ALFALFA CONTRIBUTES MORE NITROGEN TO FOLLOWING CROP THAN PREVIOUSLY THOUGHT

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ABSTRACT

Alfalfa in high-yielding environments fixes significant amounts of atmospheric N_2, a portion of which benefits succeeding non-legume crops and reduces fertilizer N requirement by an amount sometimes called the “legume N credit”. Field research-based estimates of the legume N credit in California and other irrigated, semi-arid or arid environments are sparse in the literature. We conducted replicated plot experiments at three field station sites in California using wheat as an indicator crop to assess alfalfa’s N contribution. The wheat was grown with N rates ranging from 0 to 250 lb N ac^{-1} after (1) continuous alfalfa or (2) sudangrass-wheat. As expected, wheat grown without N fertilizer had more dry matter and N uptake (soft dough stage) and higher grain yields and protein content when following alfalfa. Based on the first year of wheat N response data, we estimated the legume N credit at the three sites to range from 80 to 120 lb N ac^{-1}, which was higher than previous estimates in California of 40-80 lb N ac^{-1}.

INTRODUCTION

The legume N credit is an estimate of the amount of nitrogen a legume crop may contribute to subsequent crops. Such N credit values help growers estimate the amount of N fertilizer they can save on crops following the legume compared to following a non-legume (Bundy et al., 1997; Kaiser et al., 2011; Leikam et al., 2007). Legume species, stand vigor, soil, climate, and other location-related factors can affect N contributions, so N credit recommendations are generally determined experimentally, rather than estimated according to some universal factor.

The majority of research on the legume N credit for crops following alfalfa has been conducted under rainfed conditions, where hundreds of site-years of data (Yost et al., 2014) have indicated that N contributions can range from 30 to 75 lb ac^{-1} for seeding year stands (Hesterman et al., 1986; Kelner et al., 1997) and up to 175 lb ac^{-1} for older stands (Harris and Hesterman, 1990; Hesterman et al., 1987).

In irrigated semiarid and arid regions, however, experimental evidence has been comparatively lacking. Some recent work in semiarid Spain has produced estimates of approximately 140 lb ac^{-1} (Ballesta and Lloveras, 2010; Cela et al., 2011). In Idaho, crop rotation research conducted under irrigation found that alfalfa could often supply all the N needs of subsequent crops (Carter et al., 1991).

Compared to rainfed regions, high yielding irrigated regions could have higher N credits due to higher total N_2 fixation, higher yields, and longer growing seasons. Alternatively, they could have lower N credits due to greater N removal or higher temperatures promoting mineralization and losses. These areas can also have very diverse cropping systems with many possible crops in rotation. All of these factors have uncertain effects on alfalfa’s N credit. A recent cooperative extension publication from California recommends an N credit of 40-80 lb N ac^{-1} (Pettygrove and Putnam, 2009), but the recommendation is not based on recent field research.

FIELD STUDY IN CALIFORNIA

To determine the alfalfa N credit, we are conducting field trials at UC field stations in three locations: Tulelake near the California-Oregon border, Davis in the southern Sacramento Valley, and Kearney in the San Joaquin Valley. The chosen locations represent a range of growing conditions under which wheat and alfalfa are commonly grown in California: Tulelake is in the Intermountain region, where the cooler climate means alfalfa is cut fewer times per year than alfalfa growing in the Central Valley. Additionally, Davis and Tulelake have clay loam soils, while Kearney has a sandy loam.

At each location, we grew irrigated wheat in small plots within larger replicated strips that previously had either (1) alfalfa for 2.5+ years or (2) sudangrass-wheat rotation for 1.5+ years[1] before being terminated in the fall[2] of 2013 and planted to wheat shortly after. Neither the alfalfa nor the sudangrass-wheat strips received N fertilizer, but were otherwise grown using standard farming practices.

To determine the effect of the preceding crop (alfalfa vs. sudangrass/wheat) on wheat N requirement, we applied N fertilizer rates to the wheat ranging from 0 to 250 lb N ac^{-1}. Besides N fertilization, the wheat was grown using standard farming practices for the region.

When the wheat reached the soft dough stage, plots were harvested to determine aboveground biomass. Subsamples were taken for determination of plant moisture and N content. At maturity, wheat was harvested, and grain yields, grain moisture content, and grain protein content were determined.

Wheat N response data reported here were collected in 2014. We plan to collect similar data in 2015.

RESULTS AND DISCUSSION

Soil nitrate content

Soil nitrate-N levels (0-12 inch depth) in the fall of 2013 were 5-7 ppm NO_3-N in plots that had just been in alfalfa and 0.5-4 ppm in plots following the sudangrass-wheat rotation. This soil nitrate difference between the two rotations was consistent across the three locations.

