ANNUAL REPORT

Grant Code: AP7213|16 14

Title: Active Canopy Sensors to Prescribe In-Season Supplemental N for Barley

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Accomplishments: Describe accomplishments relative to the proposed objectives.

It is estimated that <51% of fertilizer nitrogen (N) applied is used by cereal crops with the rest either being lost to the environment or bound in soil organic matter. For barley production, N must be carefully managed to prevent excessive vegetative growth and lodging, delayed maturity, pest pressure, and to ensure grain protein meets end-use targets. The University of Idaho's current N fertilizer rate recommendations are determined by accounting for the amount of residual soil inorganic N in the soil, the previous crop, soil mineralization potential, and yield goal. These guidelines were last updated in the early 2000s. One of the objectives of this study is to provide more recent data about the response of barley yield and grain protein content to N availability. Further, given the high cost of N fertilizers, improving N use efficiency is an important aspect of a farm remaining economically viable. Split fertilizer applications are one approach that may improve fertilizer use efficiency, reduce the total N rate applied, and improve a producer's overall sustainability. Split-applying N fertilizer allows time for the barley crop to integrate weather, mineralization, residual N, and pest pressure into its growth before a producer makes a final N fertility decision. Crop sensing technologies can then be used to rapidly assess the crop's greenness accounting for field variability and providing variable N rate prescriptions. The objectives of this study are:

Altorado (Feed)	Goldenhart (Food)	ABI Voyager (Malt)
0/0/0	0/0/0	0/0/0
90/0/0	50/0/0	90/0/0
180/0/0	100/0/0	180/0/0
270/0/0	150/0/0	235/0/0
315/0/0	200/0/0	270/0/0
360/0/0	250/0/0	360/0/0
400/0/0	300/0/0	135/0/0
135/0/0	125/0/0	135/45/0
135/45/0	125/25/0	135/100/0
135/135/0	125/75/0	135/135/0
135/180/0	125/125/0	135/225/0
135/225/0	125/175/0	135/80/20

Table 1 N fertilizer treatments where the amounts of fertilizer applied at planting/Feekes 5/Boot is denoted in lb/ac.

1) Determine food, feed, and malt barley yield, grain protein, and N use efficiency response to in-season N application
2) Develop crop sensor algorithms for Idaho conditions for different barley classes

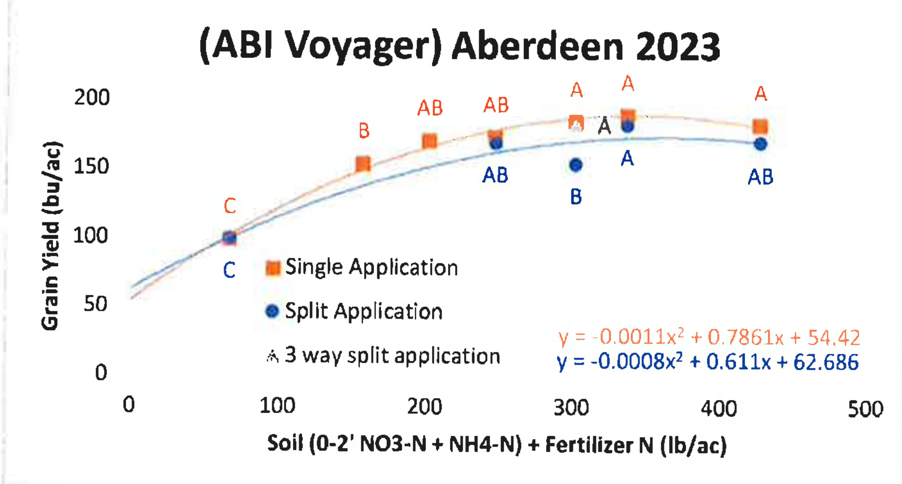
We successfully established field plots at the Aberdeen Research and Extension Center. At planting, urea was banded between the seed rows, whereas the Feekes 5 and boot split applications were broadcast applied and irrigated into the soil within 4 hours of fertilization. We collected soil samples by replication at 1-foot increments down to 2 feet at pre-plant and analyzed them for complete nutrient analysis. Additional soil samples were collected from each plot at 1-foot increments down to 2 feet at jointing, flowering, and post-harvest for a total of 912 soil samples. Soil samples were stored in a walk-in cooler at 40F until they were shipped to Brookside Laboratories in December for soil nitrate and ammonium content analysis. Our pre-plant soil samples indicated that we had 67 lb N/ac in the top 2'.

