SECTION FOUR
Other Management Issues

Proper management of native grass forages should take into account several additional issues not covered in the previous chapters. Of particular importance is being prepared to deal with weeds, minimizing their presence and controlling those that do develop. Growers should also be aware of diseases and insects that can impact production. There are also opportunities for improved management of native grasses including use of prescribed fire and enhancing stand diversity through overseeding legumes and/or native forbs. These subjects are addressed in the next four chapters.

CHAPTER FIFTEEN
Weed Control in Established Native Grass Stands

As has been stressed previously, the principles that govern establishment, grazing management and hay production for native grasses are very similar, often identical, to those for managing other forage grasses. Likewise, with weed control the only real difference with native grasses is that, because they are warm-season species, there are some management options you can use that are not available with cool-season species. In comparison to other warm-season perennials, weed control practices are nearly identical. In this chapter, the focus will be on weed control in established stands, those in their second growing season or thereafter. Competition control during the establishment process was addressed in Chapter 6 (pre-planting), Chapter 7 (late winter weeds in association with dormant-season planting and dealing with summer annuals) and Chapter 8 (follow-up during the seedling year).

THE BEST DEFENSE IS A GOOD OFFENSE

The best defense against weeds in native grasses is to not let them get started. Easy to say, harder to do. Nevertheless, **weeds can be minimized by a very simple rule of thumb: keep the grass vigorous**. Having a good offense, that is, a stand of vigorous, thick grass, leaves little room for the weeds to establish and compete. The management practices described in the previous section — maintaining appropriate canopy heights, avoiding excessive hay harvests and applying fertilizer at appropriate rates and times — will enable you to provide your pastures and hayfields with that "good offense." Therefore, the priority

Figure 15.1. With good management, native grass pastures and hayfields can remain productive and have minimal weed pressure.

for weed management in native grasses must be to focus on good grass management (Figure 15.1).

This is also a good place to reemphasize the importance of good establishment practices. Stands that develop quickly during the seedling year, have high plant density and achieve closed canopies early in the process will have fewer problems with weeds than those that develop slowly or are poorly stocked. Thin stands with large gaps leave a wide-open opportunity for weeds to become established and persist. If you did have poor establishment success, consider implementing some of the recommendations in Chapter 9 for thickening your stand.

TOOLS FOR WEED CONTROL

There are several tools — the same ones that can be used in most pastures and hayfields regardless of the forage species in question — that can be used when weed problems do arise. These include, in order of increasing cost: grazing, haying, burning, clipping and herbicides. With all of these tools, the issue of thresholds for implementing control measures within native grass stands needs to be considered. With relatively low weed pressure, the incentive for intervention may not be great as the weeds may have only limited impact on the stand (Figure 15.2). However, ignoring the problem early on can lead to heavier infestations requiring more substantial control measures with greater associated costs. Thus, use of the less expensive and simpler tools early on can yield dividends by keeping weed pressure limited. On the other hand, it is worth being reminded that weeds can never be completely eliminated. Thus, weed control is really an issue of balance, of managing weeds not eradicating them.

Figure 15.2. Scattered weeds such as seen in this pasture are not reducing growth or productivity of the native grasses. Under such circumstances, no weed control is warranted. However, it is important to monitor such fields and be prepared to take timely action to prevent the problem from becoming much more serious and control much more expensive.

Grazing

The first tool you should think of using to manage weeds is your cattle. They are the tool that causes you the least work, costs almost nothing and has the potential to even make money for you. Appropriate timing and intensity of grazing can be very important in suppressing various weeds. Consider johnsongrass as an example. This aggressive species can become prevalent in native grass stands. However, if grazed early in the season when palatable, cattle can keep enough pressure on johnsongrass to keep it from becoming a serious problem. On the other hand, I have seen cattle refuse johnsongrass that has become stemmy and is beginning to develop seedheads (Figure 15.3). Timing is also important for using grazing to suppress broadleaf weeds. Many of these

Figure 15.3. Johnsongrass can be a substantial competitor in native grass stands. In this field, the johnsongrass is seriously impacting the native grasses and must be controlled quickly before it begins to develop seedheads (a). However, it can be easily controlled through grazing so long as the plants are not allowed to become mature (b) and are no longer palatable for cattle.

species can actually be good forages with solid nutritive value if grazed at early stages of plant maturity. For example, CP in ragweed can be as much as 18 percent in early summer. Another example is prickly lettuce, a species that cattle readily graze at early stages of plant maturity. Of course, there are a number of broadleaf species that cattle do not readily graze, but these could be mob grazed to suppress them somewhat and remove flowers or seedheads that have not fully developed. Cool-season species, such as tall fescue, can encroach on dormant warm-season grasses, reducing their productivity (Figure 15.4). And, as mentioned in Chapter 13, because many such species can be good forages, especially early in the season, grazing should be the first step in keeping them from becoming a more serious problem. Heavy stocking of encroaching cool-season grasses in early spring, prior to the emergence of the warm-season grasses, will provide good suppression as well as additional grazing days on what are typically good forages. Based on these examples, it should be clear that simply adjusting the **timing of grazing**

Figure 15.4. Cool-season grasses can easily encroach on dormant warm-season grass stands. Note the green areas evident following this early spring prescribed burn. These are patches of cool-season grasses, including tall fescue. The competition resulting from the presence of these cool-season species can lead to delayed growth and reduced productivity of the warm-season grasses. Early spring, before the warm-season species are actively growing, is an excellent time to control these weeds.

entries into a native grass pasture can be effective in addressing numerous weed issues and at virtually no additional cost.

Haying

As is the case with grazing, timing of hay harvests can be used to reduce weed pressure. Trade-offs between quality and yield are always a part of timing for hay harvests. Introducing weed suppression into this equation may alter timing, but as with grazing, does not increase direct costs. The goal for such timing adjustments is removal of any aggressive canopy that may interfere with the growth of the native grasses and/or prevention of any weeds from producing viable seed.

Burning

Prescribed fire can be an effective tool for weed suppression. Properly timed fires can destroy existing weeds, weed seed in the thatch layer or close to the ground surface and increase the competitive position of the native grasses. Timing and application of prescribed fire for native grasses is addressed in further detail in Chapter 17. As with the other tools mentioned below, burning requires some outlay of time, equipment and labor but does not directly produce revenue. However, burning has been shown to increase pasture productivity and, therefore, can provide an indirect improvement in revenue.

Clipping

Clipping also represents an additional cost to your operation, but nevertheless can be used similarly to hay harvests to help suppress weeds. Perhaps the most important distinction is that clipping can be used at stages of stand development when a hay harvest is not imminent and weeds must be removed from the canopy. For example, early in the growing season if cool-season weeds are impacting stand growth, clipping as high as possible to minimize amount of leaf surface area removed from the native grasses themselves can be effective. Similarly, late in the summer if fall weeds are creating a problem, clipping could be a good alternative.

HERBICIDES

Herbicides have become a widely used tool for forage management over the past half-century and can be quite effective when used properly. Recommended herbicides, formulations and other information for controlling weeds in native grasses are listed in Table 15.1. Unlike grazing and haying, they are a weed control tool that requires a direct cash outlay and, therefore, are often the most expensive option. On the other hand, herbicides will kill the entire plant, even prevent additional germination of weed seed in some cases, whereas the other tools simply suppress weeds temporarily by removing a large part of the growing plants. This needs to be considered when evaluating the overall cost of this tool. Before discussing use of herbicides for particular weed problems, it may be of benefit to reflect on two key issues and to address a third issue often raised by producers regarding herbicides. Each of these issues is addressed below.

Herbicide stewardship

Everyone who uses herbicides has a responsibility, ethically and legally, to ensure they are properly used. This includes reading and being familiar with all label instructions *before* applying any herbicides. **Follow all label instructions when applying herbicides. Be aware of grazing and/or hay harvest restrictions** (Table 15.2). Accurate weed identification and proper timing and application rates are all essential to effectively control weeds with herbicides. Also, do not rely on just one herbicide over a period of years for weed control as some weeds may develop resistance to that herbicide. Instead, utilize best management cultural practices (grazing, haying and fertilization, as described above) along with rotating herbicides over a period of years for the most consistent long-term weed control.

Spray timing

Timing of herbicide applications is critical to achieve successful weed control. Most weeds are more effectively controlled when they are young and in early developmental stages. Cool-season annuals are normally an issue in late winter/early spring and need to be treated then, preferably before they flower. Cool-season perennials may be treated during spring but are more effectively controlled in fall. Warm-season annuals are best controlled during late spring or early summer. Warm-season perennials are best controlled during early summer (as seedlings) or late summer/early fall if they are already established. In all cases, weeds should be actively growing and not under stress, such as during a period of drought, to ensure effective control.

Toxicity

The issue of herbicide toxicity is being raised more and more in recent years. **Modern herbicides are safe when used properly. These chemicals have very limited direct toxicity and the volume of active ingredient applied on a per acre basis is extremely low**. As an example, table salt has about 4.4 times more toxicity to mammals than triclopyr, a widely used herbicide in pasture management. The maximum labeled rate you can apply for this herbicide, 1.5 pounds active ingredient per acre, works out to be 0.0003 ounces at the scale of a normal 10-inch dinner plate—or about 1/88th of the amount of salt in one of those small white packets you get at restaurants (0.026 ounces). So, when you pour one of those small packets on your meal at the next picnic, just remember that you are putting out a substance that is 4.4 times more toxic and at 88 times the rate (88 × 4.4 = 388 times more toxic) of this herbicide! And that herbicide will only be applied once every few years versus the daily use of that salt. By the way, because many herbicides, including triclopyr are, based on their chemistry, actually salt compounds, this comparison is all the more appropriate.

Herbicides for specific weed control issues

In established (second year or after) native grass stands, most broadleaf weeds will be controlled readily with herbicides that contain active ingredients such as 2,4-D, dicamba (e.g., Weedmaster®), metsulfuron

(Cimarron Plus®) and aminopyralid (e.g., GrazonNext HL®) products. For some grass weeds (e.g., annual foxtails, broadleaf signal grass, vasseygrass), another option is imazapic-based products (Plateau® or Panoramic®)—but not for switchgrass, which will be damaged by imazapic. If johnsongrass needs to be controlled—a problem more likely to develop in a hay production setting rather than in pastures—that can be accomplished with imazapic or, for switchgrass, with sulfosulfuron (OutRider®). Woody plants can be controlled with products containing triclopyr (e.g., PastureGard®), picloram (Grazon P+D®), or

What about glyphosate?

