Achieving Efficient Nitrogen Fertilizer Management in California Wheat: 2022 CDFA-FREP Interpretive Summary

Project Leaders

Mark Lundy, Ph.D.
Assistant CE Specialist
University of California, Davis
Department of Plant Sciences
melundy@ucdavis.edu

Taylor Nelsen, M.S.
Assistant Specialist
University of California, Davis
Department of Plant Sciences
tsnelsen@ucdavis.edu

Nicholas Clark, M.S.
Assistant CE Advisor
UCCE Kings County
neclark@ucanr.edu

Giuliano Galdi, M.S.
Assistant CE Advisor
UCCE Siskiyou County
gcgaldi@ucanr.edu

Thomas Getts, M.S.
Assistant CE Advisor
UCCE Lassen County
tjgetts@ucanr.edu

Michelle Leinfelder-Miles, Ph.D.
CE Advisor
UCCE San Joaquin County
mmleinfeldermiles@ucanr.edu

Sarah Light, M.S.
Assistant CE Advisor
UCCE Sutter-Yuba Counties
selight@ucanr.edu

Konrad Mathesius, M.S.
Assistant CE Advisor
UCCE Yolo County
kpmathesius@ucanr.edu

INTRODUCTION

Wheat and other small grains are grown in diverse agricultural environments throughout California. Approximately 90% of the wheat, triticale and barley in California are fall-sown and rely on precipitation that varies dramatically across the state. These conditions make efficient N fertilizer management difficult because the right rate varies from field-to-field and year-to-year. With increasing regulatory, market and social demands for sustainable N management, growers and crop consultants need improved N fertilizer management strategies and innovative tools that enable adaptive management and responsive farming. Therefore, the goal of this project is to demonstrate and enable new ways of achieving best N management practices in California wheat and related winter cereals.

OBJECTIVES

1 Demonstrate how to use N-rich reference zones and site-specific measurements of the soil and plant N status on a field-scale to guide real-time N management decisions in wheat and related winter cereals. Demonstration sites are located on diverse California farms and implemented across three growing seasons.
2 Measure crop yield and N uptake resulting from N fertilization management decisions in response to site-specific, real-time information. Compare results in alternative management scenarios within and across demonstration sites.
3 Produce case-studies for each demonstration site that document agronomic conditions, in-season measurements, management responses, final grain yield and N uptake as well as provide an agronomic interpretation of the results.
4 Develop guidelines for implementing N-rich reference zones, taking site-specific measurements, interpreting results, and making responsive farming decisions.
5 Develop, beta-test, and extend dynamic, web-based decision support tools that provide customized information and management recommendations based on site- and time-specific farm management variables, environmental conditions and California-specific models of wheat growth and development.

DESCRIPTION

Sixteen field-scale demonstrations were completed between the 2019-21 and 2021-22 seasons. Demonstration sites included 8 fields in the Sacramento Valley, 3 fields in the San Joaquin Valley, 3 fields in the Intermountain region of Northern California, and 2 in the Delta region. Fields included highly productive, irrigated locations with grain yields as high as 9000 lb/ac. They also included low productivity, rainfed locations with yields as low as 1500 lb/ac. Each site had one to four 90-ft by 180-ft N-rich reference zones that were established in representative areas of the field at or near the time of planting. N fertilizer rates in these zones were 2-3 times the amount of expected crop N uptake from planting until the start of in-season plant and soil monitoring.

From the tillering stage of growth to the heading stage of growth, project leaders measured canopy reflectance (i.e. NDVI/NDRE) both within N-rich reference zone(s) and in the broader field and also measured soil nitrate-N in the top foot of soil using quick tests. Measurements were made prior to participating growers' fertilizer management decisions. When crop N deficiency was detected by real-time plant and soil measurements, N fertilizer recommendations were produced using a combination of the site-specific measurements and the expected crop N demand remaining for the field

via a customized web-tool. When no deficiency was detected, monitoring continued until either deficiency was detected or the grower decided to apply N fertilizer in-season. When possible, the alternative to the cooperating grower's management action (either applying N fertilizer when the grower applied none or excluding fertilizer when the grower decided to apply) was enacted to measure the effect of the management decision and the accuracy of the modeled, in-season fertilizer recommendation. Alternative N management scenarios were successfully implemented at 10 of the 16 locations. When the crops reached maturity, yields and crop N uptake were measured within the main field, the N-rich reference zones, and the alternative management zones (when applicable).

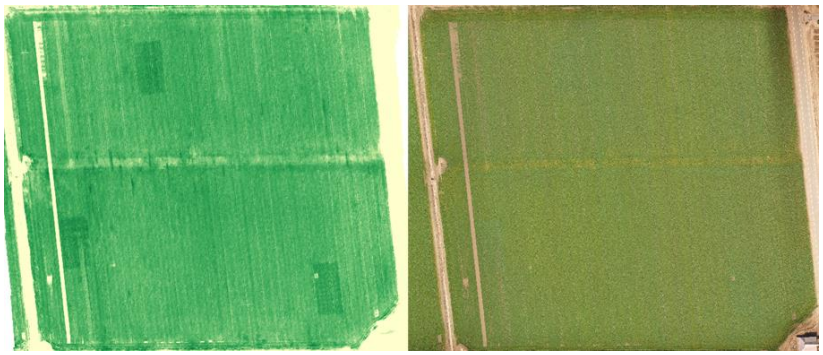

Figure 1. Demonstration site showing crop N deficiency signal. The three N-rich reference zones appear in the NDRE measurement (on the left) but are not visible to the naked eye (RGB image on the right).