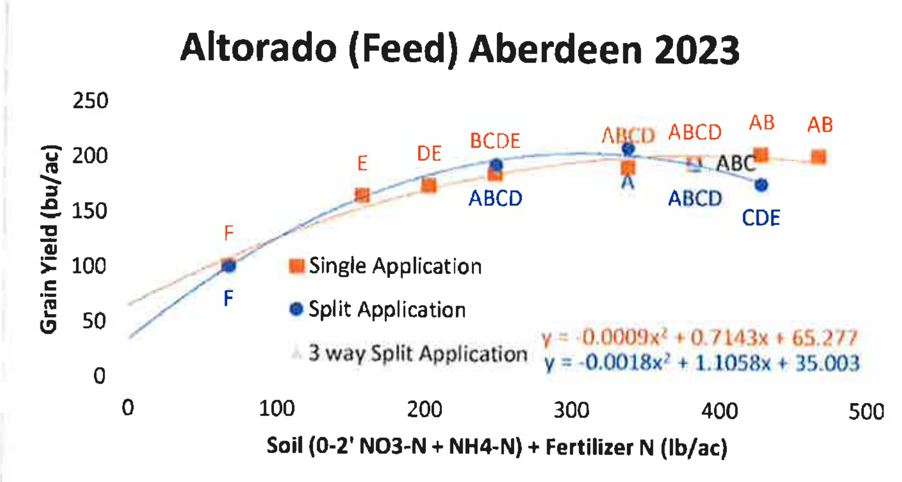
Crop canopy greenness was measured from each plot using the Apogee, SPAD, and Greenseeker sensors at jointing and flowering (912 measurements). Sensor measurements will be transcribed from paper to electronic format by a temporary help. Whole plant tissue samples were collected from each plot at jointing, flowering, and immediately before harvest by harvesting 1 meter of row. Samples collected before harvest are currently being partitioned into heads and straws. The heads were counted and will be threshed to quantify the number of viable heads per meter of row and the average number of kernels per head. All plant tissue samples were dried, weighed, and will be submitted to Brookside Laboratories for total N analysis in February 2024. All harvest grain samples have been analyzed for test weight. We will also analyze the grain samples for protein concentration.
Our initial results for 2023 indicated that all three wheat varieties' yields responded positively to pre-plant and split N applications. Quadratic responses were observed for all varieties indicating that we successfully applied insufficient through sufficient levels of N with our treatment structure. The point at which yield plateaus indicates the maximum yield to be achieved under the growing conditions tested and N rates applied. In these studies, the amount of soil + fertilizer N required to maximize yield for ABI Voyager was greater for the split fertilizer applications than the single application done at planting (Table 2). In contrast, the opposite response was observed for Altorado and Goldenhart. Despite the 80-90 lb fertilizer N/ac differences to maximize yield for the single vs split fertilizer application regimes, the yield plateau was only 1-2 bu/ac different.

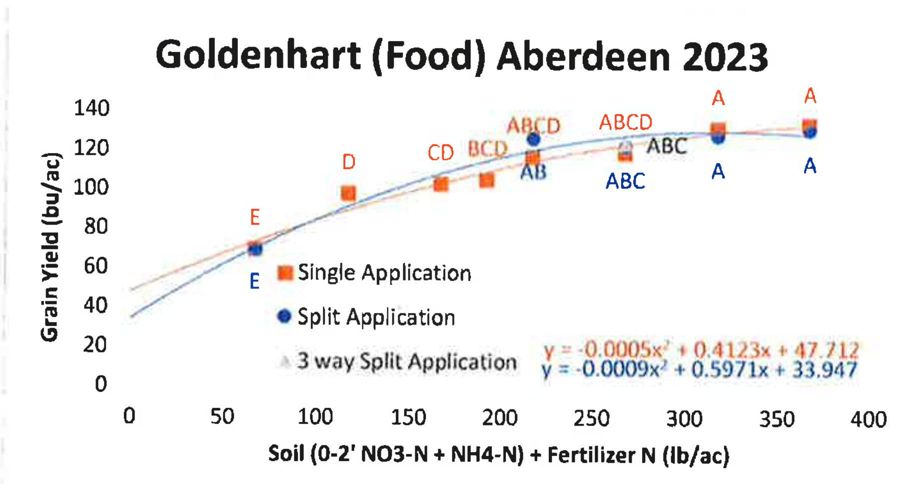
Table 2. The amount of N (soil + fertilizer) required to maximize yield (yield plateau) for the single and the split fertilizer application treatments in each barley class tested at Aberdeen 2023.

