Renovation of established switchgrass with forage legumes

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Abstract
Livestock forages, especially legumes, are an integral component of sustainable agriculture. But as farms have changed from diversified, integrated crop-livestock enterprises to highly specialized, intensive cash-grain operations, perennial forages have been drastically reduced in Iowa. As livestock and pasture decrease, the risk of soil erosion and associated nutrient and pesticide runoff increases.

Keywords
Agronomy, Animal management and forage, Soils and agronomy

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Renovation of established switchgrass with forage legumes

Background
Livestock forages, especially legumes, are an integral component of sustainable agriculture. But as farms have changed from diversified, integrated crop-livestock enterprises to highly specialized, intensive cash-grain operations, perennial forages have been drastically reduced in Iowa. As livestock and pasture decrease, the risk of soil erosion and associated nutrient and pesticide runoff increases.

The Conservation Reserve Program (CRP) provided a unique opportunity to reverse this trend. As switchgrass seedings in particular have increased, producers recognize its role in a more sustainable farming operation. To maintain and increase producers' interest in profitable forage-livestock systems, more information is needed on establishing and maintaining productive, nutritious forages. Typically, Iowa forage-livestock producers experience a mid-summer slump in pasture supply because introduced cool-season forage grasses are relatively non-productive during July and August, when temperatures are higher and rainfall is lower. Native, perennial, warm-season prairie grass species (especially switchgrass) offer promise for filling this serious shortfall in pasture supply. These grasses, which are well-adapted to Iowa's soil and climate, are deep-rooted, drought-tolerant, highly productive, and capable of thriving during high summer temperatures.

Previous research has determined that switchgrass is superior in yield and quality of forage, it is relatively easy to establish, it produces seeds prolifically, and mid-summer forage quality is improved by partial early defoliation in early Iowa. However, like any productive grass species, switchgrass has a relatively high need for nitrogen (N). Because producers are reluctant to purchase N fertilizer for grass pasture, and because of concern over extensive N fertilizer use in production agriculture, this project investigated the feasibility of growing switchgrass in combination with legumes. The N contributed by legumes could meet switchgrass's N requirement while minimizing purchased fertilizer inputs.

Because switchgrass vigor is poor at the seeding stage, this project was designed to renovate established switchgrass with legumes rather than seeding legumes and switchgrass together in new stands. Thus, the primary objectives of this project were

1) to identify legumes that are compatible with the vigorous growth of switchgrass,
2) to determine effective methods for successfully establishing and maintaining economic densities of these legumes in established switchgrass, and
3) to measure the impact of legumes on resulting forage yield and quality compared with that for N-fertilized switchgrass.

Cool-season legumes were deemed most appropriate for this study.

Approach and methods
Field studies were conducted at the Agronomy and Agricultural Engineering Research Center near Ames. Three experiments were conducted on Cave-in-rock (cultivar) switchgrass: (1) interseeding, (2) frost-seeding, and (3) interseeding and defoliation management of switchgrass during legume establishment.

Experiments 1 (interseeding) and 2 (frost-seeding): Sites were clipped to an 8-inch (in.) height in the fall before seedings were made the next spring, when they were clipped again to a 2-in. height. Clipped vegetation was removed from the plots. Investigators pro-
ected plots from pests and sampled soil and adjusted rates of potassium and phosphorus on the basis of ISU recommendations for tall warm-season grasses. For the N fertilizer treatments in the studies, ammonium nitrate was topdressed annually before switchgrass growth was visible.

Legume treatments were seeded into established switchgrass and compared with 54,107, and 214 lb/acre N fertilization rates as well as with a non-renovated check plot. Experiment 1 included 11 interseeded legume treatments; Experiment 2 contained six. All legume seed was inoculated with the proper strain of *Rhizobia* bacteria before planting. Investigators used recommended seeding rates; interseedings were made in early April 1991 and 1992 for experiment 1; frost-seedings were made in mid-March 1991 and 1992.

Four 4-feet-square quadrats (small subplots) were identified in each plot to aid in subsequent legume plant density counts and hand harvests of herbage to determine yield. In early June of each seeding year, stand counts were made to determine establishment success; legume persistence was determined by making stand counts again in July and October of each seeding year and in June of the respective second and third years after seedings were made. Because quadrats were abandoned after being hand-harvested at ground level (and thus destroyed), data for legume plant densities were based on four quadrats in June of the seeding year, three in July and October of the seeding year and June of the second year, and one quadrat in June of the third year.

