QUANTIFYING N CREDITS OF ALFALFA IN ROTATION

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ABSTRACT

In addition to its value as a forage and soil improver, alfalfa is noteworthy as one of the most effective sources of N credits for succeeding crops in rotations. When fertilizer N is expensive, these credits can add considerable value to an alfalfa rotation. However, quantifying the exact amount of legume N to credit to the next crop is challenging because it is affected by many environmental factors like soil texture, local climate conditions, and soil N mineralization rate, as well as by management factors like stand density, age, or height at termination, time since termination, irrigation, and use of manure. States and commercial soil testing laboratories rarely agree on the amount of N to credit after an alfalfa rotation, with values ranging from 0 to 190 lb/acre. This variability reduces producer confidence in N credits, who then often err on the side of caution and apply more fertilizer N than they need, reducing profitability and increasing N leakage into the environment. This paper will present an overview of the current situation.

Key Words: alfalfa, nitrogen credit, fertility, crop rotation

THE IMPORTANCE OF N CREDITS IN CROP PRODUCTION

Alfalfa is noteworthy as one of the most effective rotation sources of N credits and this increases the value of alfalfa when N prices are high. Nitrogen credit is defined as the fertilizer N replacement value of a rotation crop for the next crop in the sequence. Many, but not all, states and commercial laboratories take this credit into account when making fertilizer application recommendations. Use of legume N credits can considerably enhance the economic value of an alfalfa rotation when fertilizer N prices are high. When fertilizer N is priced at US$1/lb (US$2.20/kg), the greatest N credits from the table can add up to US$240/acre (US$593/ha) saved over two years of succeeding crops.

Yost reviewed hundreds of site years of data for corn following alfalfa (Yost et al., 2012; 2013; 2014a; 2014b; 2014c; 2015) and concluded that alfalfa can usually provide all the N needed by corn grain or silage in the first year after alfalfa, and often makes a large contribution in the second year. An exhaustive review is past the limits of this paper but alfalfa is also documented to provide significant fertilizer replacement value to crops other than corn.

Factors Influencing Soil N Availability after Alfalfa Termination

The amount of alfalfa N that enters the soil is dependent on the total biomass of alfalfa at termination. This is controlled by the stand density and forage mass at termination. Therefore,

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many recommendations for N credits take into account stand density either as crown counts per unit area or simply as estimated percentage of legume. Wisconsin research established 5 crowns/ft^2 (53.8 crowns/m^2) as a threshold density for termination of alfalfa stands so many recommendations focus on this number to evaluate stand density. However, recommendations based solely on stand density or proportion may be misleading because there are many other factors that can influence N credits. Allowing alfalfa top growth to grow back before termination or skipping the last cutting altogether will increase total biomass and N added to soil, assuming that the top growth is incorporated. This also ensures that sufficient top growth is present to absorb herbicide for an effective chemical termination.

Soil texture influences N credits. Nitrogen credits are generally greater on fine- or medium-textured soils than on coarse-textured ones (Yost et al., 2014b).

Age of the alfalfa stand influences N credits but results are inconsistent. Yost et al. (2015) reported that alfalfa stands in Minnesota did not provide enough N to supply the needs of a first-year corn rotation until alfalfa stands were at least three years old, even when the stand density of the younger stands was excellent. In contrast, Fernandez et al. (2019) indicated that one year of alfalfa was enough to provide credits for organic corn.

The timing of N availability is a key factor influencing the usefulness of N credits. When the alfalfa crop is terminated, most of its N is tied up in the plant tissues of leaf, stem, root, and nodules. This N is not available to the next crop until the alfalfa residues have been recycled into mineralizable N by soil microbes. Nitrogen mineralization takes time and is influenced by all factors that enhance soil microbe activity such as soil moisture, temperature/ growing degree days, and C/N ratios (Clark et al., 2020). Moreover, the timing of crop N need must match the rate of N release from the residue. If the N is released before the crop is ready to capture it, it may leach out of the root zone. This is both a financial loss of a valuable nutrient and an environmental cost if the N makes its way into ground water. Nitrogen credits are usually only given to the first year after legume termination but Yost et al. (2014a) demonstrated that alfalfa can sometimes provide significant N to succeeding crops even in the second year after termination, but others have reported that legume N was gone by the second year (Schmidt et al., 1996).