	Single Application		Split Application	
	Soil+Fert N rate (lb/ac)	Yield Plateau (bu/ac)	Soil+Fert N rate (lb/ac)	Yield Plateau (bu/ac)
ABI Voyager	357	195	382	179
Altorado	397	207	307	205
Goldenhart	412	133	332	133

Figures 1,2,3. Grain yield responses to soil+fertilizer N rate when the majority of N fertilizer is applied as a single application done at planting or as a split application done at Feekes 5. Data points with the same upper case letter (irrespective of color) within a barley class indicate that there are no significant differences between treatment means at alpha<0.05. Orange letters correspond to the single application points, blue letters correspond to the split application points, and black letters correspond to the 3-way split application point.





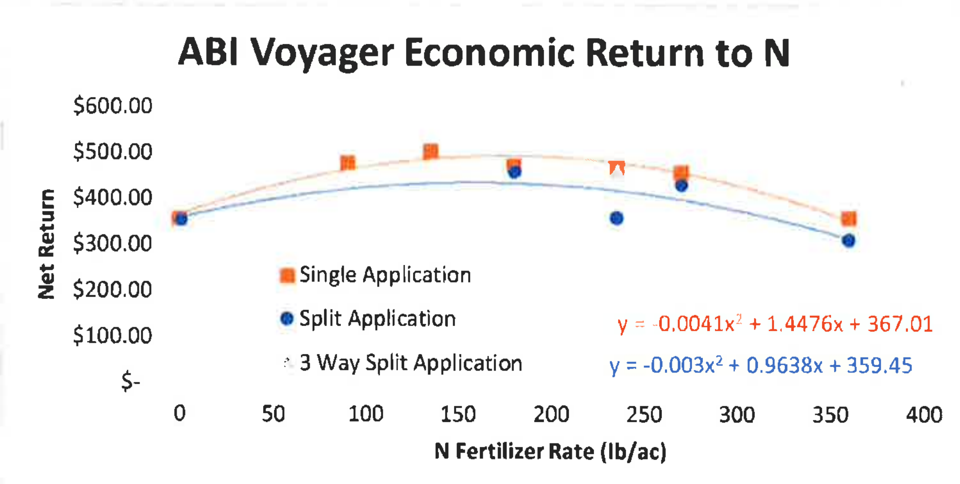


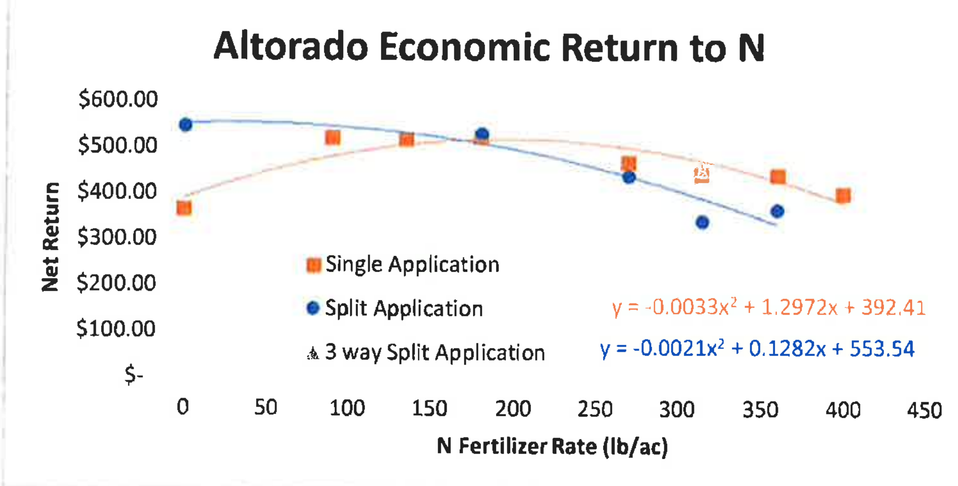
For all barley classes, there was generally no difference in yield between the single or split fertilizer applications when the total applied N rate was the same (Figures 1,2,3). The only differences were when the split application yielded 28 and 30 bu/ac less than the single application for Altorado at the 427 lb N/ac rate and ABI Voyager at the 302 lb N/ac rate.