In recent years, the widely used non-selective herbicide glyphosate has received a good deal of attention in the press, mainly focused on its potential as a carcinogen. This concern has been based on a 2015 report from the International Agency for Research on Cancer (IARC) that classified glyphosate as a "probable carcinogen." It is worth noting, though, that same report (monographs.iarc.fr/list-of-classifications-volumes) included red meat and late-night work shifts as probable carcinogens and that all alcoholic beverages and sunlight were even more dangerous, classified as "known carcinogens". Two recent reports, one published in 2017 (www.epa.gov/pesticides/epa-releases-draft-risk-assessments-glyphosate) and the other in 2019 (www.epa.gov/newsreleases/epa-takes-next-step-review-process-herbicide-glyphosate-reaffirms-no-risk-public-health), both concluded that glyphosate is not, in fact, carcinogenic. Indeed, to date there are no published scientific studies that have demonstrated a direct link between glyphosate and cancer in humans. Nevertheless, as with all herbicides, glyphosate products should be used with care and label instructions followed to prevent human exposure.

aminopyrailds (Chaparral®). These are just general suggestions; it is essential that you check the herbicide label for the legal recommendations for herbicide application in your state.

With the warm-season native grasses, the dormant season provides another opportunity to control weeds. Once the native grasses have become completely dormant, non-selective herbicides such as glyphosate can be used without any concern for damaging the stand. Dormant-season sprays can be useful for controlling encroaching cool-season grasses (e.g., bromes, bluegrass, tall fescue, orchardgrass) that can weaken native grass stands through excessive competition during spring. Fall and spring are also excellent times for controlling weeds such as thistles and plantains.

Spraying glyphosate after dormancy break in the spring (typically about April 1 in the Mid-South) can injure the native grasses. However, switchgrass has a remarkably high tolerance to glyphosate in the spring and treatment with a low rate (one quart per acre) can be used following the initial break in spring dormancy without injury (Figure 15.5). Later applications, after mid-May, increase the risk of injury to the grasses and, as a result, could suppress forage production. To a lesser extent eastern gamagrass and big bluestem are also tolerant to spring applications of glyphosate.

Common bermudagrass cannot be easily controlled in a native grass stand and can become a serious problem. Cattle prefer the native grasses and, because they do not graze bermudagrass within native pastures, it will continue to spread. Common bermudagrass provides lower rates of gain than native grasses, is less drought tolerant and offers no advantages in terms of stocking rates. Like any other weed, keeping it from getting started is the best strategy. Keeping it out of the stand with good establishment practices and maintenance of vigorous native grasses are the best approaches. In addition, there are some management alternatives that can give native grasses a greater competitive advantage. First, reduced nitrogen inputs favor the less nutrient-demanding native grasses. Secondly, allowing the taller native grasses to grow up for a full

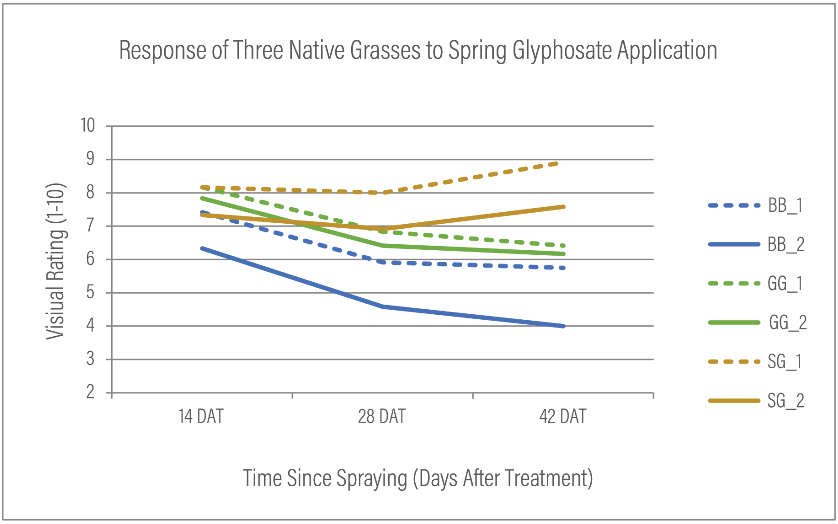

Figure 15.5. Application of one and two quart per acre rates of a glyphosate herbicide product during spring on three native grass species. Treatments occurred between April 12 and June 3 over two springs for big bluestem (BB), Eastern gamagrass (GG) and switchgrass (SG). Visual ratings were taken of sprayed stands at 14, 28 and 42 days after treatment (DAT). University of Tennessee, unpublished data.

season can help suppress the bermudagrass through shading. In terms of herbicides, there are two options, neither of which is completely satisfactory. First, a spring application of a high rate of imazapic can suppress the bermudagrass. The application should be timed shortly after the bermudagrass has begun spring growth. Second, you can implement spot control before the problem gets worse. Two to three applications of a high rate of glyphosate at approximately four-week intervals will eliminate these patches. A final alternative is spot spraying imazapyr herbicides at moderate rates (i.e., 32-48 oz. per acre). This material has shown nearly 90 percent control with a single application and 100 percent when applied two years in a row[5; 16]. Although this product can be used on big and little bluestem and indiangrass, it is not clear if it is safe to use on eastern gamagrass. Switchgrass may show modest injury at the higher rates.

Because switchgrass is such a vigorous species, it typically does not develop as many weed problems as some of the other native grasses. I have seen switchgrass pastures that are 10 years old or older that have had no weed control since the establishment year and have remained largely weed free (Figure 15.6). Because of the shorter growth form of bluestems, weeds can become more easily established. Similarly, eastern gamagrass stands, because of the large size of individual plants, can have fairly open stands that become weedy more easily.

Figure 15.6. This lowland switchgrass stand is an example of the ability of this forage to maintain clean, productive stands for many years without any interventions for weed control. At the time this picture was taken, the stand was 21 years old and had never been sprayed.

SUMMARY

With good forage management that maintains thick, vigorous stands, most weed problems can be avoided. Where weeds do become a problem, all of the same tools that have proven effective in managing weeds in other pastures and hayfields can be used with native grasses. These include grazing, hay harvest, clipping, prescribed fire and use of herbicides. When used in a timely manner, these tools can help ensure that a native grass stand remains productive for decades.

Table 15.1. Herbicides for use on native warm-season grass pastures and hayfields. Check product labels to determine appropriate application rate for your particular circumstances. Application rates will vary depending on stage of plant maturity, degree of competition and the stage of your native warm-season grass development (continued through page 317).

Native grass Species	Safe for Seedlings?	Trade Name	Active ingredient	Application
All	established stands only, dormant	Gramaxone 2SL	paraquat (2.0 lbs./ gal ai)	postemergence
All	established stands only, dormant	Roundup Weathermax and others	glyphosate (5.5 lbs./ gal ai)	postemergence
All	greater than 4-leaf stage only	2,4-D Amine 4L	2,4-D (3.8 lbs./gal ai)	postemergence
All	greater than 4-leaf stage only	2,4-D Ester 4EC	2,4-D (3.8 lbs./gal ai)	postemergence
All	greater than 4-leaf stage only	Weedmaster/ Brash/ Range Star	dicamba (1 lbs./gal ai) + 2,4-D amine (2.9 lbs./gal ai)	postemergence
All	well-established seedlings only	GrazonNext HL	aminopyralid (0.41 lbs./ gal ai) + 2,4-D amine (3.33 lbs./gal)	postemergence with residual reemergence activity
All	well-established seedlings only	DuraCor	aminopyralid (0.667 lbs./gal ai) + florpyrauxifen-benzyl (0.067 lbs./gal ai)	postemergence with residual reemergence activity
All	post-tillering only	Grazon P+D	picloram (0.5 lbs./gal ai) + 2,4-D (2.0 lbs./ gal ai)	postemergence
All	greater than 4-leaf stage only	Surmount	picloram (1.2 lbs./gal ai) + fluroxypyr (1.0 lbs./gal ai)	postemergence
All	post-tillering only	Crossbow	triclopyr (1 lb./gal ai) + 2,4-D ester (2 lbs./gal)	postemergence
All	post-tillering only	Remedy Ultra 4EC	triclopyr (4 lbs./gal ai)	postemergence
All	post-tillering only	Redeem R&P	triclopyr (2.25 lbs./ gal) + clopyralid (0.75 lbs./gal)	postemergence

Reseeding interval	Surfactant	Comments
none	nonionic or crop oil concentrate	Use to control annual weeds when established native warm-season grasses are dormant.
none	check individual formulations	Use to control annual and perennial weeds including cool-season grasses such as tall fescue and orchardgrass when native warm-season grasses are dormant.
two weeks per pint plant back interval	nonionic	Use to control broadleaf weeds when seedlings are well-established or in native warm-season grass stands two years old or older. Less volatile than ester 2,4-D.
two weeks per pint plant back interval	nonionic	Use to control broadleaf weeds when seedlings are well-established or in native warm-season grass stands two years old or older. More volatile than amine 2,4-D.
10 days per pint plant back interval	nonionic only	Use to control broadleaf weeds when seedlings are well-established or in native warm-season grass stands two years old or older. Generally more effective than 2,4-D alone.
up to four months	nonionic	Use to control broadleaf weeds when seedlings are well-established or in native warm-season grass stands two years old or older. Legumes may require one year or more before planting on treated sites.
45 days	nonionic	Use to control broadleaf weeds when seedlings are well-established or in native warm-season grass stands two years old or older. Legumes may require one year or more before planting on treated sites.
up to 60 days	nonionic only	Restricted use pesticide. Use for broadleaf weed control when seedlings are well-established or in native warm-season grass stands two years old or older.
three weeks for grasses, up to 12 months for legumes	nonionic	Restricted use pesticide. Use for woody brush and broadleaf weed control when seedlings are well-established or in native warm-season grass stands two years old or older.
three weeks for grasses	none	Use for woody brush and broadleaf weed control when seedlings are well-established or in native warm-season grass stands two years old or older.
three weeks for grasses	nonionic or crop oil concentrate	Use for woody brush control when seedlings are well-established or in native warm-season grass stands two years old or older.
14 days	nonionic	Use for woody brush control when seedlings are well-established or in native warm-season grass stands two years old or older. Do not transfer animals from treated areas to areas with sensitive crops without a 7-day interval.

