bulk of GPS harvest data was received later than planned, which caused a slip in the project timeline. This delay was reported in the January-March 2021 quarterly progress report. The analysis of 2020 trial data begin in February 2021 and completed in April. The individual trip reports were completed by the service provider between February 10 and March 17. A copy of these individual trial reports is included as part of the outreach requirements, included at the end the report.

In the quarterly progress report from July 2020, a process for identifying management zones was presented. The management zones were created from prior yield history. The "A" management zone contains the highest yields. The "B" management zones are average yields. The "C" management zone contains the lowest yielding area of the field. Appendix F contains a copy of the slides to illustrate this method of determining where high and low yielding areas are within the field.

The analysis of on-farm research data for the 2020 season follows the same process documented in 2019. The analysis requires GIS software such as QGIS, ArcGIS, or similar. In some cases yield monitor data analysis requires the use of specialized precision ag software such as AgLeader SMS, myJohnDeere, or similar programs. These are off-the-shelf programs that any fertilizer retailer, agronomist, or farmer can purchase. The analysis follows a rigorous process with each step documented in Appendix G. The output from each step of the analysis provides an opportunity for generation of a map to use in the education, reporting, and outreach of the project. A full set of these maps is included in Appendix H.

In addition to maps, the GIS analysis generates tabular results for each trial of the yield differences observed with each fertilizer rate. These files were input into R (or SAS) for statistical analysis of each plot. Each trial has 3 rates of fertilizer replicated at least 3 times for a total of 9 plots per trial. With 25 trials established, a total of 225 individual research plots (25 trials x 9 plots per trial) support the analysis in the following tables, charts, and graphs. The individual data used for the following charts is included in Appendix I with Appendix J containing box plots for the yields in each trial.

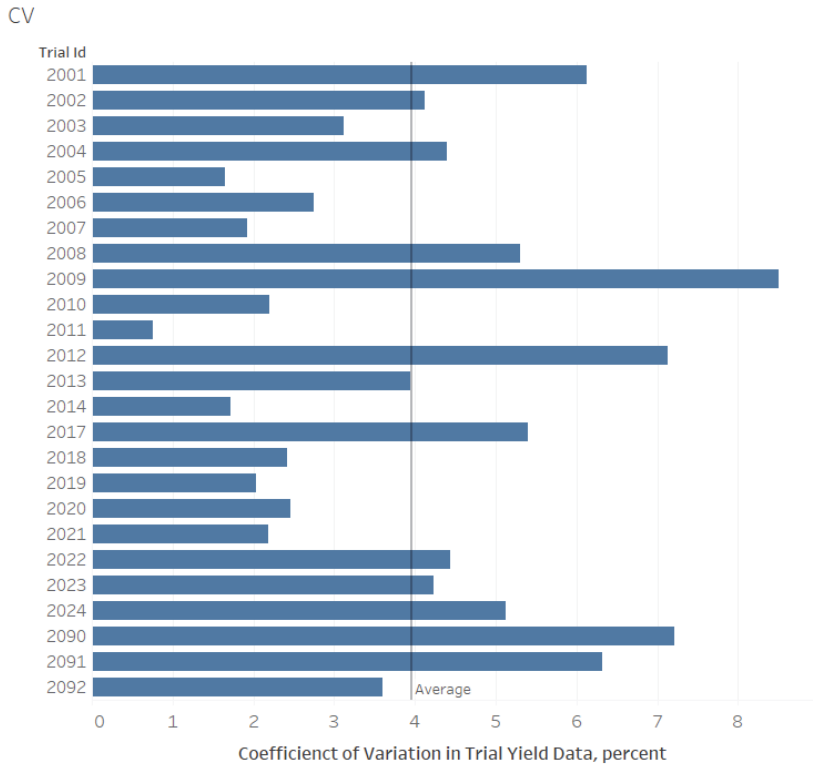
Each trial was placed into a known management zone based on prior yield history. As previously mentioned, the "A" management zone contains the highest yields. The "B" management zones are average yields. The "C" management zone contains the lowest yielding area of the field.

Each trial exists in only one management zone (except trials 2004 and 2010 which spanned multiple zones). The table below lists number of bushels of grain that are required to indicate a statistically significant yield increase. In general, the LSD (least significant difference) increases as the amount of yield variability increases in a plot. The key observation from this table is that the highest yielding areas in Zone A had a much lower LSD of 6.1 bu/ac versus 13.2 bu/ac for Zone C. This observation creates a larger challenge for future research projects as the process to prove statistical difference in yield increases could be more challenging in the low yielding areas of fields.

