USDA Agricultural Research Service
U.S. DEPARTMENT OF AGRICULTURE

Adding Legumes to Pastures

U.S. Dairy Forage Research Center

Introduction

The abilities of legumes to fix nitrogen (**N**), increase pasture productivity, and improve forage nutritive value make them highly desirable components of perennial cool-season grazing systems. Maintaining legumes in grazed pastures requires specific management practices, which can be very different from mechanized harvest systems. Why? Potentially, maintaining legumes in mixed species pastures can be complicated by:

- livestock traffic
- preferential consumption of legumes compared to grasses in mixed swards
- competition from grasses
- disease and insect infestations
- N excreted within feces and urine
- limited herbicide options for controlling certain broadleaf weeds, which provide effective control, but also are tolerated by the desirable legumes growing within the pasture

Plant Maturity and Stocking Density

An experiment was established in 2013 in southern Wisconsin to assess the effects of plant maturity and stocking density on pasture productivity, nutritive value, and legume persistence (Zegler et al., 2018). For that specific experiment, several forage establishment procedures are worthy of notable mention. During October 2012, a mixed-species, cool-season grass sod was sprayed with 2,4-dichlorophenoxyacetic acid and clipped to a 2-inch stubble height. Alfalfa, red clover, birdsfoot trefoil, or white clover were overseeded (drilled) into plots during early April 2013 at respective rates of 10, 8, 6, and 3 lbs pure live seed/acre. Two weeks after seeding legumes, meadow fescue was drilled into the same plots in a perpendicular direction at a rate of 10 lbs/acre; this procedural step was included to ensure uniform grass competition across all plots. For the remainder of the establishment year (2013), plots

Adding legumes to grass pastures is generally beneficial to grazing livestock productivity and profitability.

were clipped to a 5½-inch stubble height in June, August, and October. Clipped forage was removed from the plots following each of these plot-maintenance operations. Data were collected during 2014 and 2015 after legume stands were fully established, such that there were no visible gaps in seeded rows. The sod was grazed in factorial combinations of two maturities (vegetative or mature) and two stocking densities (70,000 or 300,000 lbs liveweight/acre) with Holstein dairy heifers (mean weight = 1,000 lbs/heifer). The experiment included mechanical harvests at both maturity levels (vegetative or mature), as well as a grass-only treatment to compare against the overseeded plots.

Generally, overseeding grass pastures with alfalfa or red clover resulted in the greatest seasonal productivity (lbs dry matter (DM)/acre). For 2014 (first year), > 75% of the variation among treatments was related directly to the overseeded legume species. Pasture productivity (Figure 1) was greater for grass plots overseeded with legumes (mean = 7,235 lbs DM/acre) compared to those with grass