In previous years, we have observed split applications underperforming, performing as well as, and outperforming single applications. Once we finish processing all of our grain data, the next step will be to synthesize our results to determine what the predominant pattern is for each market class.

While yield response to available N is an important component of determining the optimal N rate for barley production, economics also plays a role. The economic N return rate (Return to N) was calculated by subtracting the cost of the applied N fertilizer (assumed $0.83 per unit of fertilizer N) from the value of grain yield [assumed barley was $7.50/cwt irrespective of the barley class]. As with yield, there was a quadratic response of return to N rate with the applied N fertilizer across all classes of barley and application timings (Figures 4,5,6) The point at which net return was maximized is considered the economic optimal N rate. This quick analysis does not account for the costs to apply N fertilizer that would vary depending on the application method (e.g., fertigation, aerial application, spreader). Accounting for these additional application costs would reduce the economic optimal N rate for the split applications as this would require an additional pass across the field.

Figures 4,5,6. The economic return from N fertilizer additions for the single and split application treatments.





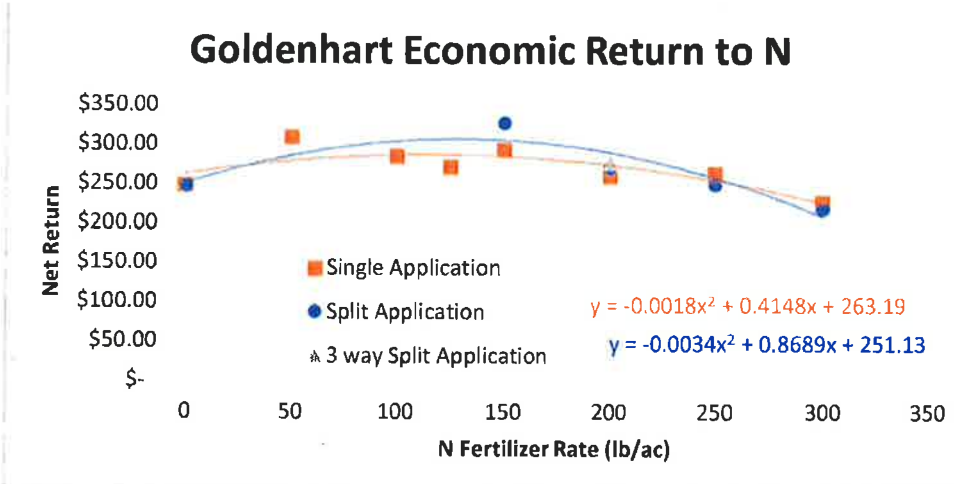


Table 3. The amount of N fertilizer (N Rate) or soil N plus fertilizer N (Soil + Fert N Rate) required to maximize the economic return for a single or split application done in each barley class tested at Aberdeen 2023. The values in parentheses indicate the range of N rates that would give a -$1 net return on investment.

	Single Application			Split Application		
	N Rate (lb/ac)	Soil + Fert N rate (lb/ac)	Net Return ($/ac)	N Rate (lb/ac)	Soil + Fert N rate (lb/ac)	Net Return ($/ac)
ABI Voyager	177 (161-193)	244 (228-260)	$495	161 (143-179)	228 (210-246)	$437
Altorado	197 (179-214)	264 (246-281)	$520	31 (9-52)	98 (76-119)	$555
Goldenhart	115 (91-139)	182 (158-206)	$287	128 (111-145)	195 (178-212)	$307

For ABI Voyager, the economic optimal N rate was 16 lb N/ac greater for the single application than the split application and returned an additional $58/ac (Table 3). In contrast, Altorado's economic optimal N rate was 166 lb N/ac more for the single application than the split application and returned -$35/ac compared with the split application. For Goldenhart, the economic optimal N rate was 13 lb N/ac less for the single application and returned -$20/ac compared with the split application.

Because growers are willing to accept different levels of risk, the economic N rates reported in Table 3 also contain a range of N rates shown in parentheses. These ranges of N rates indicate how much less or more N could be applied that would reduce the net return by $1. The reported ranges in this study are 11 to 24 lb N/ac wide indicating that near the economic optimal N rate, there is some flexibility in N application rates that will minimally impact net return. The next step is to incorporate grain quality dockage factors (e.g., test weight and protein) and in-season application expenses into the economic analysis.

Projections: Discuss how any latest information and project results can or will be used. Comment on potential design of objectives of possible related future projects.