LSD by Management Zone

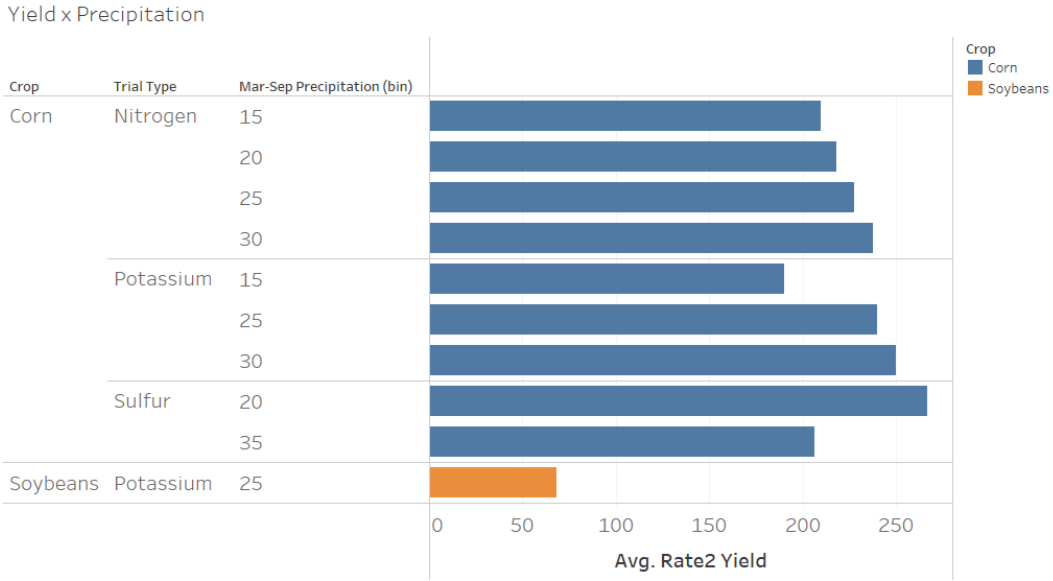
		Management Zone					
Crop	Trial Id	A Zone	A-B Zone	B zone	B-C Zone	C Zone	NA
Corn	2003	9.21					
	2004		12.99				
	2006			9.52			
	2008					12.28	
	2009					24.56	
	2010				5.50		
	2011	3.02					
	2012					16.15	
	2013					14.91	
	2014					5.39	
	2017					13.10	
	2018			6.74			
	2019			5.57			
	2020					7.30	
	2021			6.60			
	2022					12.26	
	2023			10.81			
	2024			14.96			
	2090						18.65
	2091						23.68
	2092						16.89
	AVERAGE	**6.11**	**12.99**	**9.03**	**5.50**	**13.24**	**19.74**
Soybeans	2001				4.11		
	2002	3.71					
	2005	1.21					
	2007	1.64					
	AVERAGE	**2.18**			**4.11**		

Coefficient of Variation



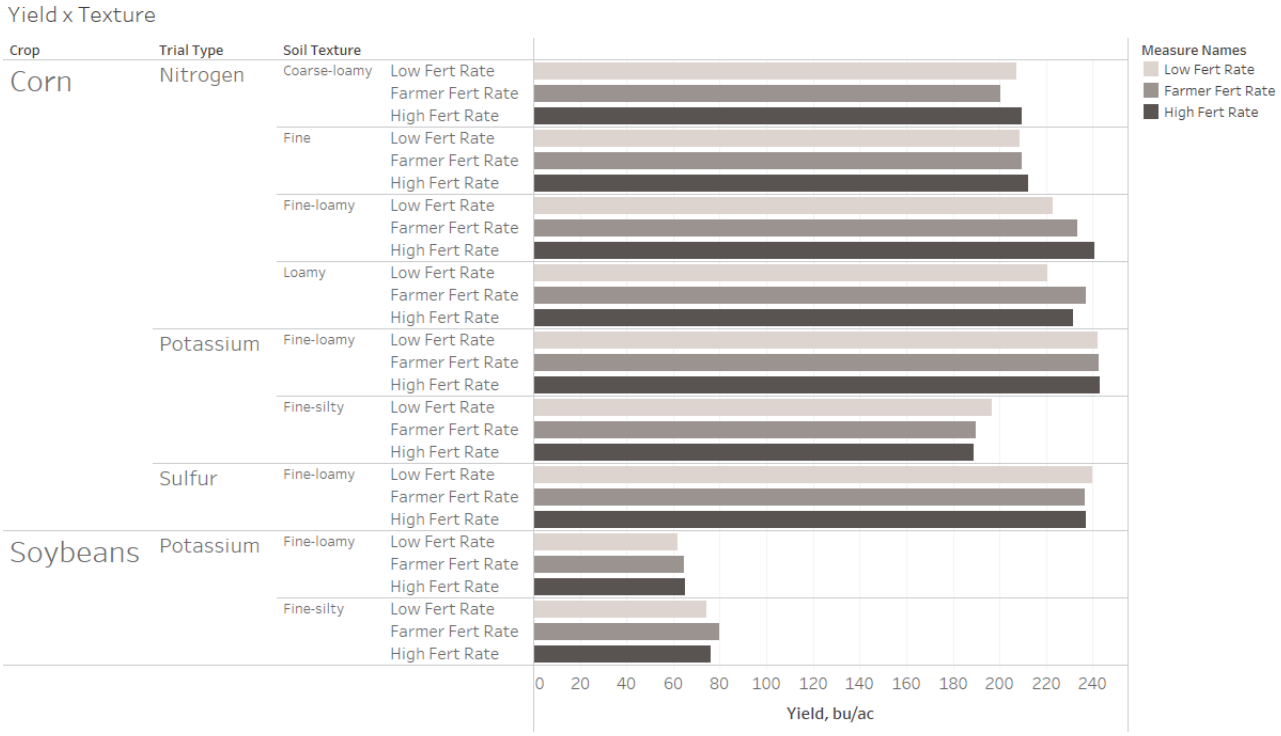
Coefficient of varation for each trial averaged 4% in 2020. This is consistent with values reported in 2019 and 2018 AFREC on-farm research projects.

