Alfalfa non-feed uses

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Abstract: Non-feed uses for alfalfa such as biomass energy and phytoremediation could increase alfalfa acreage and improve farm profitability. The new bio-energy alfalfa and production system increased forage yield and ethanol production. New alfalfas with enhanced nitrogen cycling capacities would protect water quality and enhance alfalfa's value in crop rotation systems.

Key words: bio-energy, ethanol production, leaf crude protein, nitrate uptake, nitrogen (N) cycling, phytoremediation, symbiotic N_2 fixation

Introduction

Alfalfa plays an essential role in sustainable agriculture. Its perennial growth habit and extensive root system permits the crop to aerate soil, access deep water resources, capture nutrient run-off and mitigate soil erosion. Using alfalfa in rotation interrupts pest and pathogen cycles and through symbiotic N_2 fixation with soil bacteria, provides up to 100% of the N nutrient requirement of the subsequent crop. Non-feed uses are needed to increase and diversify revenue streams for growers and allow alfalfa a greater role in sustainable agricultural systems. New uses include alfalfa as a renewable biomass feedstock that can help meet the energy demands of the future (2), and as an inexpensive and efficient remediation tool to remove sub-soil nitrate from polluted sites (2).

Alfalfa biomass energy system

A biomass energy production system using alfalfa would separate leaves from stems creating two products. The stems would be processed to produce electricity (combustion) or biofuel [ethanol (fermentation) or bio-oil (pyrolysis)], and the leaves would generate a secondary income as valuable protein feed for livestock (Fig. 1). Therefore, the key traits of interest for an alfalfa bio-energy germplasm would include concentrations and seasonal yields of leaf protein, stem biomass, and/or stem cell wall polysaccharides, depending on which the energy conversion platform is being used. Increasing stem yield in alfalfa can be as simple as harvesting forage at a later maturity than early bud, which is typically used in hay production.

An experimental bio-energy alfalfa population was created through selection for large, erect, non-lodging stems when the alfalfa was in bloom. Management protocols have also been modified to (i) reduce population stand density to allow the development of larger crowns and decrease light competition to keep leaves from senescing and (ii) harvest at later maturity stages to maximize both leaf and stem yield. The bio-energy alfalfa under bio-energy management harvested at the green pod maturity stage increased stem yield by 56% and doubled the ethanol yield compared to commercial cultivars grown under standard hay management practices. Leaf crude protein yields were similar between the hay and bio energy production systems for two of three of the site-year combinations (4). In another comparison between the bio-energy and high quality hay cultivars under the two management schemes, stem yields increased 40%, and potential ethanol yield increased between 50% and 97% when harvested at full bloom compared to early bud stage (1). The bio-energy alfalfa under the bio-energy production system shows great potential for helping meet the energy demands of the future.

Phytoremediation

Nitrogen laden ground water is a well documented human health risk and practical remediation methods are needed when over-fertilization of annual crops with inorganic N threatens ground water quality. Although alfalfa can obtain most of the N required for growth through symbiotic N_2 fixation, it is also very effective at removing nitrate-N from the sub-soil (Fig. 1) (2, 5).

At the site of an anhydrous ammonia spill where nitrate-N concentration of the ground water exceeded drinking water standards, a conventional cultivar and an ineffectively nodulated population (incapable of symbiotic N_2 fixation) were irrigated with the N containing ground water for three years. Cumulative N removal from the site was over three times greater by the ineffectively nodulated alfalfa than would be expected with annual cereal grains (5), and soil nitrate-N concentrations were rapidly reduced to low and stable levels. With these results in mind, we successfully created a selection protocol that produced new, contrasting cultivars that can either reduce N losses to ground water by increased nitrate-N uptake capacity, or decrease fertilizer N requirements in production systems through enhanced symbiotic N_2 fixation (3). These new cultivars could strengthen the crop's role in sustainable agriculture by protecting water quality and enhancing its value in crop rotation systems. ■

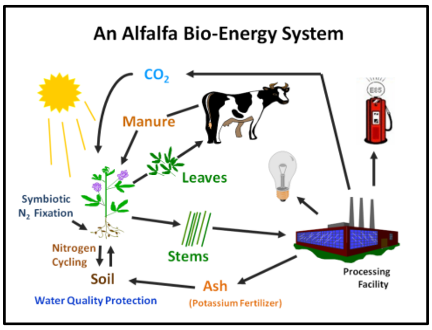

Figure 1. The alfalfa bio-energy system with two product streams, stems for energy and leaves for animal feed as well as value added products with enhanced nutrient cycling

References

(1) Lamb JFS, Sheaffer CC, and Samac, DA (2003) Population density and harvest management effects on leaf and stem yield in alfalfa. Agron J 95:635-641

(2) Lamb JFS, Jung H-JG, Sheaffer CC, Samac DA (2007) Alfalfa leaf protein and stem cell wall polysaccharide yields under hay and biomass management systems. Crop Sci 47:1407-1415

(3) Lamb JFS, Russelle MP, Fenton DM (2008) Field-based selection method creates alfalfa populations that differ in nitrate nitrogen uptake. Crop Sci 48:450-457

(4) Lamb JFS, Jung H-JG, Riday H (2014) Growth environment, harvest management and germplasm impacts on potential ethanol and leaf crude protein yields in alfalfa. Biomass Bioenerg 63:114-125

(5) Russelle MP, Lamb JFS, Montgomery BR, Elsenheimer DW, Miller BS, Vance CP (2001) Alfalfa rapidly remediates excess inorganic nitrogen at a fertilizer spill site. J Environ Qual 30:30-36

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