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Nitrogen (N) management is a key management practice impacting the productivity and profitability of hard spring wheat. Wheat growers are paid not only for a crop’s yield, but also for its protein content—factors that are often inversely related and influenced by the rate and application timing of N fertilizer. High rates of pre-season N fertilization are normally attractive to growers due to the reduced cost of the pre-season forms of N and the ease of application.

However, applying high rates of N pre-plant can result in reduced grain protein content because average root-zone N levels and plant N uptake may have declined once the crop reaches the grain filling stage, which is a critical time in determining grain protein.

Additionally, very high early rates of N fertilization may cause excessive vegetative growth and lodging as well as increase N losses to the environment through pathways such as nitrate leaching.

For these reasons, over the past several seasons we have evaluated how the timing

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crops at Dutton (Figure 1). Grain yield was higher after the pea and N-fixing treatments than after the full eight species mix when averaged across the three N treatments.

Protein was higher (more than 1 percentage point) after pea and N-fixing treatments than any of the other CCMs when no N was applied. Soil quality parameters (e.g., soil penetration resistance, potentially mineralizable N (PMN), temperature, soil enzyme activity, Olsen P, etc.) were not different between pea and the full mix after one cycle, but will be measured again after two cycles. In the companion field study, grain yields following CCMs were up to ~15 bu/acre lower than following fallow, likely because of high water and N use by late terminated cover crops (often approaching seed set).

**Long-term trial (Study 3)**

In the first three cycles of no-till LGM-wheat at Bozeman (annual precipitation ~16”), wheat yield was the same between wheat grown after LGM or fallow. However, after four LGM cycles, grain yield at the full N rate was 5 bu/acre higher following LGM than following fallow, and was 16 bu/acre higher following LGM than fallow at the ½ N rate (Figure 2).

Most notably, grain yield was the same following LGM with the ½ N rate (only 5 lb N/ac applied) as following fallow that received 129 lb N/acre. Moist conditions in 2010 were apparently ideal for substantial N release from decomposition of accumulated legume residue. In fact, PMN in April 2010 was 50% higher in the LGM system than the fallow system (O’Dea et al., 2015). From 2009 to 2012, average economic return was similar between fallow-wheat and LGM-wheat at both N rates for both flat and steep protein

![Figure 1. Spring wheat grain yield at Dutton, MT in 2014, averaged across three N rates (0, 60, and 120 lb N/acre) following ten cover crop treatments and a fallow control. Brass-brassica; Fibr- Fibrous rooted. All 8 spp = full mix. If no letters are the same above two bars, then there is more than a 95% chance that the yields are different between those two means.](image1)

![Figure 2. No-till spring wheat grain yield in 2010 following fallow or pea green manure after four cycles for full and ½ available N rates, Bozeman, MT, Study 3.](image2)
Effects of cover crop termination, Continued from pg 2

discounts (Miller et al., 2015). Perhaps more importantly, the range in 4-yr net returns were much narrower for the LGM-wheat system ($378–$441/acre) than for the fallow-wheat system ($303–$477/acre), suggesting LGMs can reduce uncertainty about economic returns without reducing the expected value of those returns.

Management implications

In dry regions of the western U.S., cover crops need to be terminated early (e.g., by first pea bloom) to avoid large yield losses of the following crop, and the cover crop should contain at least 50% legume to enhance subsequent wheat grain protein. At least three cycles of cover crops are needed before they provide economic benefits. Finally, although diverse cover crop mixtures may have some benefits to pollinators or reduced risk of crop failure, they do not appear to increase yield, protein, or soil quality compared to pea in the short term.

Acknowledgments

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References


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of N applications affect the yield and protein content of hard red and white spring wheats grown in diverse California environments. In experiments in the Intermountain Region and the Sacramento Valley we applied N fertilizer in different proportions at four stages of the crop cycle: pre-plant; tillering; late boot/early heading; and at flowering. For a given rate of N application, some treatments received all the N fertilizer pre-plant, whereas others received none until tillering, and still others received a portion at each of 2 or 3 crop growth stages. Urea was the fertilizer used and, for in-season applications, it was broadcast just before rain or irrigation events both to ensure that the N was available in the crop root zone and that volatilization losses were minimized. We compared the grain yield and protein content of the various N rate and timing treatments. We found that crops receiving pre-plant fertilizer application used N less efficiently than crops that received N applications at tillering and later. The reason is that, prior to tillering, the crop has relatively little demand for N. Then, between mid-tillering and the boot stage, the daily demand for N by the crop nearly triples, and this high rate of N demand continues through the flowering stage. Crop biomass is increasing rapidly during this period and grain formation is also occurring.

As a result, N fertilizer applied at tillering and beyond, accompanied by enough water to move it into the root zone and stimulate crop growth and N uptake, results in higher yields and higher grain protein content.