Precipitation



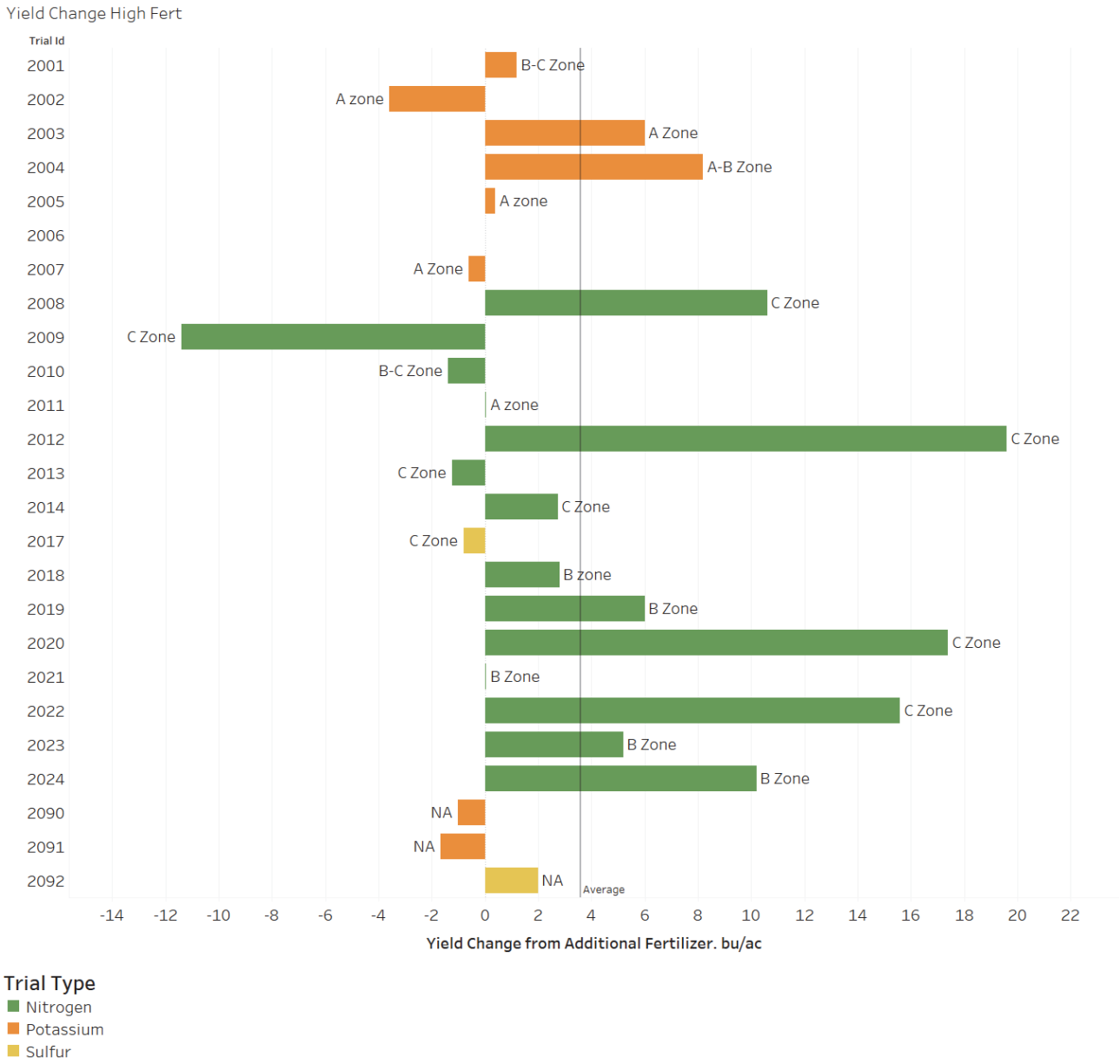
In most cases, increasing amounts of rainfall between March 1 and September 30, 2020 led to higher yields.