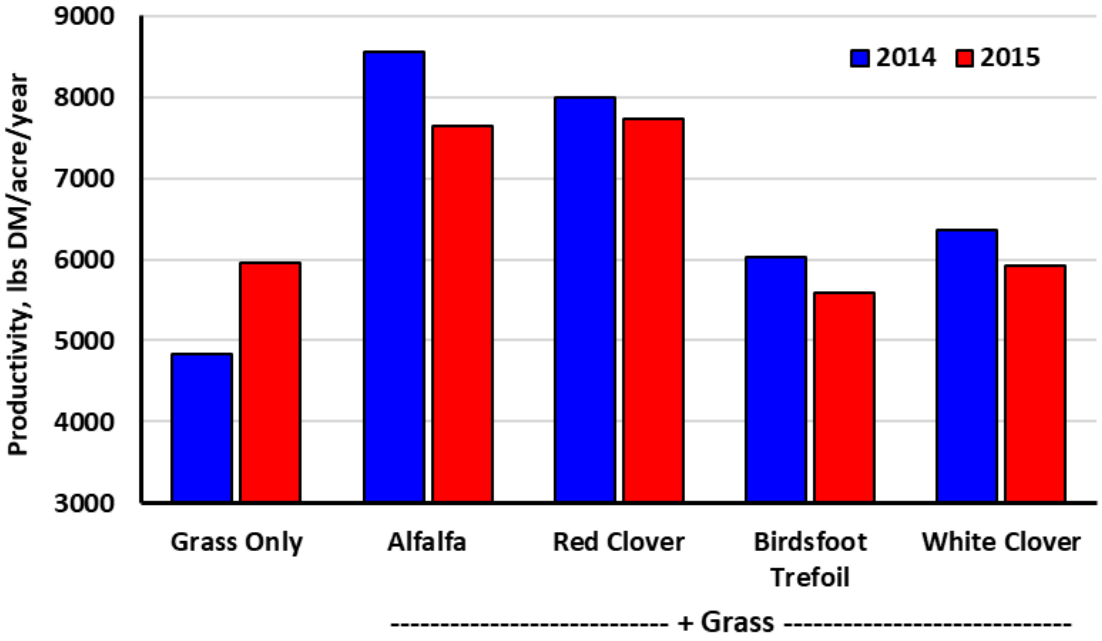

Figure 1. Productivity of grass plots overseeded with legumes during 2014 and 2015 in southern Wisconsin [adapted from Zegler et al. (2018)].

alone (4,831 lbs DM/acre). During 2015 (second year), overseeded legume species accounted for considerably less variation among treatments (31%). However, overall productivities ranked similarly to the previous year, where overseeding with alfalfa or red clover were superior to the other legumes. Three other trends were identified during 2015:

- Productivity was generally greater with grazing or mechanical harvests at the vegetative compared to mature stage of growth (7,185 vs. 5,960 lbs DM/acre; Figures 2 and 3).
- Plots grazed at a vegetative state with high and low stocking rates generally were more productive than plots with mechanical harvest management (8,055 vs. 5,444 lbs DM/acre; Figure 2).
- Grass-only plots grazed by heifers exhibited more than twice as much productivity as those harvested mechanically (7,296 vs. 3,271 lbs DM/acre; Figures 2 and 3).

The large discrepancy between grazed and harvested grass-only plots might be explained by the nutrients deposited via urine and feces in grazed plots, which were not provided for mechanically clipped control plots. This also may have driven the greater productivity in grazed plots overseeded with legumes. Persistence of legumes was also evaluated in the spring of 2015 and 2016 based on legume presence every 2 inches along a fixed transect. Large percentages of the overall variability in persistence (> 73%) were related directly to legume species. These data are presented by year in Figure 4. The decline in persistence for all legumes between the first and second evaluation years illustrates the short-term nature of including these legumes in mixed-species pastures managed under different systems.

Evidence of reduced legume cover was apparent from subsequent laboratory determinations of neutral-detergent fiber (**NDF**), which is typically greater in grasses than legumes. Averaged over all treatments and harvests, the mean NDF in 2014 was 40% compared to 44% in 2015 when legume cover had declined.

At the end of the trial, legume persistence was substantially greater for mechanically clipped plots compared to those grazed at a high stocking density. The reproductive organs of erect, crown-forming legumes, such as alfalfa and red clover were likely damaged by hoof traffic at the high stocking density. Red clover also appeared to be sensitive to hoof traffic at the low stocking density. In contrast, white clover was largely unaffected by hoof traffic, which may be due to its stoloniferous growth habit as well as a positive response to deep light penetration into the canopy following either type of defoliation. The branched nature of shoots in crown-forming birdsfoot trefoil contributed to strong susceptibility