Native grass Species	Safe for Seedlings?	Trade Name	Active ingredient	Application
All	post-tillering only	PastureGard HL	triclopyr (1.5 lbs./gal) + fluroxypyr (0.5 lbs./gal)	postemergence
Big bluestem, Little bluestem, Indiangrass, Switchgrass	established (second year stands) only	Cimarron Plus	metsulfuron (48% by weight) + chlorsulfuron (15% by weight)	postemergence or preplant
Big bluestem. Indiangrass, Little bluestem, Eastern gamagrass	established stands only	Journey	imazapic (0.75 lbs./gal) + glyphosate (1.5 lbs./gal)	preplant and postemergence
Big bluestem, Little bluestem, Indiangrass, Switchgrass	greater than 4-leaf stage only	OutRider 75 DF, Maverick 75 DF	sulfosulfuron (75% by weight)	postemergence
Big bluestem, Indiangrass, Little bluestem, Eastern gamagrass	greater than 4-leaf stage only	Plateau, Panoramic 2SL	imazapic (2.0 lbs./gal)	preplant and postemergence
Big bluestem, Little bluestem, Indiangrass, Switchgrass	established stands only	Arsenal	imazapyr (2.0 lbs./gal a.i)	postemergence

	Reseeding interval	Surfactant	Comments
	three weeks	nonionic	Use for woody brush control when seedlings are well-established or in native warm-season grass stands two years old or older.
	seven days	nonionic or crop oil concentrate	Use to control broadleaf weeds in native warm-season grass stands two years old or older.
	except for switchgrass, none for native warm-season grass	nonionic or methylated seed oil	Provides control of a number of broadleaf and grass competitors including crabgrass, foxtail, johnsongrass, fall panic grass, broadleaf signal grass.
	14 days	nonionic	Alternative for johnsongrass control in switchgrass. Avoid use for other native grasses due to grazing restrictions.
	except for switchgrass, none for native warm-season grass	nonionic or methylated seed oil	Provides control of a number of broadleaf and grass competitors including crabgrass, foxtail, johnsongrass, fall panic grass, broadleaf signal grass.
	up to 12 months	nonionic	For spot treatment of bermudagrass; do not treat more than 1/10 of pasture. Do not apply more than 0.75 lbs. (40 oz.) per acre per year.

Table 15.2. Grazing, haying and slaughter restrictions for herbicides used for weed control in native warm-season grass pastures and hayfields.

	Beef cattle, non-lactating dairy, other livestock		
Trade Name	**Grazing**	**Hay harvest**	**Slaughter**
Gramoxone 2SL	None listed	None listed	None listed
Roundup and others	none in established pastures	none in established pastures	none in established pastures
2,4-D Amine 4	None listed	30 days	3 days
2,4-D Ester 4EC	None listed	30 days	3 days
Weedmaster	None listed	37 days	30 days
GrazonNext HL	None	7 days	None
DuraCor	None	14 days	None
Grazon P+D	None	30 days	3 days
Surmount	None	None	3 days
Remedy Ultra	None	14 days	3 days
Redeem R&P	None	14 days	3 days
Crossbow	None	14 days	None
PastureGard HL	None	14 days	3 days
Cimarron Plus	None	None	None
Journey	None	14 days	None
Arsenal	None	7 days	None
OutRider 75 DF, Maverick 75 DF	None	7 days	None listed
Plateau, Panoramic 2SL	None	14 days	None

Lactating dairy cattle			
Grazing	**Hay harvest**	**Slaughter**	**Comments**
None listed	None listed	None listed	
none in established pastures	none in established pastures	none in established pastures	
7 days	30 days	3 days	
7 days	30 days	3 days	
7 days	37 days	30 days	
None	None	None	graze at least three days on non-treated pasture before moving onto areas with sensitive broadleaf crops due to transfer through urine and/or manure
None	14 days	None	graze at least three days on non-treated pasture before moving onto areas with sensitive broadleaf crops due to transfer through urine and/or manure
7 days	30 days	3 days	
14 days	14 days	3 days	remove animals from treated hay or pasture three days prior to slaughter
Following growing-season	14 days	3 days	remove animals from treated hay or pasture three days prior to slaughter
Following growing-season	Following growing-season	3 days	remove animals from treated hay or pasture three days prior to slaughter
Following growing-season	14 days	3 days	
Following growing-season	14 days	3 days	remove animals from treated hay or pasture three days prior to slaughter
None	None	None	
None	14 days	None	
None	7 days	None	
One year	One year	None listed	
None	14 days	None	

CHAPTER SIXTEEN

Diseases and Insects

Native grasses have very few important pests, perhaps because they are native to the eastern U.S. and, therefore, adapted to the region's pathogens and insects. Nevertheless, there are diseases and insects associated with native grasses. These pests include fungi, viruses and insects and are described further below. Fortunately, few of them cause substantial problems in terms of production.

FUNGI

There have been at least 100 pests identified with big bluestem and 50 associated with little bluestem, most of which were fungi[3]. Switchgrass has had more than 42 species of fungus identified on it[8]. Perhaps the most important fungal pathogen on the native grasses are rusts (*Puccinia* spp) (Figure 16.1). In the Mid-South, rusts seem to be most

Figure 16.1. Rust on a switchgrass leaf (a) and in a stand of eastern gamagrass (b). Credit (a), M. Windham.

consistently a problem with eastern gamagrass. And as is the case with most diseases that affect native grasses, there appears to be some difference in the degree to which various cultivars are susceptible. Rusts also occur on switchgrass but are more often a problem in the northern and northeastern U.S. with that species.

Unfortunately, little is known about how the life cycle of the rusts on switchgrass (or other native grasses) actually works. Typically, there is an alternate host, but with *Puccinia* rusts we have not been able to confirm that cycle. Because there is no way to influence the occurrence of rust in native grasses, the only management option is to remove the infected foliage as soon as possible to prevent its further spread. Once the infected area has been cut, the rust will die because it requires living tissue as a host. Rust infections are windborne and spread northward in spring but do not affect native grasses until after they are actively growing. Therefore, early spring prescribed burns are not effective for rust control. However, overwintering rust teliospores have been found as far north as Knoxville, Tennessee, and those would be destroyed by an early spring fire. Plants infected with rust will experience reduced yield, seed production and forage quality due to damaged leaf tissue, but do not otherwise impact grazing animals. Hay made from infected leaves can be fed without any negative health implications — it will simply be a lower quality hay because of the damage to the harvested leaves.

Another common fungal pest is leaf spot (*Phyllosticota, Ascochyta*, *Phoma* and *Bipolaris genra*), which afflicts big and little bluestems, indiangrass and switchgrass[3; 17; 23]. Although these are unsightly, they rarely have a substantial impact on productivity (Figure 16.2). As is the case with rust though, leaf spot infections, if severe, can negatively impact forage quality.

Smuts of the genera *Sphaceolotheca*, *Tolyposporella* and *Tilletia* can be a serious problem on big bluestem, indiangrass and switchgrass, respectively[3; 17; 23]. As is the case with rust, smuts tend to be more of a problem in the northern portions of the eastern U.S. They can have a substantial impact on seed crops (Figure 16.3). Depending on

Figure 16.2. Gray leafspot on crabgrass leaves. Leaf spot on switchgrass has a similar appearance. Credit, A. Windham.

Figure 16.3. Smut on a switchgrass seedhead. Smut can cause substantial damage to seed crops. Credit, M. Windham.

the severity of the infection, an entire seed crop can be lost and plant biomass yield can be suppressed as well. In most cases though, infections are less severe and the impact is much less serious.

Take-all root rot (*Gaeumannomyces graminis*) occurs in many grasses including eastern gamagrass. This disease causes yellowing of leaves and dieback of foliage. It is usually associated with stressful conditions such as drought or overgrazing and is most apparent in late summer (Figure 16.4). While I have not observed plant mortality resulting from take-all root rot, it clearly stresses individual plants, substantially reducing yield and forage quality of those plants.

Figure 16.4. During late summer, take-all root rot can become a problem such as seen here on this eastern gamagrass plant, lower left and left. Note also that nearby plants (immediate right of infected plant) can remain unaffected.

VIRUSES AND BACTERIA

Panicum mosaic virus (PMV) is a disease that infects switchgrass causing yellow spots, streaks and, in later stages of infection, a mosaic on leaves. Characteristically, leaves will die beginning from the tip downward. A small proportion of infected plants will die from this disease within a year or two of infection[23]. Fortunately, most released cultivars of switchgrass appear to have some resistance to PMV and, in any case, it is not a common problem. Similarly, maize dwarf mosaic virus and sugarcane mosaic virus have both been documented on eastern gamagrass.

Eastern gamagrass can be infected by bacterial leaf spot[20]. Such infections often lead to subsequent fungal infections that can make the impact greater to forage production. As is the case with the various fungal leaf spots mentioned above, leaf tissue and therefore forage quality can be degraded by such infections.

INSECTS

Grasshoppers will feed on native grasses, but only in cases of large infestations does this become an issue. Leafhoppers, seed midges, aphids and leafminers have also been documented feeding on native grasses but no impact to production or stand vigor has been documented. Eastern gamagrass is susceptible to damage from corn borers and maize billbugs[20]. In some cases, feeding by these pests can lead to reduced vigor and seed production of infested plants. Stem-boring caterpillars have been reported on switchgrass in the Corn Belt[18]. Nematodes feed on the roots of many plants including native grasses but as is the case with some of the other plant-feeding organisms, impacts to plant vigor and yield are not well documented.

During establishment of native grasses insects may cause damage to developing seedlings. This has been noted in Virginia when competing vegetation has been killed and alternative food sources for insects are limited[26]. A specific problem has been the corn flea beetle which can damage or kill seedlings when they are still small and have not yet developed perennial structures. The primary host for this species within pasture settings is horsenettle (Figure 16.5). Where it persists in fields undergoing pasture renovation, the flea beetle may remain active and depredate the new native grass seedlings. If the problem were to be severe, treating the field with a malathion or permethrin insecticide may be warranted. However, such instances are rare.

Figure 16.5. The Corn flea beetle (a) can cause considerable damage to grass leaves, particularly when those plants are small seedlings with limited leaf area (b). Credit (a) ©Blackthorn Arable, (b) S. Stewart.