Soil Texture



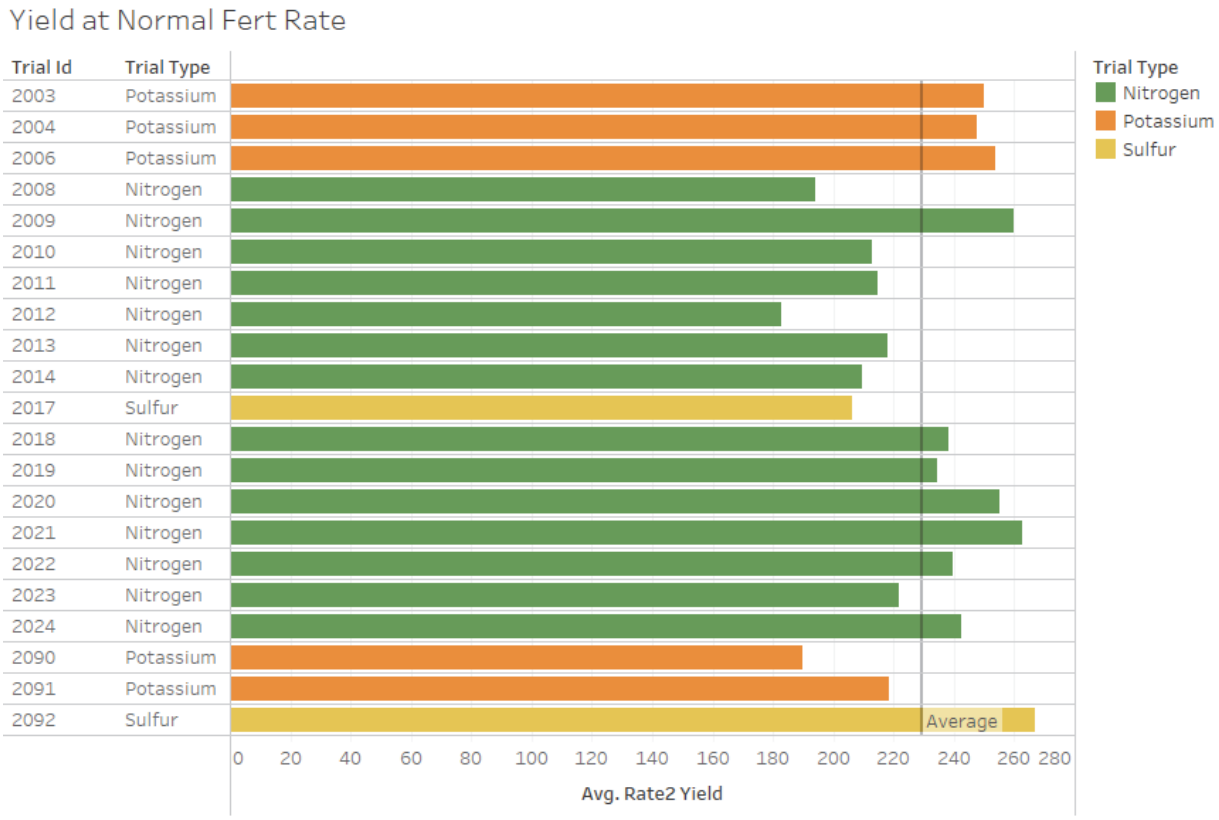
Soil texture did not appear to be related to any yield patterns in 2020, possibly because many areas received just-in-time rainfalls for optimum production.