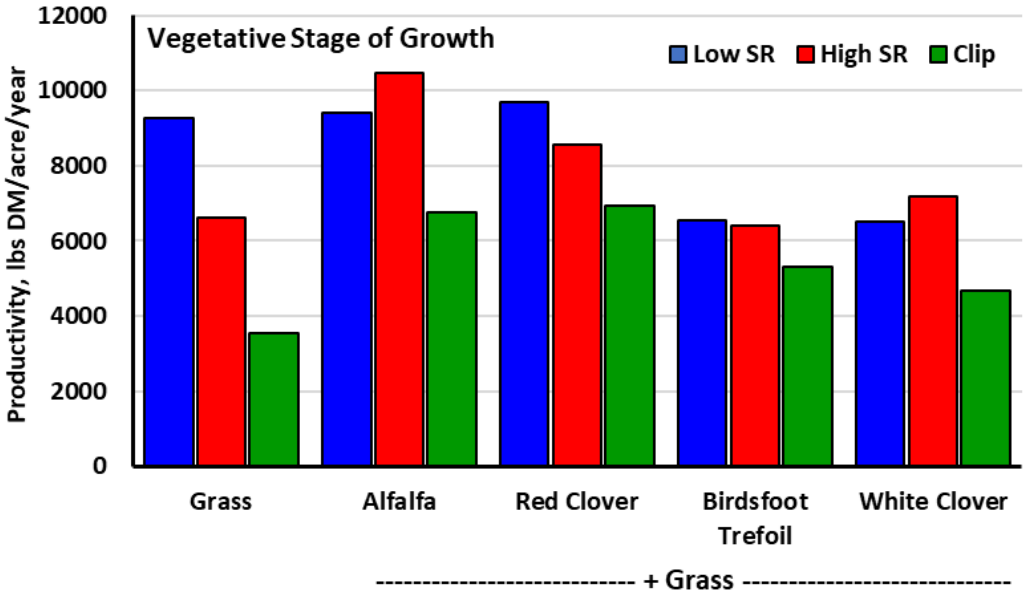

Figure 2. Forage productivity for grass plots overseeded with legumes as affected by defoliation treatment, where Low SR = low stocking rate (70,000 lbs liveweight/acre), High SR = high stocking rate (300,000 lbs liveweight/acre), and Clip = mechanical harvest. Assessments were made at a vegetative stage of growth in 2015 [adapted from Zegler et al. (2018)].

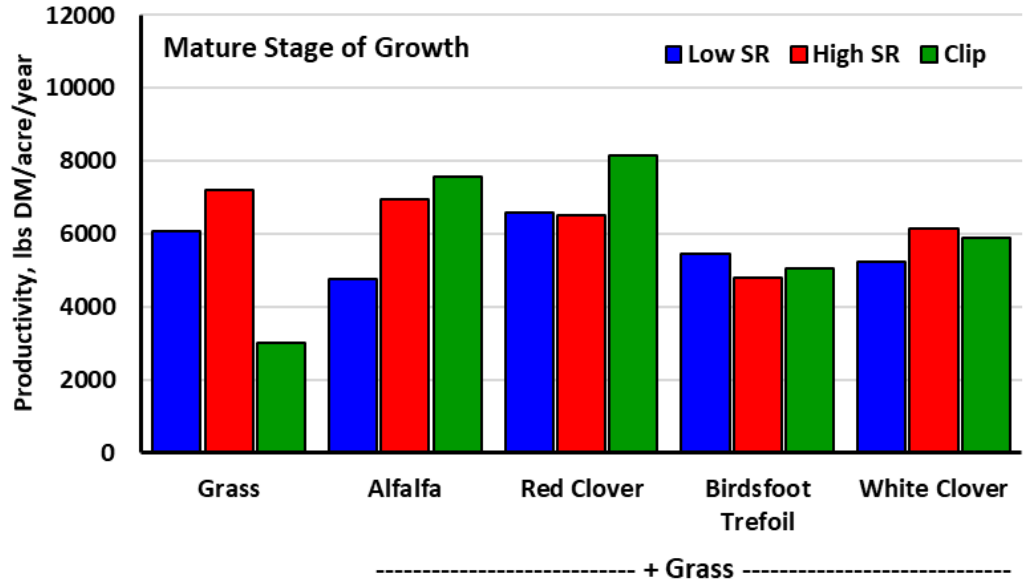

Figure 3. Forage productivity of grass plots overseeded with legumes as affected by defoliation treatment, where Low SR = low stocking rate (70,000 lbs liveweight/acre), High SR = high stocking rate (300,000 lbs liveweight/acre), and Clip = mechanical harvest. Assessments were made at a mature stage of growth in 2015 [adapted from Zegler et al. (2018)].