To simulate topgrazing and minimize competition from switchgrass while legumes were getting established, investigators defoliated plots to a 6-in. height in early June of each seeding year and to 4 in. in early June of subsequent years. Herbage yield was determined; subsequent harvests each year were hand-harvested at ground level from within one of the four quadrats. To determine total biomass yield and botanical composition, yet still evaluate the herbage situation above the 8-in. recommended minimum grazing height for switchgrass, workers separated harvested herbage from the upper and lower canopy at an 8-in. lower canopy height.

Quadrat harvests were taken in late July of the seeding years, early July, and again in mid-August of each respective second year and early July of each respective third year. July and August quadrat harvests, made at ground level, were again considered destructive and thus were not used for subsequent measurements. Investigators determined total N (crude protein) concentration and dry matter digestibility (in vitro dry matter disappearance, or IVDMD). Experiments had four replications except the 1991 frost-seeding; it had three.

**Experiment 3:** This study, initiated in 1990 and repeated on a new set of plots in spring 1991, consisted of three replications of a strip-split-plot experiment on which legume renovation treatments were assigned randomly to 3 x 6-ft. subplots and initial defoliation treatments were assigned randomly in 3 x 18 ft. strips across the three legume treatment subplots. Legume treatments consisted of a non-renovated check and two legumes (sweetclover and red clover). Pre-inoculated seed was interseeded in April 1990 and again on a new set of plots in April 1991. Experimental sites were burned before seedings were made.

Six initial spring defoliation treatments of switchgrass were made at different times in June and were used to evaluate the benefit of—and need for—reducing switchgrass canopy competition during legume establishment. Investigators compared a non-defoliated check with 2- to 8-in. defoliation heights in June 1990 and 1991. Switchgrass canopy height at early defoliation was approximately 10 to 12 in. About one-quarter of the 20 most advanced switchgrass tillers (shoots) reached early heading at late defoliation; those legumes that had reached 8 in. were partially clipped with the 4-in. treatment.

Investigators measured legume seedling density (reporting data as plants or stems per 4 sq. ft) after spring defoliation treatments in the seeding year. They harvested the south quadrat of each plot near ground level in late July of the seeding years to determine herbage dry
matter yields (only the north quadrat was later used for legume density counts and overall herbage evaluation). Harvested herbage was separated into grass and legume components and further divided into upper and lower canopy at the 8-in. height; samples were analyzed for herbage quality.

**Findings**

**Stand densities:** In general, excellent legume seedling stand densities were observed about 75 days after seeding, though densities varied both by species and variety (see Fig. 1). These legume stands persisted well from June to October of the seeding year, and from October of the seeding year to June of the second year for first-year seedings, but not for second-year seedings, probably because of severe winter weather (which damaged legume stands throughout Iowa).

Birdsfoot trefoil and mammoth red clover showed very good survival into spring 1993; sweetclover, alfalfa, and medium red clover suffered serious stand reductions during winter 1992-1993. Apollo alfalfa tended to be superior to Alfagraze alfalfa under these unfavorable conditions. Most of the legumes that were interseeded or frost-seeded into established switchgrass achieved adequate stand densities to provide significant contribution to second-year dry matter yield; they should also provide higher herbage quality, improved animal performance, and symbiotic N to associated switchgrass when grown in mixed swards. Partially defoliating established switchgrass in June to minimize competition with legume seedlings during establishment appears unnecessary, at least with the Cave-in-rock cultivar (although it is a useful management practice for improving the quality of switchgrass herbage for mid-summer grazing).

When legume and grass stem densities were determined at harvest time during the establishment year and the second year to evaluate compatibility of the various legumes and switchgrass, neither legume renovation nor N fertilization caused large variation in grass stem density in July of the establishment year. Thus, legume renovation did not reduce grass productivity by that measure; however, stem density varied among the legumes, apparently due to varying establishment success and seedling growth habits of the different legume species. While grass stem density was often somewhat lower for legume renovation treatments compared with the N fertilization treatments in June of the second year, these differences were not serious. In fact, these densities generally increased by July and August of the second year. Investigators concluded that a dynamic relationship exists between legume and grass stem densities in the second year after renovation, but in general the legumes did not appear to cause serious competition to, or reduction in, the contribution made by switchgrass in the mixed legume-grass sward.