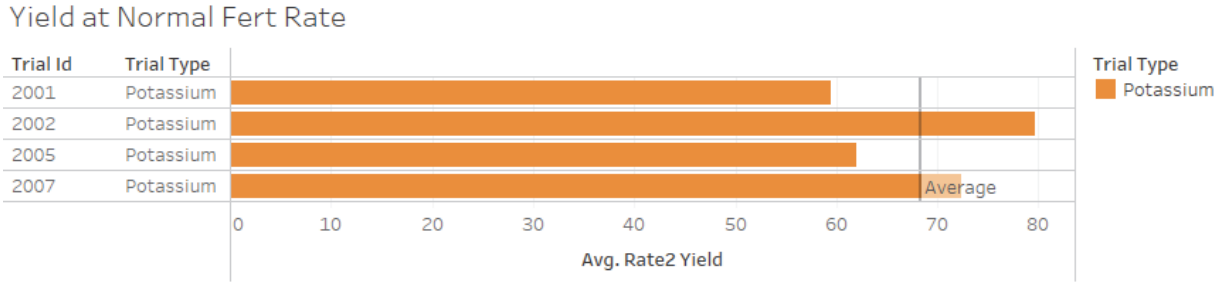
INCREASING THE FERTILIZER RATE



Across all 25 trials, when growers increased fertilizer rates above their normal practices, yields increased on average by 3.6 bu/ac. This is on track with increases seen in the 2018 and 2019 AFREC on-farm research data sets. The largest four yield increases were from trials placed in the lowest yielding areas (Zone C).

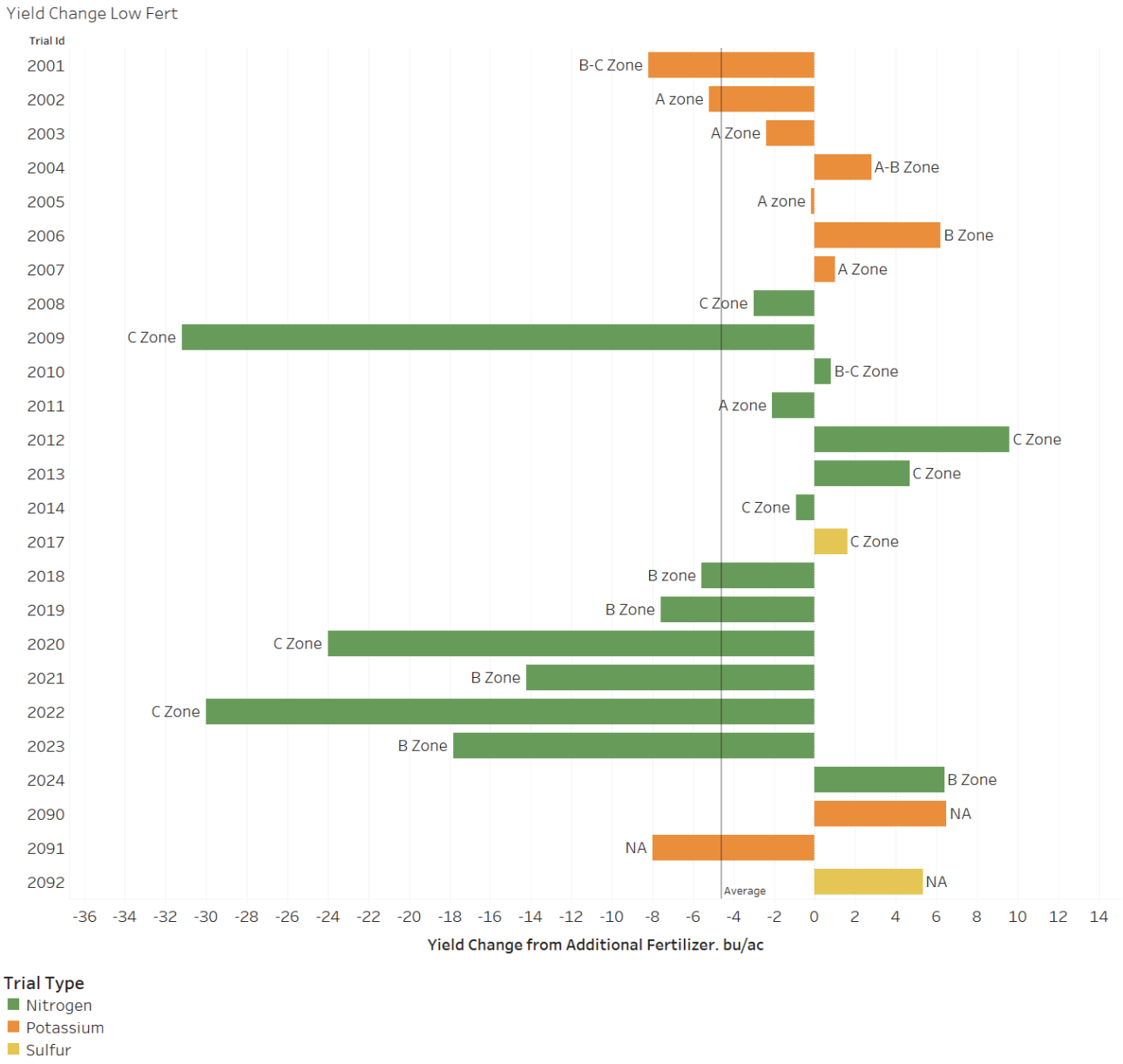
STANDARD / NORMAL FERTILIZER RATE





The two charts above illustrate the yield averages using the farmer fertilizer rate for each trial. AFREC corn yields averaged 230 bushels per acre and soybean yields averaged 68 bushels per acre. The state of Minnesota average yields for 2020 were 191 bu/ac for corn and 50 bu/ac for soybeans. The growers in the AFREC research project achieved 20-25% above state averages even in their lower yielding areas.