to both hoof and wheel traffic, resulting in the poorest persistence at the end of the trial (7%) compared to all other overseeded legumes (mean = 45%). Thus, it appears that a high stocking density typically employed in a mob-grazing management system may be particularly problematic for crown-forming legumes, and especially so for birdsfoot trefoil.

Complex Mixtures

Recently, there has been increased interest in using complex species mixtures within grazing programs. Some benefits of this approach include:

- improved production of DM, especially within nutrient-poor grasslands

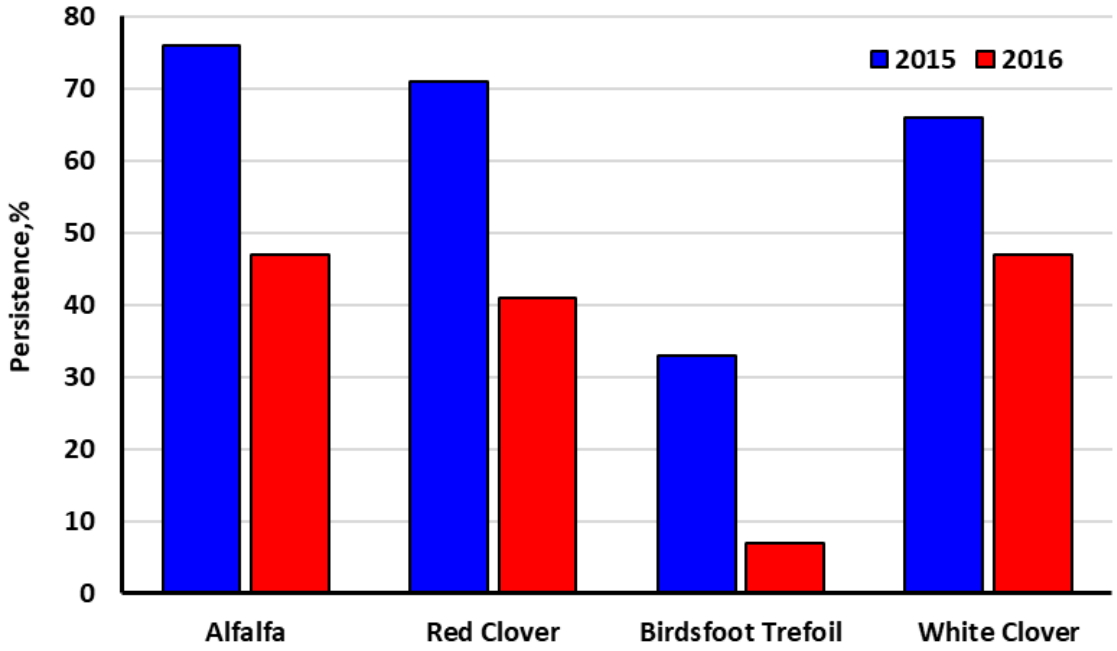

Figure 4. Persistence of legumes overseeded into a grass sod after one (2015) or two (2016) years of grazing or mechanical clipping. Percentages were based on legume intercepts at 2-inch intervals along a fixed transect [adapted from Zegler et al. (2018)].