Wheat aboveground whole plant biomass and N content

In plots receiving no N fertilizer, wheat whole-plant above-ground biomass was higher following alfalfa than following sudangrass-wheat at all locations (Figure 1), indicating that, as expected, the alfalfa contributed more plant-available soil N than did the sudangrass-wheat rotation. At Davis, Tulelake, and Kearney, wheat following sudangrass-wheat required 100-150 lb N ac^{-1}, 100-150 lb N ac^{-1}, and 50-100 lb N ac^{-1}, respectively, to produce the same amount of biomass as wheat grown without N fertilizer following alfalfa. Additionally, at Davis, wheat biomass following alfalfa was the same regardless of N fertilization levels, indicating that alfalfa likely satisfied a high proportion of the wheat's N needs there.

Indeed, nitrogen uptake data from the wheat biomass suggest that, in plots at Davis

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[1] At Kearney and Tulelake, strips of alfalfa were removed from existing stands and planted to sudangrass to establish sudangrass-wheat rotations. Remaining strips of alfalfa were used for plots of alfalfa for 2.5+ years. At Davis, the sudangrass-wheat rotation was established in a separate field.

[2] Alfalfa and sudangrass were both terminated by tillage before establishment of wheat.

receiving no N fertilizer, wheat following alfalfa assimilated 80 lb ac^{-1} more N than wheat following sudangrass-wheat (Figure 2). In order to sequester this additional 80 lb N ac^{-1}, the wheat following sudangrass-wheat needed about 114 lb N ac^{-1} fertilizer (Figure 2). Similarly, for 0 N plots following alfalfa, 119 lb N ac-1 were required for wheat following sudangrass-wheat at Tulelake to achieve similar levels of N uptake, and at Kearney, 82 lb N ac^{-1} were required.

From these N uptake data, alfalfa's N contribution might range from 80 lb N ac^{-1} at Kearney, up to 120 lb N ac^{-1} at Davis and Tulelake.

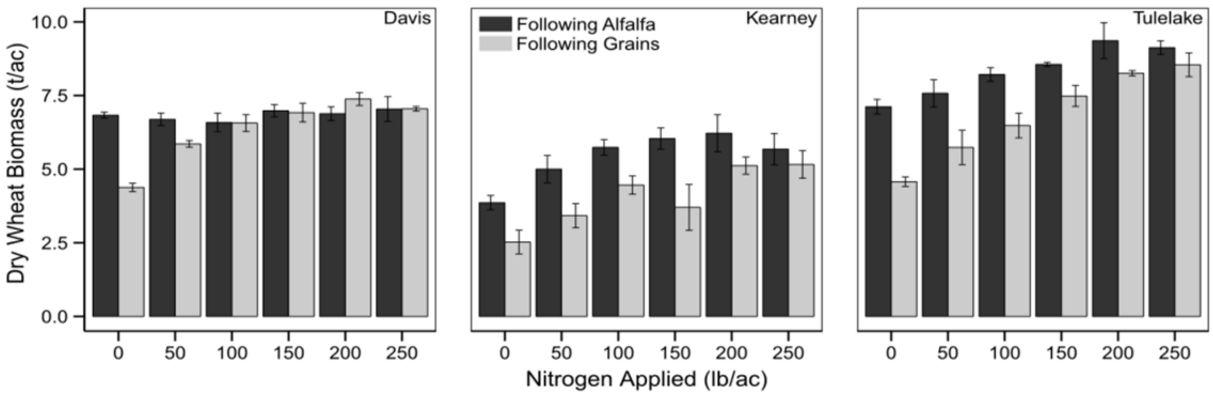

Figure 1. Response of wheat to N rate as affected by previous crop in rotation. Wheat yield expressed as above-ground plant biomass (dry weight) at soft dough stage. Error bars represent standard errors of the mean.