TOXINS

As mentioned in Chapters 1 and 6, switchgrass contains saponins, a compound that is toxic to horses and small ruminants but not cattle[23]. Saponins are found in many species of the genus *Panicum*. The compound occurs in both lowland and upland cultivars, in stems as well as leaves. The amount of saponins in leaves, though, is about five or more times greater than in stem tissue[15]. It is not known whether there is a time of year or stage of plant maturity during which concentrations within any particular plant part are elevated or reduced. Likewise, impacts from management practices such as harvesting, fertilizing or prescribed burning on saponin levels in switchgrass have not been studied. It is also not known how long a susceptible animal would have to graze switchgrass or at what concentration of the diet (i.e., mixed stands versus pure stands) to induce health problems. Although data are currently limited on how severe the problems can be, the symptoms include photosensitization (a form of dermatitis) and liver damage. In the case of the liver damage, some horse and lamb mortality has been associated with saponins ingested from grazing switchgrass[14; 23]. On the other hand, in a feeding trial with horses, goats and sheep in which the animals were fed switchgrass hay for 90 days, none developed liver problems and only the goats showed signs of photosensitization[21]. Regardless, based on our current knowledge of this issue, **switchgrass should not be used as a feed source for small ruminants or horses.**

As described in Chapter 3, the native grasses being addressed in this book do not have any other meaningful problems with toxicity for grazing livestock. The concentrations of prussic acid in indiangrass are low, only exceeding thresholds for toxicity early in spring at a stage of development when the grass is too short to graze, less than 8 inches tall, and only then in pure stands[17]. Regardless, no case of prussic acid toxicity has ever been documented in cattle grazing indiangrass.

SUMMARY

Numerous species of fungi, virus, bacteria, insects and nematodes have been identified on native grasses. However, few cause serious problems. The biggest problems are caused by fungi, especially rusts and smuts. Insects are commonly associated with native grasses, but to date none have proven to be serious pests with the possible exception of flea beetles during switchgrass establishment. In terms of toxins, the only concern is with switchgrass due to the presence of saponins. Little is known about how saponins are affected by a number of factors related to stand management, plant maturity or under what circumstances they are most likely to induce health problems for horses or small ruminants. However, it is not recommended to use switchgrass as a forage for these livestock species. Cattle are not affected by saponins so switchgrass can be readily used for cattle forage.

CHAPTER SEVENTEEN

Prescribed Fire

As described in Chapter 2, the warm-season grasses native to North America and the grasslands which they dominate have been maintained for millennia by fire. **Fire is part of the natural history of these species and, not surprisingly, they respond extremely well to burning**. Native Americans took advantage of this and used fire for thousands of years to improve range for bison and other game. To this day, ranchers in many parts of the country continue to use fire as a tool to manage native grasses (Figure 17.1). Land managers with a focus on conservation also use fire for managing native grasses because of its ability to enhance wildlife habitat and maintain healthy grasslands.

An important corollary question that may come to mind is whether the use of fire is really necessary in the management of native grasses. The simple answer is no. **Native grasses can be managed for years, even decades without fire and still remain very productive** (Figure 17.2). To the extent you are able or willing to use this tool to manage

Figure 17.1. Early spring prescribed fires such as was used on this mixed bluestem and indiangrass pasture result in vigorous forage growth that produces large volumes of high quality forage. For this reason, fire has been used for generations by cattle producers to manage native grasses. Credit, K. Brazil.

Figure 17.2. Despite the benefits of prescribed fire, native grasses can remain productive and provide high quality pasture for many years without burning. This 10-year old pasture is quite productive and has never been burned.

native grass pastures or hayfields, you should take advantage of it. If you cannot or prefer not to use this tool, you can still maintain productive, high quality forages using these species.

WHY USE FIRE TO MANAGE NATIVE GRASSES?

There are several reasons that ranchers burn native grasses, many of which have been mentioned in preceding chapters. These include weed suppression (Chapters 8, 9 and 15), improved seed yield (Chapter 9) and improved growth and forage quality (Chapters 9 and 10). Why does fire have these benefits? The quick answer is because fire destroys, releases and warms. Let's deal with each in more detail.

A prescribed fire contributes to competition control by destroying two things, weeds that are currently alive and exposed seed. Exposed seed refers to seed which is in the thatch layer, on top of the ground or within the soil but very near the surface. However, it is important to understand that perennial weeds, grasses or forbs and established woody plants are not normally killed by fire. Rather, fire will typically only destroy the above-ground portion of such plants. So, for example, if you have blackberry bushes in a pasture, fire will destroy the existing above-ground growth, but not the root stock. And because the root system survives, the plant will quickly grow back. Most prescribed fires do not (and should not) get hot enough to raise temperatures deep enough into the ground to be lethal to the rootstocks of perennial plants. Just below the surface, however, fires can be hot enough to reach temperatures that will kill small (less than 1.5 inch groundline diameter) hardwoods such as sweetgum or cherry. Such fires are effective because the root collars of these small trees are near the soil surface.

Another direct result of fire is that it releases nutrients bound up in the litter layer. It also releases the nutrients within living plant parts, but in those cases, because such living parts are often close to 90 percent water, the amount of nutrients released are not necessarily great. Conversely, litter accumulation can be substantial, as much as 4.0-4.5 tons per acre in undisturbed prairie[13; 25:148] and, therefore, the amount of nutrients that can be released can also be substantial. Based on estimates from Tallgrass Prairie in Kansas, the amount may be between 9 and 36 pounds of N per acre with the higher amounts reflecting losses in prairies that had not been burned in several years that had greater litter loads[2]. The two most important nutrients released in a burn are nitrogen and phosphorous, both essential to plant growth. Regardless, because almost all of the stored N and P in grasslands is belowground, the impact is negligible (see Chapter 22). And, in fact, the stimulation of growth of the grasses actually results in greater amounts of N taken up from those belowground sources resulting in improved forage quality (Table 17.1). It is important to recognize though that this boost in forage quality is short-term, lasting only about 6-8 weeks following the fire.

Table 17.1. Changes in big bluestem plants as a result of burning. Values are the percent increase in burned versus unburned big bluestem for each plant characteristic. These plant responses underscore why native grasses are considered to be "fire-adapted." Adapted from Knapp et al., 1998.

Plant characteristic	Increase (%)
Leaf N-content	41
Net photosynthesis rate	48
Shoot mass	223
Tiller density	110
Leaf Area Index	49

Finally, fire benefits native grasses because it warms the soil, not directly, but indirectly, by removing thatch and vegetation that then enables more solar radiation to reach the soil surface. Another factor that allows for increased soil temperatures is the blackened soil surface that absorbs heat from the sun. Soils on burned sites can be as much as 15-20 F warmer within the top 4 inches of the soil than on unburned sites[2]. These warmer temperatures translate into, on average, a two week earlier start on spring growth, which adds up to a longer growing season and increased yields (Figure 17.3). But there is another very important result of this increased solar radiation. Native grass rhizomes are close to the soil surface and they are stimulated by this increased sunshine to produce a large crop of new tillers. The rapid growth of these tillers also has an indirect effect on competition control. Given that the natives are perennials, they are in a position to respond rapidly to this increased solar radiation and growing space. In turn, these rapidly closing grass canopies can suppress weed growth (Figure 17.4). This increase in light

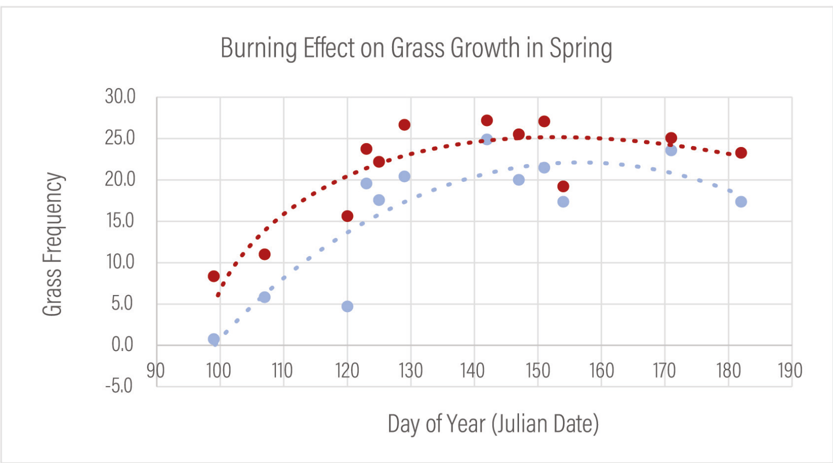

Figure 17.3. Comparison of grass emergence in native range in response to spring burning. Burning (red dots and line) led to greater grass cover (as measured by plant frequency) compared to unburned sites (blue dots and line). Burned grasses reached 10 percent frequency about 10 days sooner, 15 percent frequency about 13 days sooner and 20 percent frequency 18 days sooner than unburned grasses. Note too that burned grasses maintained greater frequency of grass cover throughout the growing season. Hensel, 1923.

Figure 17.4. This mixed big bluestem/indiangrass pasture was burned in early spring. The removal of litter allowed sunlight to reach the plant crowns and this, combined with warmer soil, led to rapid spring growth. Winter and early spring weeds were removed by the fire and these plants are now well positioned to compete with summer weeds as a result of their tremendous head start. Credit, E. Holcomb.

reaching the exposed root crowns of the sun-loving warm-season native grasses likely has more influence on their increased growth response to fire than any other factor.

As mentioned in preceding chapters, prescribed fire can be useful for reducing competition in second-year stands (Chapter 8), in those that need to be thickened or renovated (Chapter 9) as well as in established stands (Chapter 15). It also can be beneficial where seed yield needs to be increased or improved forage quality is at a premium. And, as described in Chapter 10, prescribed fire can be used to manipulate grazing pressure by taking advantage of cattle's selective grazing of the most recently burned patch within a pasture. Periodic burns (once every two to three years) can also benefit wildlife habitat, notably for species such as northern bobwhite (Chapter 22).

WHEN TO USE PRESCRIBED FIRE

What about season of burn—does it matter what time of year a native grass field is burned? Where forage is the primary goal, **the best time to burn is early spring**. This is the time of year at which native grasses are on the verge of breaking dormancy and beginning a period of rapid growth. A tell-tale sign that the grasses are at this point is **when the buds emanating from the root crown have begun to elongate and leaves have reached a length of about 3-4 inches** (Figure 17.5). In the Mid-South, this will correspond to the first week of April, depending, of course, on spring weather patterns. Timing burns at this point in the plant's development will maximize its ability to respond and lead to maximum domination of the site by these perennial grasses (Figure 17.6).

Burns conducted earlier in the year, before late March, can still be beneficial to the native grasses because the fire will have many of the same effects. However, those effects will be in place before native grasses can take advantage of them but precisely at a time when cool-season perennials can respond strongly. Thus, **winter burns can actually**

Figure 17.5. Early spring leaves indicating these big bluestem plants are just breaking dormancy. This is an indication that these plants are preparing for a period of rapid growth. It is also the best time to conduct prescribed burns where improved forage production is the goal. The burn should be implemented at this stage.