- less year-to-year variability in forage production
- less pressure from undesirable invasive weeds
- positive symbiotic benefits of N-fixing legumes

However, obtaining these benefits depends on a host of factors, including the relative adaptability of each species to the local environment and producer management. Other work has suggested that differences in forage production are often driven by a dominant species or group of species within the pasture, which can change over time. As a result, perhaps the benefits of biodiversity are best realized in simpler mixtures of species that are well adapted to the livestock enterprise's specific conditions. In other words, it is likely the composition of the mixture, rather than its diversity that regulates differences in forage production and nutritive value.

This discussion begs the question – how much can the nutritive value of mixed-species pastures be improved by adding specific grasses or legumes to the mixture? It would seem the potential for improvement would be more easily realized by adding legumes since there are greater differences between legumes and grasses compared to a within grasses-only approach.

A unique experiment was conducted in both Wisconsin and Pennsylvania (Brink et al., 2015), in which four-species mixtures (two grasses, two legumes) were planted in different proportions to assess the effects of individual species on the nutritive value of mixed-species swards. A complex series of mixtures were planted at 93 pure live seeds/ft^2, ranging from 7 to 15 lbs/acre depending on the assigned proportions of the species within each mixture. Forages were harvested when grasses were vegetative, and legumes were at the late-bud to mid-flower stages of growth.

One conclusion drawn from the work was that species with high nutritive value within a functional group (legumes or grasses) had a disproportionate effect on the overall mixture's nutritive value. Figure 5 is a simplified illustration of this response, where NDF concentrations increased as greater percentages of the seeded mixture were assigned to orchardgrass (and less to white clover). However, this was true only for Year 1 of the trial. Except for the monocultures, NDF concentrations of all mixture combinations were nearly identical in Year 2.

In general, legumes had a negative effect on NDF concentrations, while grasses had the opposite effect. Additionally, white clover and meadow fescue had a positive effect on DM digestibility. Given the stoloniferous nature and low NDF of white clover (Figure 5), this response was not surprising. The positive effect of meadow fescue on digestibility is unusual for grasses, since increasing proportions of

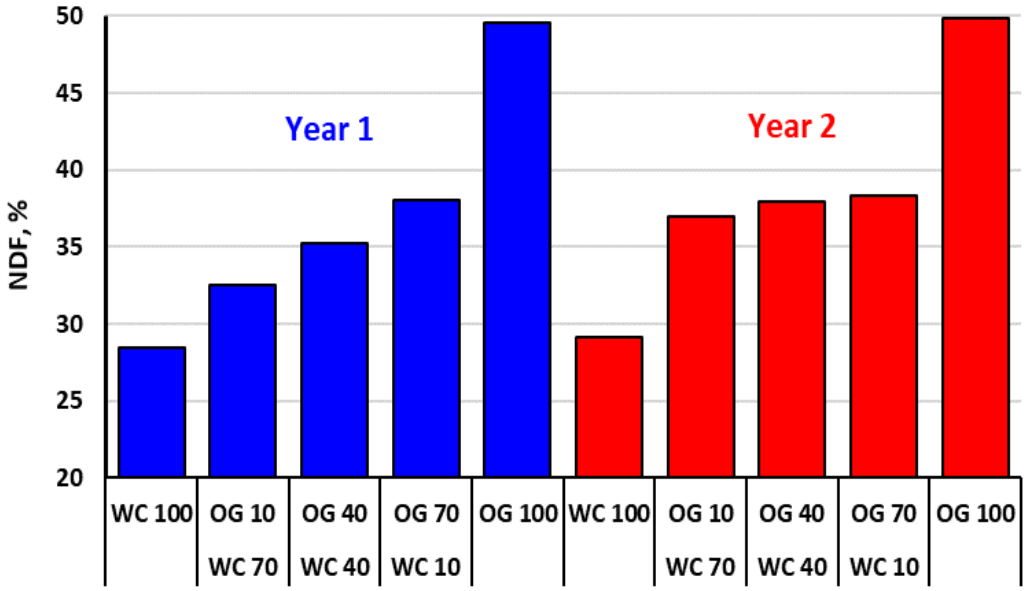

*Figure 5. Concentrations of NDF in forage mixtures including orchardgrass (**OG**) and white clover (**WC**), where the numbers in the x-axis label indicates the percentage of the mixture sown to that species. For mixtures, the remainder of the seed was assigned to equal portions (10%) of quackgrass and alfalfa [adapted from Brink et al. (2015)].*