Methodology For Quantifying N Credits

Nitrogen credits are not equivalent to total biological N fixation (BNF). There is much literature quantifying the impressive amounts of BNF that are possible during growth of a leguminous crop and greater BNF undoubtedly provides greater potential N credit than less BNF. However, that nitrogen will not all be available to the succeeding crop due to immobilization and losses, and therefore methods for determining BNF are not appropriate for calculating N credits.

There are three methods commonly used for estimating N credit values: traditional, difference, and soil N tests. The first two were compared by Lory et al. (1995). The traditional approach compares the yield of the crop grown after a legume rotation to a N response curve from the crop grown with fertilizer only to determine the amount of N provided by the rotation. The problem with this approach is that it assumes N is the only benefit provided by the legume. This assumption is not correct because it ignores the simultaneous non-N rotation effects, such as pest control, changes to soil physical properties, improved soil health, improved water retention, and others. By attributing all improvement in subsequent crop yield to N, the traditional method overestimates N credits.

The difference method was developed to discriminate between N and non-N rotation effects (Lory et al., 1995). With this method, N response curves are determined for both the crop grown after legumes and the fertilizer-only crop. The post-legume curve includes both N and non-N rotation effects while the fertilizer-only curve determines pure response to N. The difference in the economic optimum N rate between the two curves is the N credit. Local optimum N recommendations for the fertilizer-only crop may be used if available instead of making a new response curve for the fertilizer-only crop. Economic optimum N rate is defined as the point where marginal N cost equals marginal value of increased crop yield and is therefore dependent on market fluctuations.

Measurement of actual soil N during growth of the post-legume crop seems like a logical approach to quantifying N credits. Sadly, tests like basal stalk nitrate test and pre-sidedress N test have proven to be poor predictors of crop performance after legume rotations (Yost et al., 2013; 2014c), possibly because they only give a snapshot of the moment in time when the soil sample was collected and do not provide amounts or release rates for the reservoir of potentially mineralizable N that is still immobilized in SOM and alfalfa residues. Some soil testing labs are now offering potentially mineralizable N tests that attempt to predict how N might be released from SOM over the growing season. This approach shows promise to provide better estimates of N availability from rotations but it is relatively new. Unfortunately, the predictions are not yet sufficiently validated against real crop performance to be widely incorporated into state fertilizer recommendations.

Producer Confidence in N Credits

Yost et al. (2014c) compared state extension recommendations for N credits in corn following alfalfa across the Midwest. At that time, the main consideration was alfalfa stand density at termination. Since then, little has changed. There is still little agreement across states and most states still do not give N credit past the first year. Some states do not provide any N credit at all. Shifting to the soil test approach instead of book values for N credit will not help producer confidence if the N test results do not lead to predictable corn performance.

The disagreement in recommendations reduces producer confidence in the accuracy of N credits. Producers in Minnesota were more likely to ignore generous N credits than low credits and this resulted in more excess N being applied after good alfalfa stands than after poor ones (Yost et al., 2014c). This probably occurs because producers want to make sure there is enough N and are more willing to err on the side of excess than deficiency. However, this is likely costing them money as well as contributing to nitrate loading of water sources.

WHERE DO WE GO FROM HERE?

In order for producers to believe N credit values, they need to be able to see concrete positive results from adopting them. Current N rate recommendations for corn after corn or soybeans are largely based on data from multiple site-years and frequent updates. We do not have such a database for corn or other crops after alfalfa. We also do not have a clear understanding of all the factors influencing N availability from rotation crops like alfalfa. Disparate state recommendations for N credit and the shift towards non-standardized soil tests for measurable residual N and mineralization rates instead of book values suggest that new coordinated research is needed to assess how test values relate to crop yields.

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