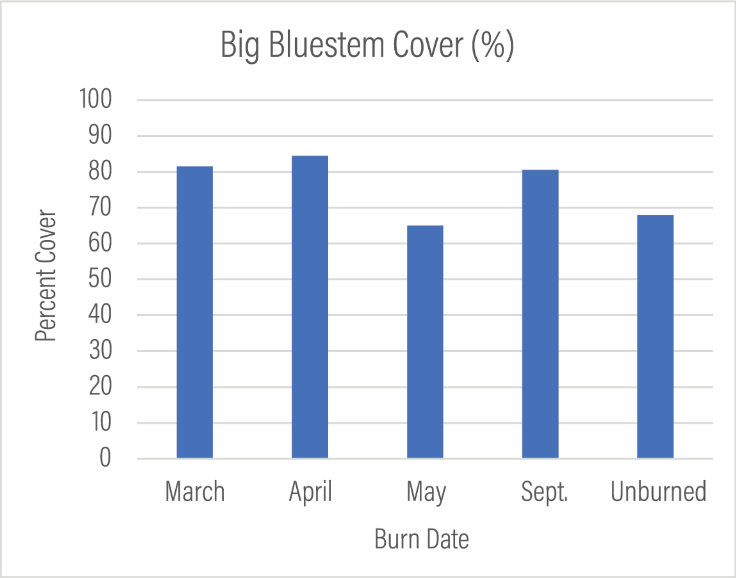

Figure 17.6. Comparison of big bluestem dominance as a result of five years of annual burning conducted each year in March, April, May, or September and an unburned control. Project was conducted in southwest Tennessee. Although there was minimal difference between big bluestem cover in March and April, this site had very little presence of cool-season species such as tall fescue and, consequently, very little encroachment of these species following the March burns. Adapted from Holcomb et al., 2014.

have negative consequences anywhere that there is appreciable pressure from cool-season perennials. In response to the earlier fire, cool-season grass will grow more rapidly, expand into the available growing space with little or no competition, and be in a position to retard growth of the warm-season species once they break dormancy.

On the other hand, all of these reasons make this an excellent time of year to burn a native grass pasture that is being harmed by too much pressure from cool-season perennials. Once the cool-season grasses are actively growing in response to the burn, but before the warm-season species have broken dormancy, there is a window that is perfect for controlling these encroaching perennials. Either graze the cool-season grasses heavily at this point (suppression) or spray with glyphosate (control) as described in Chapter 15.

But doesn't burning have a lot of negative impacts?

In recent years, concerns about air quality and climate change have led some to question the practice of burning native grasses. While there is no doubt that burning such fields releases particulate matter and carbon dioxide into the atmosphere, the amount from any given field being burned is extremely small. In pastures that have been properly grazed, the accumulation of thatch that fuels the fire is not great. Thus, the volume of smoke is limited. Furthermore, pastures typically have minimal amounts of woody material, which produces a great deal more smoke than grasses. Furthermore, when placed in context with other sources of air pollution, the contribution from burning native grasslands is negligible.

Another concern is that burning results in lost soil carbon and a reduction in soil organic matter leading to a decline in overall soil health. Again, there is some basis for this assertion – fires do consume organic matter above the soil surface. Upon closer examination though, the impact to actual soil conditions is a different story. Long-term studies of bluestem prairies have demonstrated that soils in burned sites have greater organic matter content than those that were unburned. The burned prairies had greater root biomass (i.e., carbon) and stored N than the unburned sites. Why? The natural adaptation of these C_4 grasses to fire resulted in greater growth rates and greater accumulation of root (and rhizome) mass below ground[2]. Furthermore, long-term studies have not documented decreases in site productivity, soil C concentrations, soil N concentrations or mycorrhizal fungus colonization rates of roots for burned versus unburned bluestem prairies[19]. Clearly, grassland ecosystems in North America dominated by tall C_4 species appear to be very well adapted to fire.

Where woody encroachment has become a serious problem, burns should be conducted late in the growing season, late August through September. At this time of year, maximum control of hardwood sprouts and shrubs will be obtained. This is because at this time of year, the woody plants have reduced root reserves and, therefore, are more vulnerable to the loss of nutrient—and energy-dense—above-ground material. Be aware that it will take more than one burn to completely suppress woody plants if they have become well established. Such plants have rootstocks that are many years old and can be quite large and resilient. Late summer burns may be difficult to conduct depending on the amount of green material in the field at this time of year.

A caution is in order here. As has been emphasized previously (Chapters 10 and 11), the warm-season grasses themselves need a period of rest late in the growing season and, thus, will also be set back by a late summer burn. However, with proper subsequent management, they will recover. Do *not* yield to the temptation to graze the very high-quality new growth the grasses will put out following such a burn. Remember, these plants have also lost considerable nutrients and energy through the fire and need to conserve what is left for winter dormancy and vigorous regrowth the following spring. It is also worth noting that late summer burns may increase the risk for invasion of cool-season competitors. Where woody competition is not serious and the plants you are trying to

Figure 17.7. This switchgrass stand was burned in March. Note the numerous small woody stems that have been killed by that burn. Larger stems, those well over an inch at the ground line may be topkilled by a fire, but will easily sprout back.

control are still relatively small (less than 1.5 inch groundline diameter), early spring fires will either kill them outright or keep them suppressed (Figure 17.7).

HOW TO USE PRESCRIBED FIRE

It is beyond the scope of this book to train readers on how to safely implement prescribed burns for native grass fields. However, a few key pointers are provided to give you some appreciation for what is involved. On the one hand, prescribed burning is inherently risky and must be approached only with proper care, equipment and experience. On the other hand, it is not a terribly difficult undertaking and can be safely accomplished. There are several critical considerations that must be taken into account before burning. These are listed below.

1. Have a burn plan that takes into account weather conditions, areas with high risk for potential escape of the fire and lays out appropriate fire control lines. Keep in mind that many states and localities will have laws or regulations governing prescribed burning. Make sure you are fully aware of and in compliance with them. Also, as a basic courtesy, make sure your neighbors and local fire dispatch are aware of your plan to burn.

2. Develop effective fire lines. These can be disced, mowed or even simply sprayed with water (a "wetline"), but in all cases should be able to prevent spread of fire. Have enough help and equipment (rakes, sprayers, tractor with a disc) to enable you to respond to escapes as needed.

3. Only burn when weather conditions align with those identified in the burn plan. Prescribed burns should not be conducted when winds are strong (greater than 10-12 miles per hour in most cases) or erratic. Normally, a steady wind will prevail in the wake of a cold front (typically, from the northwest) or a few days before the arrival of such a front (typically, from the southwest). These are the appropriate winds

under which to conduct a burn. In addition, relative humidity must not be exceptionally low. Rather, burns should be conducted when relative humidity is low enough to allow for an effective burn (less than 45 percent) but high enough to preclude extreme fire behavior (greater than 30 percent). Avoid burning when there is a low cloud ceiling or an inversion layer. Such conditions do not allow for good dispersion of smoke, and lingering smoke can cause problems for your neighbors.

4. Fires that are ignited on the downwind edge of the field and are allowed to "back" into the wind, known as backing fires, are the slowest moving, least intense and easiest to control (Figure 17.8). You could burn an entire field with a backing fire, but it would take more time than other approaches. By contrast, fires ignited on the upwind side of the field, known as head fires, move rapidly, can get quite intense and are the most difficult to control. In most cases, these should be avoided. Strip-head fires are lit as head fires, but only close

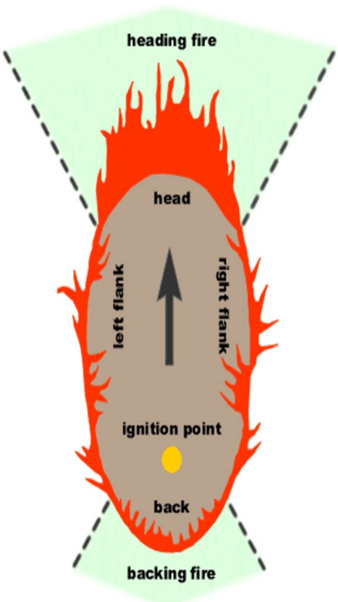

Figure 17.8. Diagram illustrating basic techniques for prescribed burning. Wind direction is indicated by arrow at center. Backing fires burn into the wind while head fires burn with the wind and can become far more intense as a result. Flanking fires burn parallel to wind direction and are intermediate in their intensity. Source: www.tn.gov/tnwildlandfire/prescribed-fire/.

to the fire line or back fire using a succession of narrow "strips" lit upwind of the previous strip.

5. A common — and safe — approach to burning any native grass field is to first light a back fire (downwind side of the field). Once a substantial area has been blackened by the back fire, flank fires (those that burn parallel to the prevailing wind) can be lit on either side of the field. These flank fires will burn into the field (perpendicular to the wind) and create an additional blackened area on each side of the field. Only after both the flank and back fires have created substantial black areas should a head fire be considered. Although it will burn the balance of the field more quickly, it is not necessary to use a head fire.

Be sure to exercise appropriate caution in using prescribed fire. And if you do not have any experience with this tool, find someone who has experience to help you with your first few burns. Contact the local office of your state's forestry or wildlife agency for further information or to find additional resources for conducting prescribed burns. For instance, many of these agencies offer prescribed burn workshops for landowners. **Always make safety your first priority!**

SUMMARY

Fire is a natural part of North American grasslands and the native grasses being considered in this book are all extremely well adapted to fire. Burning can provide a number of benefits to native grass forage production but is not essential to maintaining high quality stands. Rather, it is a very good tool, one that should be used as needed, but always with safety in mind.

CHAPTER EIGHTEEN
Interseeding Legumes and Native Forbs Into Native Grass Stands

Legumes have long been used in forage production to provide an organic source of N as well as to improve forage quality. In native grasslands of the eastern U.S., there were an abundance of forbs, including legumes, that were a part of these plant communities. Although grasses produced the overwhelming majority of the biomass, in terms of numbers of species, the forbs were far more dominant. Inclusion of introduced legumes, species such as red or ladino clover, and native forbs have both received increased attention in recent years. I am often asked whether or not such increased diversity in the pasture is beneficial, if it can be done and how it can be done. These subjects are addressed in this chapter.

INTRODUCED LEGUMES

Perhaps because we are most familiar with them, let's start with the legumes used so often in forage production. In a series of studies conducted at the University of Tennessee, red, crimson, white and arrowleaf clovers, hairy and common vetch and alfalfa were drilled into established switchgrass stands. These stands were managed as either a biomass crop (single, post-dormancy annual harvest) or were harvested once for hay in early summer (typically mid-June) and then as a biomass crop that fall. In this environment, with limited light able to reach the seedlings beneath a robust switchgrass canopy, most of the legumes did not make a large contribution to the stand[1; 24]. For example, alfalfa seedlings were abundant initially, but few if any plants recruited into the stand canopy (Figure 18.1). Of the seven species included in these trials, the most successful was red clover, perhaps because of its upright growth habit and seedling vigor (Figure 18.2). However, ladino clover, although less abundant, had the best persistence among these species, likely because of its stoloniferous growth habit.