grass in legume-grass pastures often reduce digestibility. However, similar findings about meadow fescue have been reported in numerous studies throughout the north-central United States. These results suggest that the inclusion of meadow fescue in grass-based pastures is beneficial. Adding legumes generally increased crude protein concentrations within mixtures while grasses had the opposite effect. However, these responses were less consistent than those discussed for NDF and DM digestibility, probably owing (in part) to the vegetative nature of the grasses at the time of harvest.

Nitrogen Fixation by Legumes

It is well known that legumes fix N, some of which is transferred or utilized by grasses growing in mixed-species pastures. The total amount of N fixed by legumes depends on the rate of plant growth, total forage yield, length of the growing season, and grazing or harvesting management (Hancock, 2009).

Factors that negatively affect growth rate include drought, water-logged soils, unfavorable temperatures, low light or shading, poor soil fertility, low soil pH, competition from weeds or other plants, and stresses from disease or insects. As a result, poorly managed or overgrazed pastures that don't allow sufficient time for recovery after defoliation often exhibit poorer N fixation and subsequent transfer of N to adjacently growing grasses. Dr. Dennis Hancock at the University of Georgia (now at US Dairy Forage Research Center, Madison, Wisconsin) has summarized some ranges of N fixation for legumes (Table 1).

Table 1. Annual N fixation by selected legumes used in cool-season grass pastures. The lower end of each range represents an estimate within mixed, grass-legume pastures, where the legume comprises about 25% of the stand. The upper end of the range is consistent with legumes grown in monocultures under excellent growing conditions.[1]

Selected Legume	**N Fixation** *(lbs N/acre/year)*
Alfalfa	50 to 300
Birdsfoot Trefoil	30 to 200
Red Clover	50 to 250
White Clover	30 to 250
Hairy Vetch	50 to 150

[1] *Source: Hancock (2009) https://georgiaforages.caes.uga.edu/species-and-varieties/cool-season/quantity-of-nitrogen-fixed.html.*

University of Wisconsin-Division of Extension materials (Barnett, 2006a, 2006b) suggest that a predominantly cool-season grass pasture with a 30% stand of legumes will contribute 30 to 50 lbs N/acre/year to the grasses in the pasture. Another 15 to 30 lbs N/acre may be obtained from decaying dead plants, feces, and urine, but this depends on animal numbers and grazing frequency. It also is important

to note that additional applications of N fertilizers to mixed legume-grass pastures will frequently shift the species composition away from legumes and toward greater grass representation.

Summary

- Pasture productivity was improved by adding legumes to pastures compared to grasses grown alone.
- When pastures were defoliated at vegetative stages of growth, grazed pastures exhibited greater productivity than those clipped mechanically. Mechanically clipped pastures receive no nutrient returns via feces or urine. This effect was largely absent in legume-grass mixtures when defoliation occurred at more mature stages of growth but remained clearly evident for grass monocultures.
- Legume persistence declined by the second year of evaluation. Reproductive organs of erect, crown-forming legumes may be damaged by grazing regimes, but white clover was less affected, likely due to its stoloniferous growth habit.
- Persistence of legume species evaluated in these studies suggest that legume persistence in mixed, legume-grass pastures is short-term in nature.
- Increasing the proportion of legumes in pastures will tend to depress concentrations of NDF, while grasses tend to increase it. The effects of different seeding proportions of grasses and legumes on pasture nutritive value largely disappear by the second year, but mixtures remain intermediate between grass and legume monocultures in this respect.

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