DECREASING THE FERTILIZER RATE



Across all 25 trials, when growers reduced fertilizer rates below their normal practices, yields decreased on average by 4.6 bu/ac.

CONCLUSIONS

1. Increasing fertilizer rates in C-Zones (the low yielding areas) increased yields by a greater margin than A or B Zones (high and medium yielding areas)
2. Statistical confidence in the yield results from lower-yielding zones (C-Zones) is lower than A or B Zones. The LSD (least significant differences) from the analysis are higher and so there is a larger hurdle to overcome spatial variability such as poor drainage, variable soiltypes, compaction, or other challenges. These observations suggest that conducting on-farm fertilizer research in low yielding areas is more difficult than in high-yielding areas.
3. Decreasing fertilizer rates shows a very negative yield response in several of the B and C zone nitrogen trials. This suggests that higher rates of fertilizer may be needed in low yielding areas.

OUTREACH

Appendix E contains the individual grower reports used for outreach in February and March 2021. As mentioned in the previous analysis and results section, the service providers communicated the results of individual trials to growers electronically due to COVID concerns versus the typical in-person meetings.

The marketing and publicity partners for AFREC (Clutch Performance and University of Minnesota Extension) have received access to the 2018 and 2019 on-farm trials through this website. All the data used in the preparation of the 2020 report will be made publicly available through the web-based interface Tableau Public. Tableau provides a free platform for hosting public databases such as the AFREC on-farm research.

CHALLENGES ENCOUNTERED

The top three challenges for the project included the following:

1. COVID9 and executive orders issued by Governor Tim Walz which impacted travel starting on March 27, 2020. The executive orders limited travel to meet with prospective trial partners, collect soil samples, and communicate the results.

2. A second challenge was the additional levels of communication while working with service providers to select growers and fields. The AFREC project goals may not be clearly understood by the grower or retail partner as additional layers are added to the project. As a result, fewer trials were placed into low-yielding areas (C-Zones).

3. The delay in receiving the complete set of GPS yield data shapefiles created a slip in the timeline which crossed over into the start of the 2021 growing season, which occurred earlier than usual due to drought conditions. After the start of the 2021 growing season, it was more difficult to find time to analyze data from the previous growing season.

Minnesota Department of Agriculture
Pesticide & Fertilizer Management Division
AFREC R2021-7-G
QUARTERLY PROGRESS REPORTING
FOR THE PERIOD ENDING: SEPTEMBER 30, 2021

SWIFT CONTRACT NUMBER: 191740	PURCHASE ORDER NUMBER: 38631
PROJECT DESCRIPTION:	Utilizing On-farm Research to Revise Fertilizer Recommendations in Low Yielding Zones
REPORT DUE DATE:	October 31, 2021
PRINCIPAL INVESTIGATOR:	Matt Wiebers
VENDOR/CONTRACTOR/ORGANIZATION	Minnesota Crop Production Retailers Patrick Murray
ADDRESS:	601 Carlson Parkway Suite 450 Minnetonka, MN 55305
PHONE NUMBER:	(763) 235-6472
EMAIL:	patrick@mcpr-cca.org

I. GOALS AND OBJECTIVES OBTAINED

More than 93% of the state continues to be “abnormally dry” or drier as of September 28th. The map on the next page shows the locations of 2021 AFREC trials in proximity to the classification of the drought.

- three of the trials are in the abnormally dry category
- three of the trials are in the moderate drought category

All six trials that were established in May and June are still underway and will be harvested. However, it’s likely that yield will be negatively impacted due to the dry conditions which challenged the crop for the entire 2021 growing season.

The attention during this quarter focused on activities in the work plan and a third activity helping other AFREC project teams.

1. Remote sensing data collection.
2. Planning for fall trials
3. On-boarding and training a new Clutch Performance employee (Shannon Werstein) on the current and prior AFREC on-farm research data.