**Yields:** Legume renovation did not influence either June or July yields during the establishment year compared to the non-renovated check (see Fig. 2). A yield up to 2.5 times higher for N fertilization compared to the N check and legume renovation during the establishment year suggests that producers can expect immediate yield increases in established switchgrass with N fertilization, but little or no increase can be expected until the second year for legume renovation. In fact, during a reno-

![Fig. 1. (left) Legume seedling densities in June of the establishment year, averaged for 1991 and 1992 interseedings that were made into established switchgrass.](image1)

![Fig. 2. (right) Establishment year upper canopy total-season yields and yield components averaged for 1991 and 1992 N-fertilizer and legume interseeding treatments in established switchgrass.](image2)

(Legend for both: Wsc=white sweetclover, Ysc=yellow sweetclover, Bt1=Norcen birdsfoot trefoil, Bt2=Fergus birdsfoot trefoil, AfUApollo II alfalfa, Af2=Alfagraze alfalfa, Rc1=Mammoth red clover, Rc2=medium red clover, Cvt=crownvetch, Hvt=hairy vetch, B/R=50:50 mixture of Norcen birdsfoot trefoil and medium red clover.)
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(Nota: Herbage quality data from the third year of the project were still being analyzed at press time; this information can be obtained directly from the investigator or by contacting the Leopold Center.)

In the dry matter yield of the herbage, bloat-prevention management would be important for these renovated pastures, especially during early June grazing. In the third year of the project (for the 1991 seedings), seedings were less impressive because the biennial sweetclovers had totally disappeared, and the other legume stands—except birdsfoot trefoil and mammoth red clover—suffered from unusually severe weather. However, impressive yields were still observed for trefoil, mammoth red clover, and Apollo alfalfa in the interseeding study in comparison to yields from heavily fertilized pure switchgrass stands.

In summary, this study has shown that:
- established switchgrass can be successfully renovated with cool-season legumes in mixed swards,
- partial defoliation in early June helps avoid severe grass competition with established legumes and improves mid-summer herbage quality of switchgrass,
- little or no yield benefit occurs for legume renovation during the establishment year,
- legume-renovated switchgrass will outyield switchgrass fertilized with 200 lb/acre N after the establishment year, and
- producers who use this renovation practice should (1) renovate only a portion of their pastures in each of two or more years while maintaining forage supply by N fertilization at the appropriate rate for the remaining non-renovated pasture, (2) select appropriate seeding rates and methods, and (3) choose legumes suited to their specific needs.

**Implications**

By interseeding switchgrass with legumes, producers can partially or totally substitute legume renovation of established switchgrass for costly purchased N fertilizer to maintain productive warm-season switchgrass pastures for summer grazing. This project has demonstrated that legume renovation can extend the forage supply and increase total pasture productivity compared to that for N fertilization. With proper management, the improved herbage quality from legume-grass mixed swards should benefit animal performance, productivity, and profitability.

Because legumes are less persistent than most grasses, the ease of interseeding—and especially frost-seeding, which poses fewer equipment demands and less vegetative competition—allows for periodic re-seeding for a long-term program.

Producers may reap a variety of benefits by renovating switchgrass pastures with forage legumes: the negative impact of a mid-summer slump in forage supply—common with cool-season forage species—will be reduced; switchgrass seedings on CRP land are more likely to be profitably retained when contracts expire; established legume-switchgrass fields will produce higher total yields of quality forage compared to non-fertilized pastures, resulting in better forage quality than that obtained with N-fertilized switchgrass; and a longer grazing season that improves animal performance and/or reduces harvested or purchased feedstuffs may result.

Improving the profitability of livestock operations in this way can help to revitalize the beef cow-cattle industry while adding diversity to Iowa agriculture. The legumes can significantly reduce the high N requirement of grass pastures, and a greater portion of Iowa's landscape would be protected from erosion and water runoff. The environmental benefits would also extend to improved reproductive success and winter survival for wildlife.

Although no warm-season grass constitutes a "total" forage program, switchgrass intermixed with legumes can be an important component of an effective, more environmentally friendly forage program. Future research will use actual grazing studies to further validate the findings of this study.