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GRASS-LEGUME MIXTURES can improve soil health

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Adopting grass-legume systems instead of monoculture systems (only legume or only grass) can improve overall productivity and profitability by reducing production costs and also improve long-term soil health by boosting soil properties and microbial activities.

Forage legumes fix atmospheric nitrogen (N) through the symbiotic association with rhizobium bacteria. Grass-legume mixtures have the potential to improve soil organic matter or soil carbon (C) and N in addition to increased forage productivity and net farm profit. The question is what proportion of grass and legume will be beneficial for improving soil health, in particular soil C and N, under Wyoming conditions.

Our field study from 2011-2014 at the James C. Hageman Sustainable Agriculture Research and Extension Center (SAREC) near Lingle compared soil C and N under different seeding proportions of grass and legume.

This extensive study consisted of 16 treatments with different seeding proportions of two grasses (meadow bromegrass and orchardgrass) and one legume (alfalfa) (Table 1; Figure 1). Each treatment was repeated three times to validate the results. Nitrogen fertilizer was not applied to monoculture legume and grass-legume mixtures, while monoculture grass and two grass mixtures received either no N or 134 pounds N per acre as urea (Table 1).

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Forage harvested as hay is one of the major economic contributors to Wyoming's agricultural economy. According to the Wyoming 2017 Agricultural Statistics, hay contributed 41 percent ($137 million) of the total cash receipts for all crops in Wyoming.

Among different forage species, more than 50 percent of the 1.02 million acres planted for hay production was cultivated with grass, and the remaining was cultivated with alfalfa. Grass hay producers in Wyoming apply a significant amount of nitrogen fertilizers to increase productivity; however, continuous use of chemical fertilizer may degrade soil properties by depleting soil organic matter and deteriorating soil structure.

Table 1. Total nitrogen (N), inorganic N, and mineralizable carbon (C) in soil at the University of Wyoming James C. Hageman Sustainable Agriculture Research and Extension Center, in Lingle, 2014.

Treatments (ALF-MB-OG†)	Total soil N (%)	Inorganic N (ppm§)	Mineralizable C (ppm)
100-0-0	0.13	23.71	12.27
75-25-0	0.13	28.71	10.45
75-0-25	0.12	30.00	9.89
75-12.5-12.5	0.12	25.38	13.29
50-50-0	0.08	17.49	7.90
50-0-50	0.11	27.50	7.71
50-25-25	0.09	20.14	7.81
25-75-0	0.08	19.48	6.14
25-0-75	0.08	19.29	5.70
25-37.5-37.5	0.08	15.11	6.21
0-100-0	0.07	3.46	3.88
0-0-100	0.08	3.26	3.69
0-50-50	0.06	4.27	3.97
0-100-0 + N‡	0.07	5.62	5.07
0-0-100 + N	0.09	5.60	4.94
0-50-50 + N	0.07	4.13	4.78

†ALF = Alfalfa; MB = Meadow bromegrass; OG = Orchardgrass.

‡N = Nitrogen applied at the rate of 134 pounds per acre as urea.

§ppm = parts per million.

Plots were harvested three to four times each year from 2012 to 2014. Soil samples from each plot were collected before applying treatment in September 2011 and at the end of the study in July 2014 and analyzed for total N, inorganic N, and mineralizable C (Figure 2).

Grass-legume effect on total nitrogen, inorganic nitrogen, and mineralizable carbon in soil

There were no variations among the plots for total N, inorganic N, and mineralizable C in soil before applying treatments (data not shown); however, variations were found among the treatments for total N, inorganic N, and mineralizable C in soil at the end of the study after three years of planting (Table 1).

The total soil N was higher from plots with monoculture alfalfa and 75-25 percent mixture of alfalfa and grass than other treatments. The lowest total soil N was in plots with the 50-50 percent mixture of meadow bromegrass and orchardgrass without N.

The plot having 75-25 percent mixture of alfalfa and orchardgrass had the greatest and monoculture orchardgrass without N had the lowest inorganic soil N among the treatments. The mineralizable C in soil was the highest in plots with 75-12.5-12.5 percent mixture of alfalfa-meadow bromegrass-orchardgrass and was the lowest in plots with monoculture orchardgrass without N.

Application of N fertilizer to the grass did not improve total N, inorganic N, and mineralizable C in soil; however, in general, grass-legume mixtures had higher total N, inorganic N, and mineralizable C in soil than monoculture grass plots with or without N.

Figure 1. Study plots showing different seeding proportions of alfalfa and grass at the University of Wyoming James C. Hageman Sustainable Agriculture Research and Extension Center, Lingle.

The inorganic N is the readily available form of N to plant roots, and the amount of soil inorganic N is positively correlated to the mineralization rate and the activity of soil microbes. Mineralizable C, on the other hand, is an active fraction of soil organic C, which breaks down relatively quickly and is an active source of nutrition for soil microbes. The increased mineralizable C in soil also improves mineralization of nutrients and their availability to plants.

The higher total N, inorganic N, and mineralizable C in plots with grass-legume mixtures than N fertilized grass indicates that optimum grass-legume mixtures can improve soil properties and eventually improve forage yield, quality, and profitability.

Figure 2. Soil sample analysis in the laboratory at the University of Wyoming. Nutrients measured included total nitrogen, inorganic nitrogen, and mineralizable carbon.

Summary and Recommendations

Grass-legume mixtures provided improved soil health compared to monoculture grass with or without N. Soils under grass-legume systems had similar total N, mineralizable N, and mineralizable C to soils under alfalfa monoculture.

Overall, grass-legume systems have positive effects on soils:

- The application of N fertilizer to the grass hay production system has little effect for improving soil properties; however, grass-legume mixtures without N fertilizer had great effect on the improvement of total N, inorganic N, and mineralizable C in soil.
- The 50-50 percent mixture of alfalfa and grass performed comparatively well and could be considered for use in Wyoming conditions to improve soil health and forage productivity.

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