On the other end of the spectrum, with crimson clover and the two vetches, a serious problem became apparent. With fall-planted crimson clover, stand development by the following spring was very good and the canopy shaded the switchgrass enough to retard growth and thin the stand. Similarly, the vetches could quickly overtop the switchgrass

Figure 18.1. Alfalfa interseeded into switchgrass developed an abundance of seedlings, but due to the competition with the tall grass as the summer progressed, there was no recruitment of these seedlings into the canopy. Some subsequent canopy management such as hay harvest, clipping or grazing would be needed to allow these small seedlings to compete with the robust switchgrass plants.

Figure 18.2. Red clover, especially when planted in the fall, can establish and persist in switchgrass stands. It also has done well in other native grasses and is the most reliable cool-season legume for interseeding into native grasses.

because of their vining growth habit and as a result had a negative effect on the grass (see Figure 13.7). Comparable studies conducted in Iowa[6;78] and Virginia[4] had similar results. In these studies, red clover also proved to be a good choice in terms of establishment. But studies in both states reported substantial reductions in grass yield, roughly 60 percent with red clover, as a result of competition with the legumes. In the Virginia study, switchgrass tiller density was reduced as well, in some situations by as much as 50 percent.

The studies in Iowa evaluated some additional introduced legumes that were not included in the Tennessee studies. These were white and yellow sweet clovers, crown vetch and birdsfoot trefoil. Because these four forages, like the seven studied in Tennessee, are all cool-season legumes, they grow well in fall and again in early spring. As a result, if they develop vigorous stands, they can present substantial competition to the warm-season grasses. This is exactly the same problem mentioned in Chapter 15 in regard to cool-season competitors encroaching into warm-season grass stands. Whether that competitor is a cool-season perennial grass (e.g., tall fescue), winter annual broadleaf weed or inter-seeded cool-season legume, it can have the opposite effect of prescribed fire (Chapter 17) by shading the warm-season species and maintaining ground cover that keeps soils cooler for longer. The natural consequence will be delayed dormancy break, slowed growth and, eventually, weakened warm-season grasses.

Warm-season legumes would avoid these issues and be more compatible with the growth season of the warm-season grasses. Unfortunately, the options for warm-season legumes are much more limited. While I have not ever tried to use cowpeas, I suspect their trailing habit could become a serious problem much like the vetches. Sericea lespedeza, which is used on a limited basis as forage in parts of the southeastern U.S., can quickly become a pest. In fact, there are a number of states that consider sericea lespedeza a noxious weed. The Virginia study mentioned above evaluated annual lespedeza, which is a warm-season species, and found that it established well in switchgrass and proved to be a good reseeder producing well in the second year of their experiment. Because of its seasonality and small stature, it did not result in undesirable competition to the grass.

Across these various studies, the interseeded legumes provided organic N. However, where establishment was poor or the seedlings did not recruit well into the canopy, the amount was negligible. On the other hand, well-established legumes generally provided enough N to replace inorganic input requirements, about 60 pounds per acre. Likewise, CP increases in the sward were only evident where substantial volumes of legumes were present in the canopy. Unfortunately, the observed benefits with respect to providing organic N and improved CP were only apparent with stands of legumes that were near or at the point where they had a detrimental impact on the grasses.

Lesson from a grazing study

Another study conducted in Tennessee evaluated interseeded red clover (chosen based on the experience from the studies mentioned above) in previously established switchgrass and big bluestem/indiangrass blend pastures[12]. Several lessons emerged from this study. First, even though red clover was drilled (five pounds per acre) every February for four years, the groundcover of clover was very inconsistent. There were two years with fair to good clover cover, one year very poor and one with very heavy clover. Not a big surprise, but it does emphasize clover content cannot be controlled in a pasture with any real precision.

The second lesson was a repeat of a lesson from the previously mentioned studies. In the year with heavy clover cover, which developed in early spring well before the native grasses broke dormancy, the clover completely overtopped the grass and substantially suppressed its growth (see Figure 13.6). In fact, for that year, grass cover for the big bluestem/indiangrass pastures dropped from 85 percent to 35 percent! Switchgrass pastures were not affected.

And the final lesson we learned was that the clover had no impact on pasture productivity—the total pounds of gain per acre was the same with or without the interseeded clover. Three factors likely led to this lack of an impact. First, some years had minimal clover cover. Second, the red clover was only consistently available during the early part of the grazing period; as weather warmed, clover diminished. Third, during the period when clover was available within the pastures, the native grasses themselves were already providing a very high rate of gain, about 2.6 pounds per day. There simply was not much room left for improvement. And because the addition of the clover represented an additional expense and management requirement, beef was produced at a greater cost per pound with the clover — but with no advantage.

Take-home message

The various studies described above leave us with a few takeaways regarding interseeding legumes into native grass stands. First, for legumes to become established in tall-growing native grasses, the canopy must be managed to allow enough light to reach the legume seedlings to enable them to become fully established and recruit into the canopy. In grazing situations that is normally not a problem because canopies are kept shorter. In hay fields, harvest timing should be adjusted as needed to keep the seedlings developing. Second, **any cool-season legume could potentially be a problem in terms of early spring competition with the later-emerging warm-season grasses**. This is especially true for crimson clover, the vetches and birdsfoot trefoil. With red clover, or any of the aforementioned species, stand management to prevent excessive spring competition will be necessary. Ladino clover can work so long as adequate sunlight can reach these low-growing plants. In any case, the benefit of introducing legumes may be minimal, especially relative to the cost and risk. In the case of eastern gamagrass, legumes, either red clover or white clover, may be a better complement given the large amount of space between plants that is common for most stands of this grass. Furthermore, rates of gain are lower on eastern gamagrass and clovers may provide a greater proportional benefit to animal performance. The greatest concern in incorporating a cool-season legume is with stands dominated by the bluestems. Additional work should be done evaluating the benefits of annual lespedezas in native grass stands. They do not present substantial problems with competition, have a compatible growth season, can perform well on low fertility and acidic soils and could provide an alternative, organic, N source.

When and How to Interseed

Our experience with establishing cool-season legumes confirms existing forage production recommendations: fall establishment of cool-season legumes is considerably more effective than similar plantings conducted during early spring. However, such plantings also come at greater risk to the warm-season species because the legumes may become very well established and by spring overtop the yet-dormant grasses. Moderating seeding rates appears to be of some benefit in minimizing this risk but stand density can vary a great deal for any given planting rate.

Another consideration for timing interseeding legumes into native grasses is that **it should only be done once the grasses are well established, following the third summer**. Such well-established stands will be much better able to compete with cool-season legumes should they become too rank. Consequences to long-term vigor and productivity of the native grasses will be much greater in younger stands. Also, **do not attempt to establish both the grasses and the legumes at the same time**. The slower (and later) developing native grass seedlings will be outcompeted by the legumes and stand failure is likely.

Sowing into existing native grass stands may not be effective due to the heavy thatch that could minimize seed-soil contact. For that reason, drilling is a preferable approach. Where growth and/or thatch is heavy, some treatment may be required prior to drilling to ensure proper drill operation. Although haying or clipping could work in preparation for fall planting, grazing would be preferable at this time of year because of the less severe impact to the canopy compared to mechanical treatments. Another excellent option for spring plantings, one that would make sowing more likely to succeed, would be to plant in March following a burn. Because such a burn would have to be conducted in February or early March to ensure timely planting, this approach may not be advisable where there is already a problem with cool-season weeds.

As with any legume planting, be certain that the field into which you plan to plant has not been treated with herbicides with soil residual activity that may be detrimental to the legumes. Also, be sure that if legumes have been absent from the field for a number of years, you identify and use the appropriate inoculant for the legume species you are planning to plant [11]. One other important consideration is soil pH. For native grasses, so long as pH is not extremely low, growth is not impeded. However, many legumes require considerably higher pH to thrive. Therefore, if you plan to interseed legumes be sure that pH is above 5.8 for red and white clovers and near 6.5 for alfalfa.

NATIVE FORBS AND LEGUMES

The native grasslands of the eastern U.S. included many species of forbs and legumes. In fact, in terms of numbers of species, the forbs and legumes were far more abundant than the grasses. For example, during a recent grassland restoration project in Tennessee on the Cumberland Plateau, 165 species of forbs and legumes were documented versus only 44 grass species [22]. Conversely, in terms of biomass production, the grasses were far more dominant producing about 80 percent of the annual biomass in Tall Grass Prairies [13]. Regardless, the forbs and legumes played an important role in the ecosystem. They became more prevalent following heavy disturbance, particularly grazing, but also after extended severe droughts that suppressed grass productivity. Many of the native forbs have deeper roots than the grasses and, therefore, could persist under more severe conditions. The legumes provided additional N to the soil. The flowers provided a critical food source for numerous pollinators. And the seeds from many of these plants were an important food source for birds and small mammals. Furthermore, the foliage of the plants provided forage for grazing animals. In short, the forbs and legumes were — and still are — an integral part of a healthy grassland.

Because most native grasslands in the eastern U.S. have long since been lost (see Chapter 2), most of these associated plants have become very uncommon as well. Thus, if these species are going to be a component of a field that produces native grass forage, they must be reintroduced. Our knowledge of native forbs in terms of agronomic practices and their contribution to forage production is limited. In the meantime, as we continue to learn more about these species and how to best manage them, the availability of seed will, to a large extent, dictate which species can be interseeded into native grasses. Four ongoing research projects at the University of Tennessee are exploring how native forbs and legumes can be integrated into forage management systems. Ten forbs and nine legumes were selected for inclusion in one or more of these studies based on seed availability, presumed forage benefit, cost, whether the species was perennial or a reseeding annual and tolerance to imazapic (Table 18.1). Native plant seed vendors have many more species available than what we have worked with, so additional species could certainly be considered for your planting project, depending on specific objectives.

While it is too soon to draw any firm conclusions from these studies, there are a few patterns beginning to emerge that are worth noting here. First, among these 19 species, six have not proven to be easy to establish while an additional eight species have provided good populations across the four studies. Second, we have had the opportunity to observe ten species under grazing conditions. Perhaps not surprisingly, cattle appeared to readily graze all of them throughout the summer. Evaluations of forage nutritive values of these forbs have not yet been completed but, given the selective grazing behavior of cattle (steers in this case), it seems reasonable to conclude that they are, at least, fair fodder. Finally, none of the forbs or legumes planted within the pastures have become weedy or invasive after four years. Indeed, they have persisted reasonably well in these test pastures, more so in big

Table 18.1. Native forbs and legumes currently being evaluated at the University of Tennessee for interseeding in native grass pastures. Listed seeding rates and establishment success are based on preliminary observations.