RESULTS AND DISCUSSION

In-season monitoring of the plant and soil resulted in a wide range of measurements, N fertilizer recommendations, and outcomes (Table 1). Based on site-specific, real-time measurements, The Nitrogen Management Tool for California Wheat produced a targeted recommendation. When in-season N fertilizer applications were recommended, they resulted in an average yield increase of 28% (~1500 lb/ac) compared to an in-field control ($p = 0.01$, $n = 6$). When monitoring indicated that crop response to N fertilization was unlikely and no fertilizer application was recommended, yields in the grower field were equal to the control ($p = 0.80$, $n = 4$). In addition, these growers saved an average of 50 lb/ac N compared to their typical N fertilizer rates, which translated to savings of ~$40/ac in fertilizer costs. Overall, crops at the demonstration sites removed 24 lb/ac more N than was applied as fertilizer for an average applied/removed ratio of 81%. These outcomes, measured over three seasons and across a wide range of California small grain agroecosystems, illustrate that efficient N fertilizer management can be achieved by combining plant and soil monitoring with site- and time-specific decision support information.

ACCOMPLISHMENTS

In addition to the agronomic measurements recorded at the demonstration sites, this project produced a diverse set of outreach materials and educational outcomes. These include a devoted University of California webpage containing information about the project and links to related resources. Among these resources are case studies that provide a full-season agronomic overview for each demonstration site, blog posts and articles that describe important considerations for implementing and measuring N-rich reference zones, and videos illustrating and discussing demonstration outcomes. In addition, multiple interactive web-tools were developed during the course of this project

Table 1. Indicates whether in-season N fertilizer was recommended, the rate of N fertilizer applied, and the resulting changes in yield at sites where alternative management plots permitted comparison ("-" indicates that the effect was not measured).

Location	In-season N recommended	In-season N applied (lb/ac)	Yield change (compared to control, lb/ac)	Total N Applied (lb/ac)	Total N Uptake (lb/ac)
Solano 2019-20	N	0	no change	0	97
Yolo 2019-20	Y	50	-	76	30
Siskiyou 2019-20	Y	200	+ 3672 (75%)	200	181
Colusa 2019-20	Y	46	+844 (15%)	106	156
Kings 2019-20	Y	61	-	209	161
Sacramento 2019-20	N	0	-	60	148
Yolo 2020-21 (irrigated)	Y	50	+1119 (26%)	50	115
Yolo 2020-21 (rainfed)	N	0	no change	74	58
Colusa 2020-21	N	0	-	60	146
Kings 2020-21	Y	140	+ 1088 (14%)	140	177
Sacramento 2020-21	N	0	no change	60	163
Yolo 2021-22 (rainfed)	N	60	no change	110	41
Yolo 2021-22 (irrigated)	Y	30	-	139	130
Kings 2021-22	Y	80	-	210	164
Lassen 2021-22 (forage)	Y	92	+ 3548 (29%)	98	129
Lassen 2022 (barley)	Y	40	+ 604 (15%)	46	127

along with how-to videos describing how to use these web-tools. These websites provide customized, site-specific fertilizer recommendations, real-time information about seasonal weather, and a tool to convert measurements from an in-field soil nitrate quick test to a N fertilizer equivalent based on soil type. Throughout the project, project leaders have presented about these demonstration efforts to audiences at field days, webinars, and other extension settings, including six events hosted by project leaders. At five of these events, surveys were used to evaluate efficacy of the educational content. Based on ratings from a subset of attendees (n=42), knowledge of the project concepts and associated tools increased and attendees were more likely to use N rich reference zones and associated UC webtools as a result of the information presented at these events. In addition, case studies were an effective method for learning about the tools and methods being demonstrated by this project.

TAKE-HOME MESSAGE

Shifting N fertilizer applications from pre-plant to in-season increases fertilizer recovery in small grains. Using site-specific measurements to refine in-season N application rates and timing further increases fertilizer use efficiency. This project has demonstrated how to implement N-rich reference zones in production fields and developed new tools to interpret real-time plant and soil measurements and determine whether and how much N fertilizer to apply in-season.

ACKNOWLEDGEMENTS

This project was supported by a combination of funding from the CDFA-FREP and the NRCS-CIG programs. Thanks to Micah Levinson, Joy Hollingsworth, Salvador Grover, Ben Halleck, Ramandeep Brar, Chaitanya Muraka, Ruben Chavez, Pahoua Yang, Shirley Alvarez, Daniel Rivers, Gerry Hernandez, Puja Upadhayay, Jose Luis Dias and Ryan Hall for their assistance in implementing treatments and collecting field data.