ALFALFA CONTRIBUTES MORE NITROGEN TO FOLLOWING CROP THAN PREVIOUSLY THOUGHT

Eric Lin, Dan Putnam, Stu Pettygrove, Mark Lundy, Steve Orloff, and Steve Wright[1]

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 wheat N response data, we estimated the legume N credit at the three sites to range from 50 to 125 lb N ac^{-1}, which was higher than previous estimates in California of 40 to 80 lb N ac^{-1}.

Keywords: alfalfa, *Medicago sativa*, wheat, rotation, N credit, N contribution

INTRODUCTION

The legume N credit is an estimate of the amount of nitrogen a legume crop typically contributes to subsequent crops. Such N credit values help growers estimate the amount of N fertilizer they can withhold for 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), 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).

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[1] Eric Lin (ericflin@ucdavis.edu), Graduate Student, Department of Plant Sciences, University of California, Davis, CA; D.H. Putnam (dhputnam@ucdavis.edu), Forage Specialist, University of California, Davis, CA; Stu Pettygrove (gspettygrove@ucdavis.edu), Emeritus CE Specialist in Soils, Department of Land, Air, and Water Resources, University of California, Davis, CA; Mark Lundy (melundy@ucdavis.edu), UCCE Farm Advisor, Colusa-Sutter-Yuba Counties, Colusa, CA; Steve Orloff (sborloff@ucanr.edu), UCCE County Director/Farm Advisor, CE Siskiyou County, Yreka, CA; Steve Wright (sdwright@ucanr.edu), UCCE Farm Advisor, Tulare and Kings Counties, Tulare, CA. **In:** Proceedings, 2015 Western Alfalfa & Forage Symposium, Reno, NV, 2-4, December, 2015. UC Cooperative Extension, Plant Sciences Department, University of California, Davis, CA 95616 (see http://alfalfa.ucdavis.edu for this and other alfalfa conference Proceedings).

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 conducted 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[2] before being terminated in the fall[3] 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.

The experiment was repeated in 2014 in different plots at the same locations.

RESULTS AND DISCUSSION

Soil nitrate content

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

Soil nitrate-N levels (0-12 inch depth) in the fall of 2013 were 5-7 ppm NO_3-N in plots that had

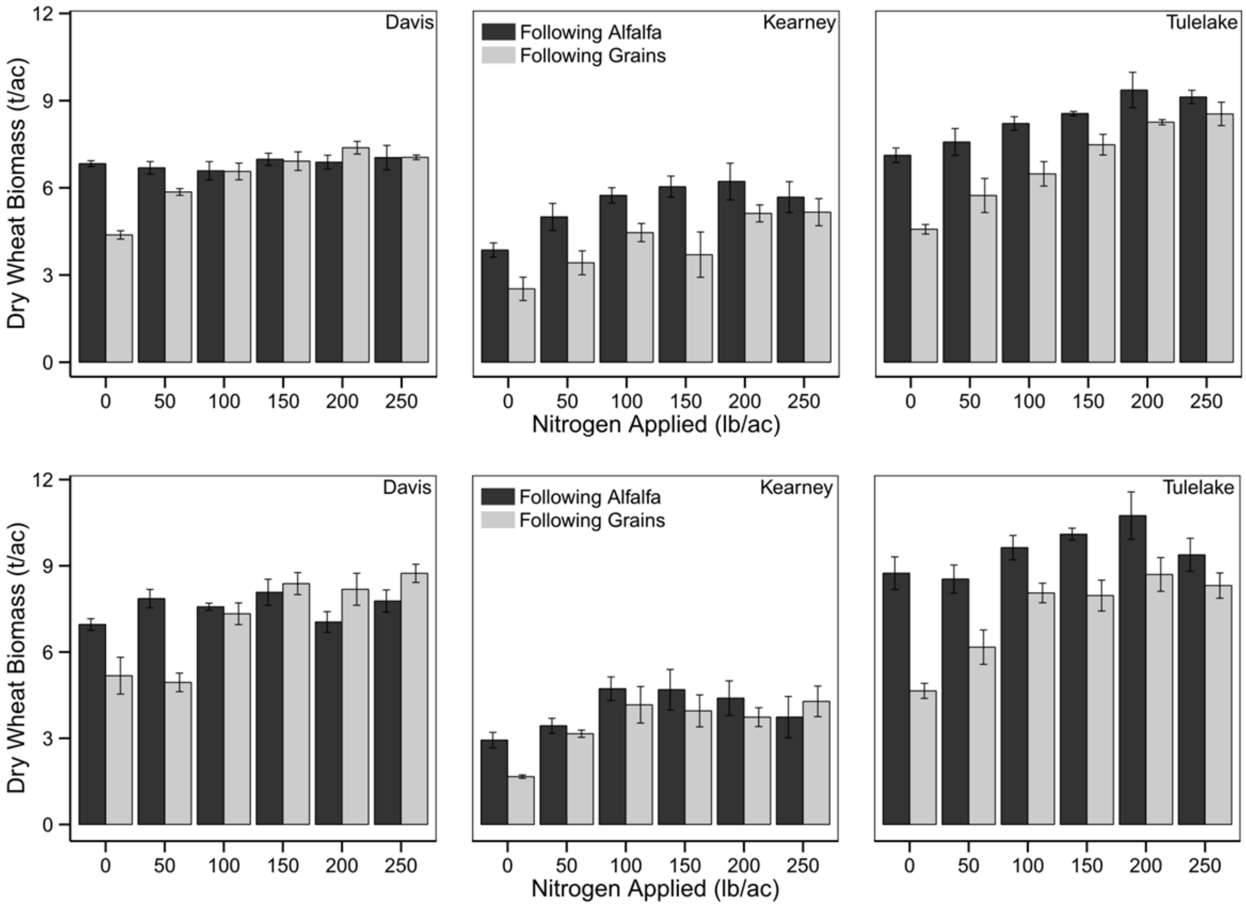

Figure 1. Response of wheat to N rate as affected by previous crop in rotation. Data from fields planted to wheat in 2013 (top) and 2014 (bottom). Wheat yield expressed as above-ground plant biomass (dry weight) at soft dough stage. Error bars represent standard errors of the mean.

just been in alfalfa and 0.5-4 ppm in plots following the sudangrass-wheat rotation. Similar levels were observed in 2014. 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 for all location-years (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 for both years, indicating that alfalfa likely satisfied a high proportion of the wheat's N needs there.