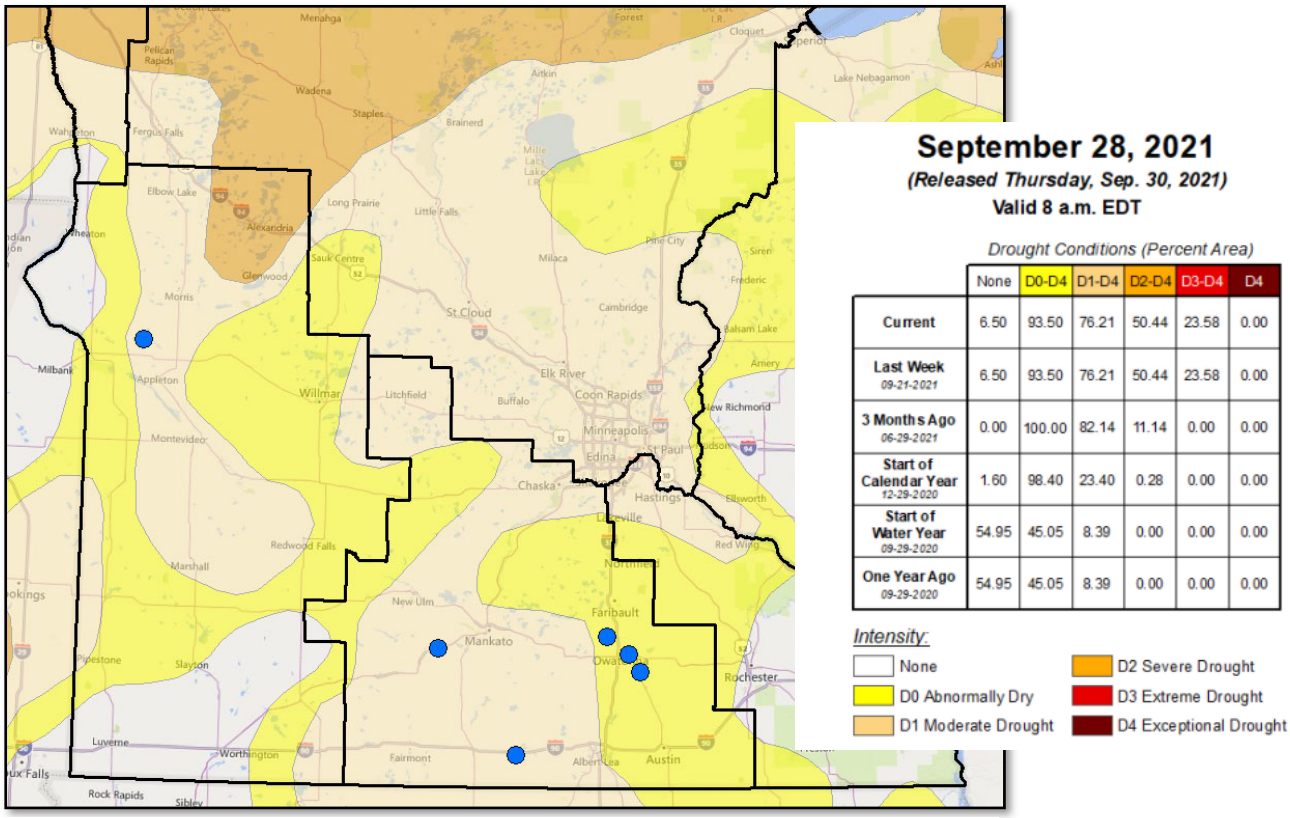


Figure 1 Spring 2021 AFREC Trial Locations in proximity to drought as of September 28, 2021

II. ACTIVITIES PERFORMED

The work plan identifies three tasks targeted for completion in the current quarter.

Task Number	Objective Number	Month(s)	Year	Description
5	3	April-June	2021	Collection of spring trial soil samples
7	3	July-August	2021	Collection of trial in-season imagery for spring 2021 trials
8	4	July-August	2021	Generate leads and commitments for fall trials with Phosphorus and Potassium
9	4	September-October	2021	Collection of fall trial soil samples

DETAILS

1. The collection of imagery for the 6 trials is in-progress as of the end of the reporting quarter. Satellite imagery can be conveniently purchased after the growing season at lower costs than in-season. Since the imagery is used for post-trial analysis, this activity will be completed by the end of the next quarter. The fall trial soil samples will not be completed until after October 1.

2. The trial service provider Premier Crop Systems is in the process of selecting leads and securing commitments for the fall 2021 trials. The on-farm research protocol used for spring trials was updated and revised for fall trials. A copy of the protocol is included as an appendix to the report.
3. Collecting soil samples for the spring trials will begin once the crop is harvested. The preparation work is complete, which included documenting the process of sample collection which is included as an appendix to this report. This activity will be completed in the next quarter.
4. Beginning on July 15th and continuing each week I am helping the new team member at Clutch Performance understand the current and prior year on-farm research projects. The goal of these meetings is to determine the articles and content that will be written in the next quarter about the 2020 AFREC on-farm research data.