After we finish our nutrient analyses and compile the project results from the last three growing seasons, (7 site-years) we will work on publishing the project as three papers. We will use data collected to investigate the relationship of in-season soil and plant tissue nitrogen content to barley yield and quality and nitrogen use efficiency. We will calculate the soil-crop nitrogen balance. We will also correlate our crop sensor readings to grain yield. We will create algorithms to estimate the in-season N rate required to achieve targeted yield and protein goals. We will also compare the apparent N use efficiency of the single vs split applications. Finally, we will further evaluate the economic optimal nitrogen rates by looking at the factors previously described. We will also combine our dataset with the work done by Dr. Chris Rogers to create a better estimate of barley responses to N rates.

The results from this trial will continue to be shared at professional meetings (such as the Tri-Societies meetings, Western Nutrient Management Conference), Extension events (Cereal Schools, field days), and Extension publications. The raw dataset will be published in a publicly available data repository to ensure the longevity of the dataset and its availability for future research applications.

Publications: There have not been any journal articles published using this data yet. However, the following are a list of scientific and Extension presentations that have been given on the data from this study over the past three years.

Scientific Posters and Oral Presentations

Bevan, J., J.A. Spackman, J. Sagers, R. Findlay, O. Adeyemi, O. Walsh, and A. Adjesiwor. 2023. Nitrogen Fertilizer Rate and Timing Implications for Malt Food, and Feed Barley Production in Southern Idaho. Western Nutrient Management Conference. Reno, NV. 8 – 10 Mar., 2023.

Walsh, O., J.A. Spackman, and A.T. Adjesiwor. Agronomy Reports. 2022. Updated on ISAID Barley and Wheat Fertility Studies. ISAID Annual Meeting and Regenerative Ag Workshop. Twin Falls, ID. 3 Oct. 2022.

Lamichhane, R., O.S. Walsh, J.A. Spackman, E. Nambi, E. Owusu Ansah, and F.E. Bautista. 2022. Use of Remote Sensing Tools for Yield and Protein Estimation in Spring Barley (*Hordeum vulgare L.*). ASA-CSSA-SSSA Annual Meetings. Baltimore, MD. 6 – 9 Nov. 2022.

Spackman, J.A. Irrigated Spring Barley Yield, Grain Quality, and Malt Quality Response to Nitrogen and Sulfur Fertilization. (*Oral Presentation and* Abstract). 23rd North American Barley Researchers Workshop and 43rd Barley Improvement Conference. Sacramento, CA. 22–24 Sep. 2022.

Spackman, J.A., O.S. Walsh, A. Adjesiwor, J. Bevan, O. Adeyemi, J. Sagers, and R. Findlay. 2022. Nitrogen Fertilizer Rate and Timing Implication for Malt, Food, and Feed Barley Production in Southern Idaho. ASA-CSSA-SSSA Annual Meetings. Baltimore, MD. 6 – 9 Nov. 2022.

Walsh O.S., Spackman J.A., Adjesiwor A.T., Lamichhane R., and Owusu Ansah E. 2021. Varietal response of wheat and barley to nitrogen. Crops and Soils. 54(5): 52–53. https://doi.org/10.1002/crso.20137

Lamichhane, R., O.S. Walsh, J.A. Spackman, A.T. Adjesiwor, E. Nambi, E. Owusu Ansah, and J.R. McClintock-Chess. 2021. Variety Response of Spring Barley to Applied Nitrogen: Nitrogen Use Efficiency and Soil Health (*Oral Presentation and Abstract*). ASA-CSSA-SSSA Annual Meetings. Salt Lake City, UT. 7-10 Nov. 2021.

Walsh O.S., Spackman J.A., Adjesiwor A.T., Lamichhane R., and Owusu Ansah E. 2021. Varietal Response of Spring Barley to Applied Nitrogen. Proc. of the Western Nutrient Management Conference

Lamichhane, R., O.S. Walsh, J.A. Spackman, A.T. Adjesiwor, E. Nambi, E. Owusu Ansah, and J.R. McClintock-Chess. 2021. Variety Response of Spring Barley to Applied Nitrogen: Nitrogen Use Efficiency and Soil Health (*Poster Presentation and Abstract*). ASA-CSSA-SSSA Annual Meetings. Salt Lake City, UT. 7-10 Nov. 2021.

Extension Presentations

Spackman, J.A. 2023. Nitrogen Fertilizer Rate and Timing and Humic Acid for Barley Production. Aberdeen Cereals Field Day. 20 July, 2023. (20 minutes).