Category	Species	Latin name	Perennial	Seeding rate (lbs./ac)		Establishment	Imazapic tolerance
				Blend	Single species		
Forbs	Canada goldenrod	*Solidago canadensis*	Yes	0.1	0.5	Poor	None
	Cup plant	*Silphium perfoliatum*	Yes	0.3-0.5	10.0	Fair	None
	Maximilian sunflower	*Helianthus maximiliani*	Yes	0.3-0.5	5.0	Fair	None
	Oxeyesunflower	*Heliopsis helianthoides*	Yes	0.2-0.5	10.0	Good	None
	Prairie dock	*Silphium terebinthinaceum*	Yes	0.3	4.0	Poor	None
	Purple coneflower	*Echinacea purpurea*	Yes	0.3-0.5	8.0	Good	PRE and POST[1]
	Plains coreopsis	*Coreopsis tinctoria*	Annual	0.2-0.5	4.0	Good	PRE and POST[1]
	Lanceleaf coreopsis	*Coreopsis lanceolata*	Yes	0.2-0.5	4.0	Good	PRE and POST[1]
	Upright prairie coneflower	*Ratibida columnifera*	Yes	0.2-0.5	2.0	Good	PRE and POST[1]
	Black-eyed Susan	*Rudbeckia hirta*	Biennial	0.2-0.5	2.0	Good	PRE and POST[1]
Legumes	Illinois bundleflower	*Desmanthus illinoensis*	Yes	0.5-1.0	8.0	Good	PRE and POST
	Partridge pea	*Chamaecrista fasciculata*	Annual	0.5-1.0	12.0	Good	PRE and POST
	Purple prairie clover	*Dalea purpurea*	Yes	0.5	3.0	Poor	PRE and POST
	White prairie clover	*Dalea candida*	Yes	0.5	3.0	Poor	PRE and POST
	Panicledleaf ticktrefoil	*Desmodium paniculatum*	Yes	0.5-1.0	6.0	Fair	POST only
	Showy ticktrefoil	*Desmodium canadensis*	Yes	0.5-1.0	6.0	Fair	POST only
	Dixie trefoil	*Desmodium tortuosum*	Yes	0.5-1.0	6	Fair	POST only
	Roundhead bush clover	*Lespedeza capitata*	Yes	0.3-0.5	3.0	Poor	POST only[2]
	Slender bush clover	*Lespedeza virginica*	Yes	0.3-0.5	3.0	Poor	POST only[2]

[1] Some possible damage has been observed on POST applications for these species.
[2] Label does not include all *Desmodium* and *Lespedeza* species, but those that are included on label have tolerance.

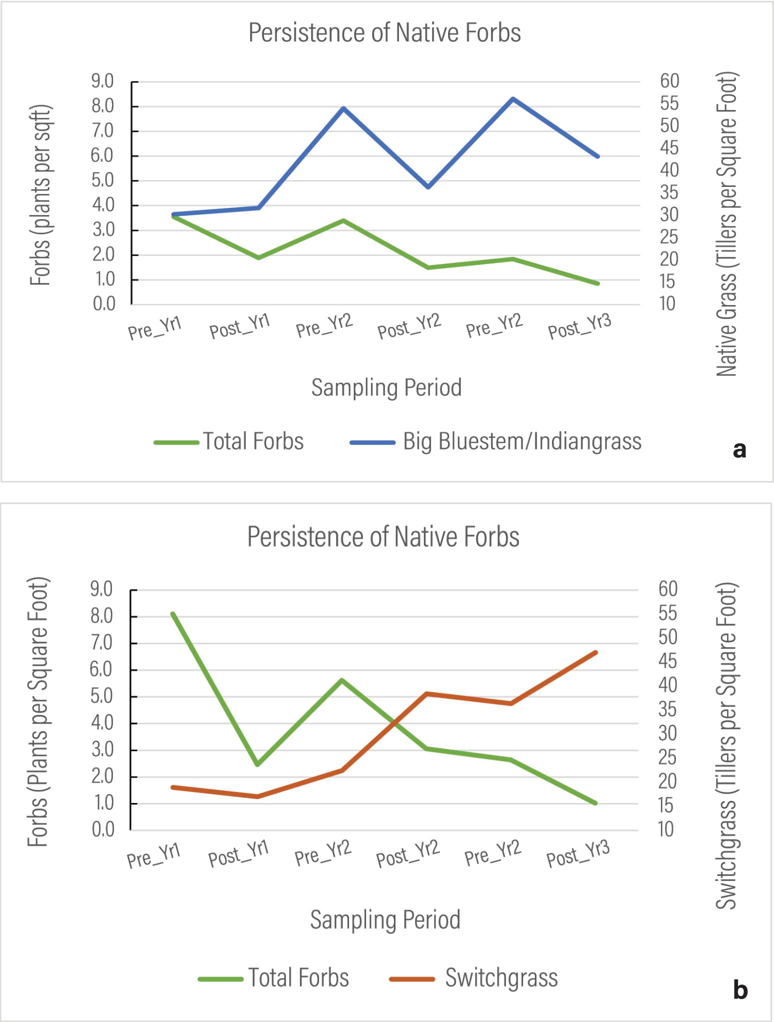

Figure 18.3. Ten native forbs interseeded into established stands of big bluestem/indiangrass (a) and switchgrass (b) have persisted over the first four years of the study. Two additional years are planned for this project. Some species have declined a great deal, while others have maintained more consistent populations. Sampling was conducted in May (pre-grazing) and September (post-grazing) annually. J. Richwine, PhD dissertation, University of Tennessee, 2021.

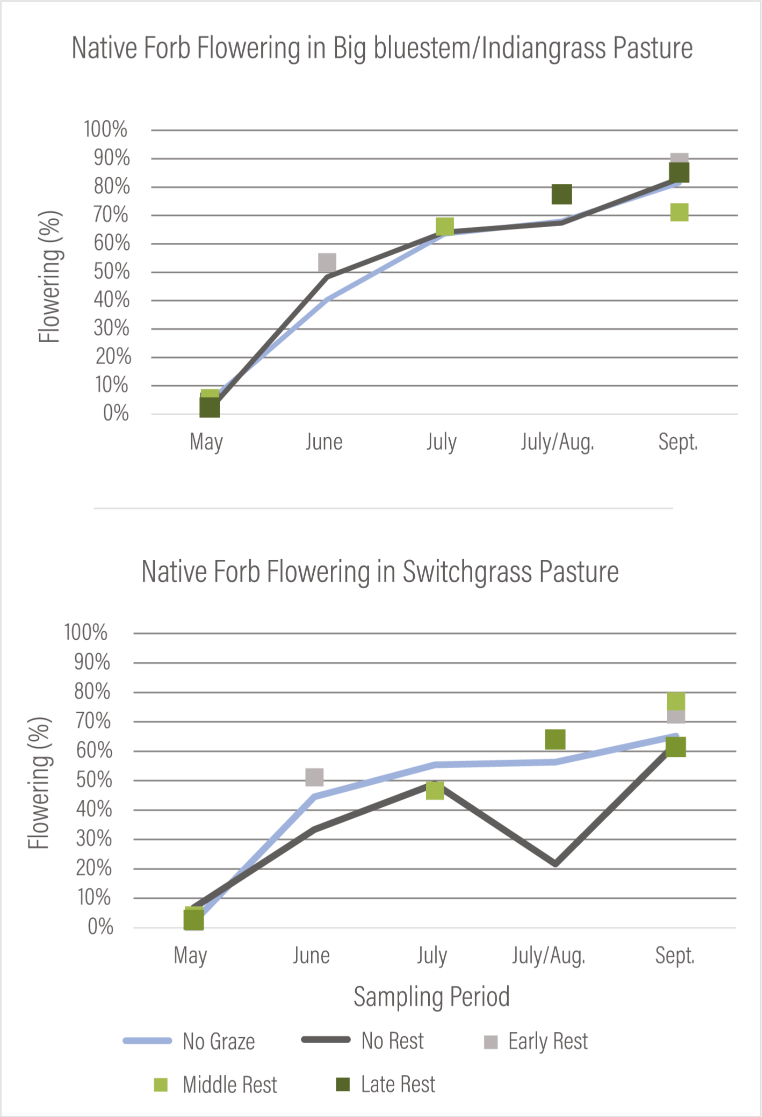

Figure 18.4. Native forbs and legumes interseeded into established stands of a mix of big bluestem/ indiangrass (a) and switchgrass (b) have produced a large number of blooms under active grazing. Pastures were grazed with one of five approaches: grazed throughout the summer (13 weeks) without a rest period, grazed all summer but with a three-week rest period during either early summer (June 1-20), mid-summer (June 21-July 11), or late summer (July 12-Aug 2), or not grazed at all. Interestingly, with the exception of the late summer rest period for unrested switchgrass pastures, the grazing treatments did not affect the percent of these forbs that were blooming. J. Richwine, PhD dissertation, University of Tennessee, 2021.

bluestem/indiangrass than in switchgrass (Figure 18.3). Furthermore, they are providing numerous blooms — even under grazing — for much of the summer (Figure 18.4).

WHEN AND HOW TO INTERSEED

In order to successfully establish these forbs and legumes into native grasses, there are several guidelines that should be taken into account. First, the species in Table 18.1 are all warm-season plants that have upright growth habits. As such, they are compatible with the warm-season bunchgrasses. Therefore, the challenges associated with interseeding the introduced cool-season legumes are largely avoided with the exception of lanceleaf coreopsis, which begins spring growth several weeks earlier than the warm-season grasses.

In terms of timing, these species can be effectively planted once soils have warmed in the spring to about 60-65 F or, alternatively, during the dormant season (February-March). And, as was described for the introduced legumes above, **interseeding should be delayed until the grasses themselves have become well established, following the third summer since planting**. Although these native species are more compatible and could be planted sooner, perhaps even after the first summer, **managing weed pressure prior to interseeding is critical to long-term success**.

The issue is that for most native grass plantings, particularly those that involve conversions from degraded pastures or hayfields, it may take several years to get good control of weeds that proliferated for many years prior to the conversion (see Chapters 6 and 8). Furthermore, the disturbances involved in conversion make the problem even worse by exposing the seedbank, one heavily infested with seeds of numerous weed species. If the native forbs are planted before you have achieved good control over these weeds, especially those that are more persistent, they will continue to plague the field for years to come. Winter annual weeds can be an issue, especially for dormant-season plantings. A good way to control such weeds in dormant-season planting projects is to apply a non-selective herbicide in late winter before the new seedlings emerge.