III. CHALLENGES ENCOUNTERED

1. In crop years with weather challenges, there appears to be a reduced interest level by farmers and advisors in conducting on-farm trials. I think this is because there is a perception by producers that years with too much moisture (2019) and drought (2021) create databases that are not representative of typical yields on their farm. This perception creates a challenge for establishing interest in trials.
2. The price of fertilizer for all three major nutrients (N,P,K) have increased rapidly in the quarter. This price increase will impact interest in committing to fall fertilizer trials as growers assess their strategies to manage high input costs such a reducing fertilizer rates, skipping a year of fertilizer P/K application, or waiting until spring to purchase and apply fertilizer.

IV. FINANCIAL INFORMATION

The financial and budget details supporting the work for this quarter are provided in a separate document.

Premier Crop Systems

For Minnesota Agricultural Fertilizer Research and Education Council (AFREC)

1 OVERVIEW

This project will partner with growers and crop advisors to identify the low and high yielding areas of fields and establish an on-farm research approach to test a range of fertilizer rates in these areas in order to assess the validity of current recommendations. The target crops will include corn, soybeans, wheat, and sugar beets with a preference for fields that have not yet received applications of fertilizer for 2022 crop.

1.1 OBJECTIVES

- To collect on-farm research data from up to 24 fields statewide, ideally 5 per BMP region, that will be used for evaluating fertilizer recommendations in low and high yielding areas of corn, soybean, wheat and sugar beet fields in the 2022 crop season.
- To produce new information that will be used by Minnesota farmers to improve their fertilizer recommendations in low and high yielding areas in future crop seasons.

2 PROTOCOLS

Trial Option	Trial Type	Application Timing	Application Rate
~~1~~	~~Nitrogen Rate~~	~~Spring 2021~~	~~MRTN recommended +/- 30 lbs actual N~~
2	Phosphorus Rate	Spring 2021 or Fall 2021 (for 2022 crop)	3 rates, +/- 100 lbs of product from UMN recommended based on soil test P
3	Potassium Rate	Spring 2021 or Fall 2021 (for 2022 crop)	3 rates, +/- 100 lbs of product from UMN recommended based on soil test K

*For P&K trials, if UMN recommended rate is 0, testing rates should be 0, 100, 200 lbs product

*Phosphorus trials should have a minimum of 175 lbs N for 1st yr corn and 200 lbs N for corn on corn applied to eliminate N as a yield limiting factor

2.1 TRIAL REQUIREMENTS

- Trial fields must have 3 years yield history for management zone creation
- Soil samples from each trial will be collected by a 3rd party when field conditions are suitable
- Each field should be capable of hosting one ELB.
- Trial size to be determined based upon product applicator width and harvester width, typically 3-4 acres
- Target trial locations where no manure has been applied for 2 years or more
- All as-applied and harvest data needs to be collected and sent to PCS following contract deadlines
- Grower must supply trial field and product
- Advisors will be paid $400/trial and can share with grower at will
- Trial results will be anonymized and made public through AFREC. See Grower Agreement.

Collecting Soil Samples for AFREC 2021 Project

1. The AFREC trial location comprises a small portion of the overall field. The trial location within the field that can be located with GPS.
2. As part of the project requirements in the work plan, soil samples are to be collected from the trial. A total of 6 samples will be collected.

Samples #1 through #4 – Stratification of nutrients Sample

1. Samples 1-4 are separated by depth. At least 10 cores must be collected in order to supply enough sample for the lab.
    a. Sample #1: 0-2” depth
    b. Sample #2: 2-4” depth
    c. Sample #3” 4-6” depth
    d. Sample #4” 6-8” depth
2. Collect 8” soil core and use a knife or a similar method to cut the sample into 2” lengths.
3. Pinch or scoop out each 2” length and place into the proper bag.
4. Refer to the photo below for an example.

Be careful to assure that each soil core is placed into the proper bag. One mistake can ruin the sample.

Sample #5 – Standard P and K Sample

This is the typical soil sample collected by agronomists and crop advisors used in recommendations of P, K, and lime across the state.

1. 0-6” of soil depth. 10 cores are collected from this depth in the trial area.
2. Mix the samples in a plastic bucket and then fill the sample bag to the line.
3. Discard any extra soil from the bucket.

Sample #6 – Nitrate and Sulfur Sample

1. Collect 8 cores in the trial area at 0-12” depth
2. Mix the samples in a plastic bucket and then fill the sample bag to the line.
3. Discard any extra soil from the bucket.
4. Be sure to advise the soil lab to run tests for both Sulfate and Nitrate.