Figure 1 depicts the percentage of the applied N converted into grain as a function of N application timing. This was determined by calculating the difference between the grain N content in the unfertilized versus fertilized plots, expressed as a percentage of the total fertilizer N applied. The highest percentages of N fertilizer recovery by the crop occurred for applications at tillering and at flowering. Although N applied at the late boot/early heading stage was less efficiently used by the crop than N applied at tillering and flowering, applications at this stage were still more effectively recovered by the crop than pre-plant applications of N.

Figure 1. Percentage of N fertilizer recovered in the grain as a function of timing of N application. Data represent averages across experimental sites in the Sacramento Valley and Intermountain Region of California during the 2013-14 season. Patwin, a hard white wheat, was grown at the Sacramento Valley site, which was flood irrigated twice during the growing season. Yecora Rojo, a hard red wheat, was grown at the Intermountain Region site, which was sprinkler irrigated throughout the season.

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Figure 2 shows plants at mid-tillering in two of the experimental treatments at the Intermountain Region site in 2014. Treatment A received all of the N fertilizer as pre-plant application. Treatment B received no N until the day this photo was taken, when it received 80% of its seasonal N; the remaining 20% was applied at flowering. Treatment B yielded 16% more grain than Treatment A and had more than 1 percentage point higher protein, despite its relative N deficiency at the tillering stage of growth.

In the end, because so much more of the N uptake occurred after this stage of growth, the tillering-flowering applications better matched the overall timing of N demand by the crop and allowed it to stage a “come from behind” victory relative to the crop that received all of its N pre-plant.

We should note that the seeding rate used in our experiment was relatively high (120 lb acre\(^{-1}\)). In a situation where seeding rates or plant populations were low and tillering was limited by N deficiency, these results might have been different. In addition, although waiting until tillering to apply N resulted in higher yield and protein content, it may not be wise for growers to completely forgo a pre-plant application.

A small pre-plant application may be beneficial to prolong the window when N can be applied and provide a “cushion” in case weather conditions do not permit an application right at tillering.

The key point is that producers should consider applying more N in-season and less pre-plant to improve yield and protein content. For more information, contact Mark Lundy at melundy@ucanr.edu.

Figure 2. Comparison of Yecora Rojo growth at mid-tillering (5/22/14; 36 DAP) at the Intermountain Region site; 100% of seasonal N application pre-plant (A), and no N application until tillering.
Fall-planted cover crops, Continued from pg 3

fall and spring. Winter hardy cover crops can also be planted as a full-season forage crop. A full-season temporary pasture of winter-hardy cover crops is most economically used to graze multiple times in the summer and fall, leaving residual regrowth for spring.

The cover crop mix selected by producers plays a role in livestock average daily gain or preference as well as soil nutrient benefits. Producers in the west commonly select cover crop mixes comprised of grasses/grains, legumes, and canola. The obvious dual-purpose cover crops are legumes, which fix atmospheric nitrogen, and accumulate nitrogen as protein in the above ground forage. Canola and other brassica species have long taproots and/or horizontal roots that scavenge nutrients deep in the soil profile, primarily nitrogen and phosphorus, preventing nutrients from leaching below the plant root zone. In order to accommodate higher average daily gains, timing of grazing and plant selection is an important component for managing dual-purpose cover crops.

University of Idaho Extension Research: Using a Western Sustainable Agriculture Research &
Education and an NRCS Critical Issues grant, University of Idaho (UI) Extension tested the suitability of fall planted cover crop species for high-desert farming systems. Researchers evaluated yield and forage quality during the fall. A demonstration-grazing period on cover crop plots provided qualitative data on livestock preference.

Dual-Purpose Cover Crop Yield and Forage Quality Results: Forage production in the fall with seven weeks of growth following grain harvest was the highest for hairy vetch/triticale followed by triticale, Austrian win-
Fall-planted cover crop, Continued from pg 6

A Austrian winter pea/triticale, and a canola/triticale mix (Figure 1). Relative feed value (RFV) is a comparison of forage quality to that of full bloom alfalfa (rated as a value of 100); a RFV above 100 is higher quality than a RFV below 100. For comparisons, good quality Idaho alfalfa hay has a RFV of 170 or higher. After seven weeks of fall growth the highest cover crop RFVs were Austrian winter pea (197), hairy vetch (195), and canola/triticale (183; Figure 2).

The RFV is slightly lower for the legume/cereal blends compared to the 100% legumes, but the advantages of the blends are reduced seed cost and increased forage biomass. Overall, the source of feed with 68 days of fall growth provided an economical source of high quality feed during a time, typically associated with fallow fields. Contact Lauren Hunter at lhunter@uidaho.edu for more information.

![Figure 1. Biomass dry matter yield for replicated cover crop species trial in Kimberly, Idaho. Biomass yields were collected on Oct. 9th, 2012. Planting date- Aug. 3rd, 2012.](image1)

![Figure 2. Relative Feed Value (RFV) for replicated cover crop species trial in Kimberly, Idaho. RFV information was collected on October 9th, 2012. Planting date - August 3rd, 2012.](image2)