Spackman, J.A. 2023. Nitrogen and Sulfur Fertilizers in Barley Production. Rupert Variety Trial Field Day. 11 July, 2023. (20 minutes).

J.A. Spackman. 2023. Tools for Sustainable Nitrogen Management in the US Corn Belt: Promoting Productivity, Profitability, and Environmental Protection. Iowa State University Agronomy Departmental Seminar. Ames, IA. 3 May 2023. (40 attendees, 60 minutes).

Spackman, J.A. University of Idaho and Shell Introductory Workshop on Dairy Sustainability: Nutrient Management in Small Grains. 10 May, 2023. (20 attendees, 10 minutes).

Spackman, J.A. Nitrogen Fertility for Small Grains. Southern Idaho Cereal School. Preston, ID. 10 Feb. 2023 (20 attendees; 30 minutes)

Spackman, J.A. Nitrogen Fertility for Small Grains. Southern Idaho Cereal School. Grace, ID. 10 Feb. 2023 (25 attendees; 30 minutes)

Spackman, J.A. Nitrogen Fertility for Small Grains. Southern Idaho Cereal School. Ashton, ID. 9 Feb. 2023 (25 attendees; 30 minutes)

Spackman, J.A. Nitrogen Fertility for Small Grains. Southern Idaho Cereal School. Idaho Falls, ID. 9 Feb. 2023 (50 attendees; 30 minutes)

Spackman, J.A. Nitrogen Fertility for Small Grains. Southern Idaho Cereal School. Pocatello, ID. 8 Feb. 2023 (61 attendees; 30 minutes)

Spackman, J.A. Nitrogen Fertility for Small Grains. Southern Idaho Cereal School. Burley, ID. 7 Feb. 2023 (60 attendees; 30 minutes)

Spackman, J.A. Nitrogen and Sulfur Management: Improving Fertilizer Efficiency. Heartland Agriculture Chemigation Training. Burley, ID. 10 Jan. 2023. (150 attendees, 120 minutes).

Spackman, J.A. 2022. Nitrogen Management Research in Small Grains. Small Grain Summer Field Day. Idaho Falls, ID. 20 July, 2022. (15 attendees, 15 minutes)

Spackman, J.A. 2022. Nitrogen Management Research in Small Grains. University of Idaho - Limagrain Cereal Seeds Field Day. 19 July, 2022. (100 attendees, 20 minutes).

Spackman, J.A. 2022. Barley Research Program Updates – Fertility Management. Scoular Field Day. Jerome, ID. 28 June, 2022. (52 attendees, 20 minutes).

Spackman, J.A. and J. Bevan. 2022. Nitrogen Management for Cereal Production. Pesticide and Nutrient Management Field Day. Aberdeen, ID. 28 June, 2022. (55 attendees, 20 minutes).

Spackman, J.A. 2022. Nitrogen Management for Cereal Production. Snake River Weed Management and Tour Field Day. Kimberly, ID. 22 June, 2022. (55 attendees, 15 minutes).

Spackman, J.A. and Rogers, C. 2022. Nitrogen and Sulfur Fertilizer Management and Managing Water for Barley Production. Tri-State Grain Growers Convention. Coeur d'Alene, ID. 1 Dec. 2022. (18 attendees, 60 minutes)

Spackman, J.A. 2022. Nitrogen Management: Increasing Fertilizer Efficacy. Valley Ag Agronomists Meeting. Jackpot, NV. 18 Nov. 2022. (60 minutes)

Spackman, J.A. 2022. Nitrogen and Sulfur Fertility Research Updates for Barley and Wheat. Southern Idaho Cereal School. Aberdeen, ID. 2 Feb. 2022. (141 attendees, 30 minutes).

Spackman, J.A. 2021. Fertility Management for Cereal Production. Breeding Class. University of Idaho. Aberdeen, ID. 18 Oct. 2021. (8 attendees, 120 minutes).

Walsh O.S., Spackman J.A., Adjesiwor A.T., Lamichhane R., and E. Owusu Ansah. 2021. Teaming Up to Improve Fertilizer Nitrogen Guidelines for Idaho Wheat and Barley. AgProud - Idaho, Fall 2021

Walsh O.S., Spackman J.A., Adjesiwor A.T., Lamichhane R., and E. Owusu Ansah. 2021. Response to Applied Nitrogen: Getting to Know Idaho Wheat and Barley. Crops & Soils, Fall 2021.