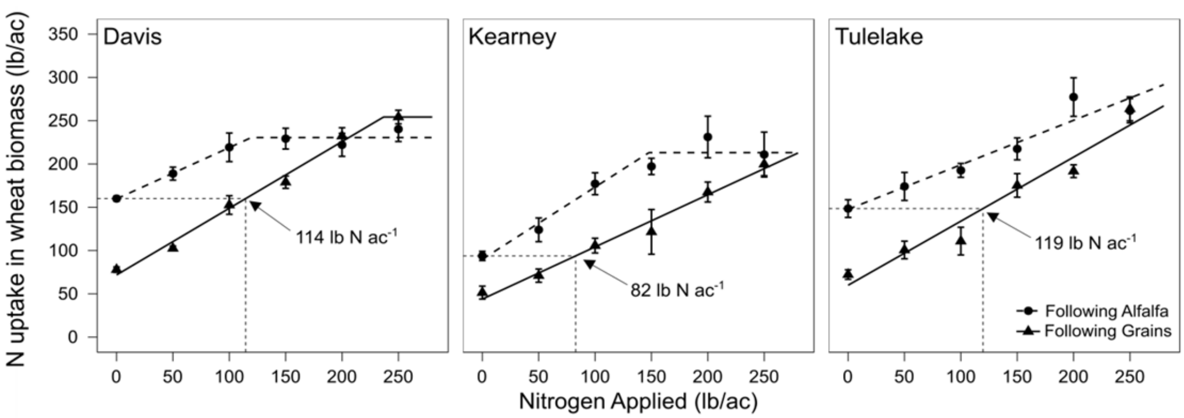

Figure 2. Total nitrogen uptake of wheat grown with 6 N rates after alfalfa and following sudangrass-wheat (grains) at the three locations. Error bars represent standard errors of the mean. Regression curves (dashed and solid lines) represent linear-plateau models. Dotted lines and arrows indicate the amount of fertilizer N required for wheat following sudangrass-wheat to take up the same amount of N as unfertilized wheat following alfalfa.

Wheat grain yield and protein content

Wheat grain yield responses to N in the alfalfa and the sudangrass-wheat were similar to above-ground dry matter yield responses and are not shown here. At Tulelake, grain yields following alfalfa plateaued beyond the 100 lb N ac^{-1} rate, but grain protein continued to increase beyond that N rate (Figure 3).

When supplied with 250 lb N ac^{-1}, wheat following alfalfa at Tulelake had an average protein content of 11.3%, and wheat following sudangrass-wheat had an average content of 9.8%. Interestingly, grain protein content at Tulelake increased more slowly in response to N fertilization when wheat followed the sudangrass-wheat rotation than when wheat followed alfalfa. Previous work has suggested that this difference in responses could be related to differences in timing of N availability to wheat following alfalfa (Hedlin et al., 1957) compared to wheat following sudangrass-wheat.

At Davis, wheat grain protein content exhibited similar responses to N fertilization. Wheat fertilized with 250 lb N ac^{-1} produced an average protein content of 12.9% following alfalfa and an average protein content of 11.9% following sudangrass-wheat. Protein content data for Kearney are not currently available.

N contributions calculated from the grain protein data (using the same method of analysis as for the plant N uptake data) may range between 0 at Tulelake and 150 lb N ac^{-1} at Davis. While these data, like the N uptake data, indicate that the N credit is likely higher than previous estimates of 40-80 lb N ac^{-1} (Pettygrove and Putnam, 2009), they also point to the uncertainty in our estimates and the need for more field data to improve these estimates.

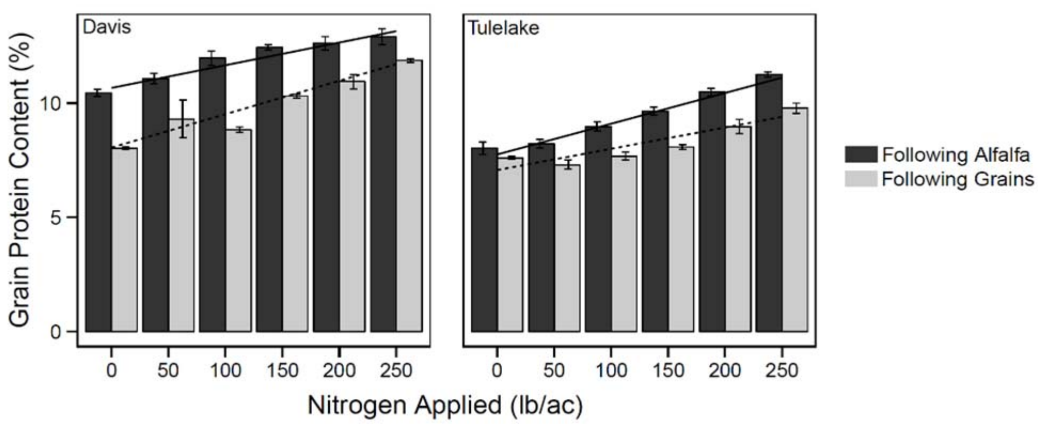

Figure 3. Grain protein content of wheat grown with 6 N rates after alfalfa and after sudangrass-wheat rotation at Davis (top) and Tulelake (bottom). Error bars represent standard errors of the mean.

SUMMARY

This study is in mid-stage and will be completed in 2015-16. Remaining work includes a second year at the same sites for replication of the same treatments and analysis of the N uptake data and N yields under the different rotation and fertilization regimes. In these first-year results, alfalfa's N contribution ranged from about 80 lb N ac^{-1} at Parlier to about 120 lb N ac^{-1} at Davis and Tulelake, but there was evidence of contributions above 120 lb N ac^{-1} at Kearney and Tulelake. These results were higher than expected, but correspond well with results from research in Spain for irrigated plots in a climate similar to California's (Ballesta and Lloveras, 2010; Cela et al., 2011).

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