One advantage a number of the native forbs and legumes have is their tolerance of the herbicide imazapic (Table 18.1). However, not all of the native forbs and legumes are tolerant of imazapic and others may only be tolerant to post-emergence applications. Therefore, be sure to check the label or with your seed supplier to determine if you should apply imazapic as a part of your establishment protocols. When planting during spring, apply imazapic within two weeks after drilling, but only where both the grass stand and the interseeded species are tolerant to this product.

Unlike the introduced legumes, the native forbs and legumes, like their native grass counterparts, can do well on acidic and low fertility soils. Therefore, do not fertilize (except where either P or K is in the low category) prior to seeding the forbs and legumes. Also, it is not necessary to correct soil pH unless it is below 5.0. Recall, these native species have a competitive advantage in these more marginal growing conditions relative to many weed species that can interfere with their successful establishment.

Similar to the recommendations for introduced legumes above, drilling is preferable to sowing, providing improved seed-soil contact. And again, if growth and/or thatch is too heavy for proper drill operation, some measures must be taken first to correct the situation. Likewise, some management of existing grass canopies through grazing, haying or clipping will be necessary to allow enough light to reach emerging seedlings to enable them to fully develop. Be sure that any recently applied herbicides do not have residual soil activity that could interfere with successful establishment of the forbs.

IMPLICATIONS FOR WEED CONTROL

Perhaps the single biggest challenge associated with **interseeding any broadleaf species into a native grass stand** is that you **will preclude**

most herbicide options for weed control going forward. White clovers are relatively tolerant of lower rates (less than 3 pints per acre) of 2,4-D and a number of the native species are tolerant of imazapic. However, there are many pasture weeds that are not controlled by either 2,4-D or imazapic. Also, controlling cool-season weeds with non-selective herbicides during the late winter will not be an option where cool-season legumes have been interseeded. Furthermore, many native forbs have basal rosettes that remain green during winter and could be harmed by herbicides applied during the dormant season. Prescribed fire, grazing, hay harvest and clipping can all still be used as competition control tools but as mentioned in Chapter 15, these normally only suppress weeds without actually killing them. Taken together, it is important to recognize that with the good may come the bad, weeds may become more prevalent in interseeded stands. This should reinforce the point that **interseeding is best implemented in stands that already have very limited weed pressure**.

SUMMARY

Native grass pastures and hayfields can be enhanced by interseeding introduced legumes or native forbs and legumes. To successfully establish these species, it is important to follow good agronomic guidelines including paying attention to soil fertility and pH requirements, existing weed pressure, subsequent canopy management of existing grasses, potential issues with past herbicide applications, proper drill operation and appropriate timing of seeding. It is also important to recognize that most introduced legumes are cool-season species and as such may produce unacceptable levels of competition with the warm-season grasses during the critical period when these grasses break dormancy. On the other hand, the native forbs and legumes are compatible with the native grasses because they are tall growing, warm-season species. Once any of these species have been planted, native or introduced, most herbicide options will no longer be available and other means of weed control will be necessary. Therefore, having excellent weed control within the field prior to planting should be a priority.

It also must be recognized that to date research has not documented consistent improvements in N supply or animal performance associated with interseeding legumes into native grass stands. And because there is an expense associated with the establishment of these legumes, it is unlikely to pay for itself. On the other hand, there are a number of benefits that could be realized from interseeding including improved habitat for pollinators, wildlife and, prospectively, soil health.

REFERENCES
Section Four

1. Ashworth A.J., F.L. Allen, P.D. Keyser, D.D. Tyler, A.M. Saxton, and A.M. Taylor. 2015. Switchgrass yield and stand dynamics from legume intercropping based on seeding rate and harvest management. Journal of Soil and Water Conservation 70:374-384. doi:10.2489/jswc.70.6.374.

2. Blair, J.M., T.R. Seastedt, C.W. Rice, and R.A. Ramundo. 1998. Disturbance, diversity, and species interactions in tallgrass prairie, pp. 140-156 in Knapp, A.K., J.M. Briggs, D.C. Hartnett, and S.L. Collins, editors, Grassland dynamics: Long-term ecological research in tallgrass prairie. Oxford University Press, New York

3. Boe, A., K.H. Keeler, G.A. Normann, and S.L. Hatch. 2004. The indigenous bluestems of the Western Hemisphere and Gambagrass, pp. 873-908 in Moser, L.E., B.L. Burson, and L.E. Sollenberger, editors, Warm-season (C4) grasses. Agronomy #45, American Society of Agronomy, Madison, WI.

4. El Hadj, M. 2000. Compatibility, yield, and quality of perennial warm-season grass-legume mixtures. M.S. thesis, Virginia Polytechnic Institute and State University, Blacksburg, June 2000.

5. Ferrell, J.A., T.R. Murphy, and D.C. Bridges. 2005. Postemergence Control of Hybrid Bermudagrass (Cynodon transvaalensis Burtt-Davy 3 Cynodon dactylon). Weed Technology 19:636-639.

6. George, J.R., K.M. Blanchet, R.M. Gettle, D.R. Buxton, and K.J. Moore. 1995. Yield and botanical composition of legume-interseeded vs. nitrogen-fertilized switchgrass. Agronomy Journal 87:1147-1153.

7. Gettle, R.M., J.R. George, K.M. Blanchet, D.R. Buxton, and K.J. Moore. 1996. Frost-seeding legumes into established switchgrass: Forage yield and botanical composition of the stratified canopy. Agronomy Journal 88:555-560.

8. Gustafson, D.M., A. Boe, and Y. Jin. 2003. Genetic variation for Puccinia emaculata infection in switchgrass. Crop Science 43:755-759.

9. Hensel, R.L. 1923. Effect of burning vegetation in Kansas pastures. Journal of Agricultural Research 23(8):631-644.

10. Holcomb, E, P. Keyser, and C. Harper. 2014. Responses of planted native warm-season grasses to seasonality of fire in the Southeastern USA. Southeastern Naturalist. 13:221-236.

11. Keyser, P., C. Harper, G. Bates, J. Waller, and E. Holcomb. 2015. Intercropping legumes with native warm-season grasses for livestock forage production in the Mid-South. University of Tennessee Extension, SP731-G. 8 pp.

12. Keyser, P.D., E.D. Holcomb, C.M. Lituma, G.E. Bates, J.C. Waller, and C.N. Boyer. 2016. Forage attributes and animal performance from native grass inter-seeded with red clover. Agronomy Journal 108:373-383.

13. Knapp, A.K., J.M. Briggs, J.M. Blair, and C.L. Turner. 1998. Patterns and controls of aboveground net primary production in tallgrass prairie, pp. 193-221 in Knapp, A.K., J.M. Briggs, D.C. Hartnett, and S.L. Collins, editors, Grassland dynamics: Long-term ecological research in tallgrass prairie. Oxford University Press, New York

14. Lee, S.T., B.L. Stegelmeier, D.R. Gardner, and K.P. Vogel. 2001. The isolation and identification of steroidal sapogenins in Switchgrass. Journal of Natural Toxins 10:273-281.

15. Lee, S.T., R.B. Mitchell, Z. Wang, C. Heiss, D.R. Gardner, and P. Azadi. 2009. Isolation, characterization, and quantification of steroidal saponins in switchgrass (Panicum virgatum L.). Journal of Agricultural and Food Chemistry 57:2599-2604.

16. Masters, R.A., S. Nissen, R.E. Gaussoin, D. Beran, and R. Stougaard. 1996. Imidazolinone herbicides improve restoration of Great Plains grasslands. Weed Technology 10:392-403.

17. Mitchell, R., and K.P. Vogel. 2004. Indiangrass, pp. 937-954 in Moser, L.E., B.L. Burson, and L.E. Sollenberger, editors, Warm-season (C4) grasses. Agronomy #45, American Society of Agronomy, Madison, WI.

18. Prasifka, J.R., J.E. Buhay, T.W. Sappington, E.A. Heaton, J.D. Bradshaw, and M.E. Gray. 2011. Stem-boring caterpillars of switchgrass in the Midwestern United States. Annals of the Entomological Society of America 104:507-514. 2011. DOI: 10.1603/AN10183

19. Rice, C.W., T.C. Todd, J.M. Blair, T.R. Seastedt, R.A. Ramundo, and G.W.T. Wilson. 1998. Belowground biology and processes, pp. 244-264 in Knapp, A.K., J.M. Briggs, D.C. Hartnett, and S.L. Collins, editors, Grassland dynamics: Long-term ecological research in tallgrass prairie. Oxford University Press, New York

20. Springer, T.L., and C.L. Dewald. 2004. Eastern gamagrass and other Tripsacum species, pp. 955-974 in Moser, L.E., B.L. Burson, and L.E. Sollenberger, editors, Warm-season (C4) grasses. Agronomy #45, American Society of Agronomy, Madison, WI.

21. Stegelmeier, B.L., S.A. Elmore, S.T. Lee, L.F. James, D.R. Gardner, K.E. Panter, M.H. Ralphs, and J.A. Pfister. 2007. Switchgrass (Panicum virgatum) toxicity in rodents, sheep, goats and horses, pp. 113-117 in Poisonous plants: global research and solutions, Editors K.E. Panter, T.L. Wierenga, and J.A. Pfister. CABI Publishing, Cambridge, Massachusetts.

22. Vander Yacht, A.L. 2018. Effects of canopy disturbance and fire on vegetation and fuel dynamics in oak forests of the Mid-South USA. Ph.D. dissertation, University of Tennessee, Knoxville, May 2018.

23. Vogel, K.P. 2004. Switchgrass, pp. 561-588 in Moser, L.E., B.L. Burson, and L.E. Sollenberger, editors, Warm-season (C4) grasses. Agronomy #45, American Society of Agronomy, Madison, WI.

24. Warwick, K., F.L. Allen, P.D. Keyser, A.J. Ashworth, G.E. Bates, D.D. Tyler, P.L. Lambdin, and C.A. Harper. 2016. Biomass and integrated forage/biomass yields of switchgrass as affected by intercropped cool- and warm-season legumes. Journal of Soil and Water Conservation 71:21-28. Doi: 10.2489/jswc.71.1.21

25. Weaver, J.W. 1954. North American prairie. Johnsen Publishing Company, Lincoln, Nebraska.

26. Wolf, D.D., and Fiske, D.A. 1995. Planting and Managing Switchgrass for Forage Wildlife, and Conservation. Virginia Cooperative Extension Pub. no. 418-013, Blacksburg, VA.