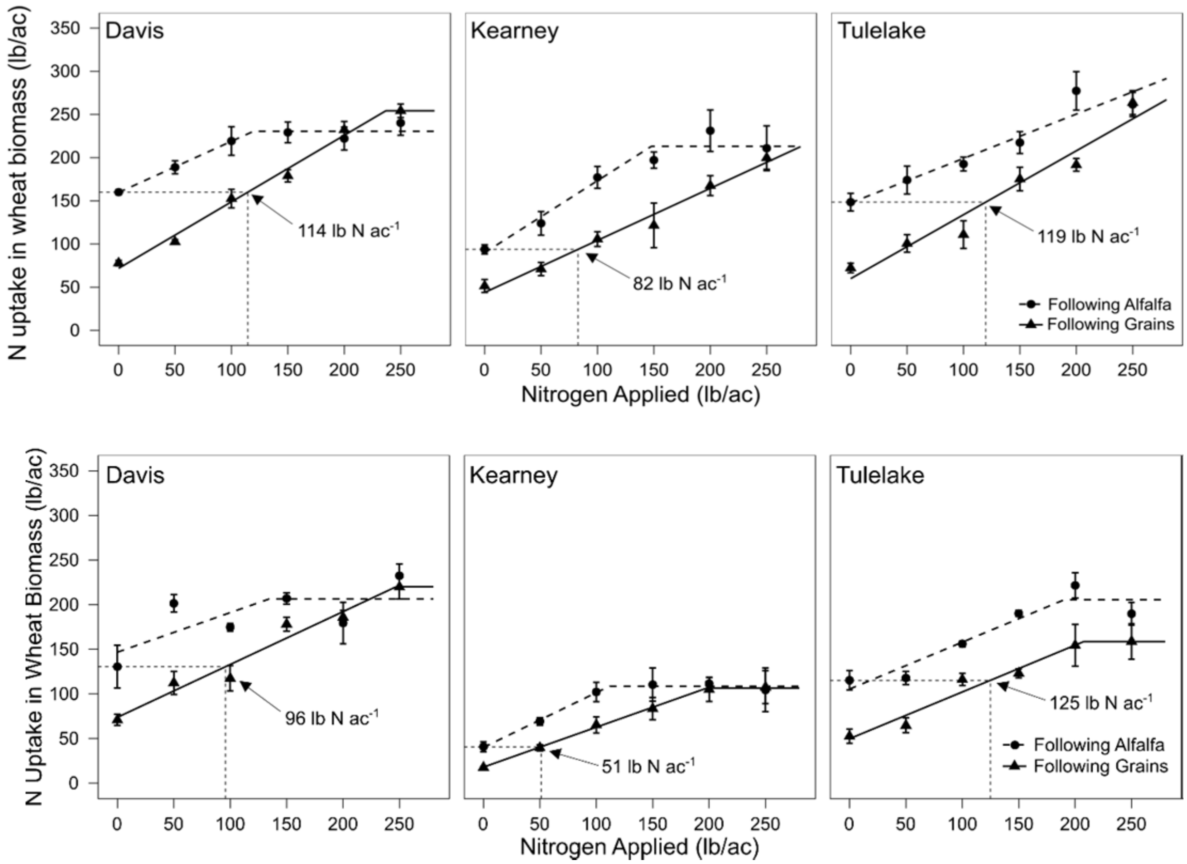

Figure 2. Total nitrogen uptake of wheat grown with 6 N rates after alfalfa and following sudangrass-wheat (grains) at the three locations from fields planted to wheat in 2013 (top) and 2014 (bottom). Error bars represent standard errors of the mean. Regression curves (dashed and solid lines) represent 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.

Indeed, nitrogen uptake data from the wheat biomass suggest that, in plots at Davis receiving no N fertilizer, wheat following alfalfa assimilated 80-100 lb ac^{-1} more N than wheat following sudangrass-wheat (Figure 2). In order to sequester this additional 80-100 lb N ac^{-1}, the wheat following sudangrass-wheat needed about 114 lb N ac^{-1} and 96 lb N ac^{-1} fertilizer in plots planted to wheat in 2013 (Figure 2, top) and 2014 (Figure 2, bottom), respectively. Similarly, for 0 N plots following alfalfa in plots planted to wheat in 2013 and 2014, 119 lb N ac^{-1} and 125 lb N ac^{-1}, respectively, were required for wheat following sudangrass-wheat at Tulelake to achieve similar levels of N uptake, and at Kearney, 82 lb N ac^{-1} and 51 lb N ac^{-1} were required.

From these N uptake data, alfalfa's N contribution to irrigated wheat in a semiarid climate might range from 50 lb N ac^{-1}, as observed at Kearney, up to 125 lb N ac^{-1}, as observed at Tulelake.

CONCLUSIONS

Alfalfa's N contribution ranged from about 50 lb N ac^{-1} at Kearney to about 125 lb N ac^{-1} at Davis and Tulelake, but there was evidence of contributions above 120 lb N ac^{-1} at Tulelake. Calculations using different metrics or different methods could yield slightly different results.

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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