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Establishing tree seedlings in mixed stands after harvesting is difficult without adequate vegetation control. Artificial regeneration can be used to ensure desirable future stands, but competing vegetation decreases survival and growth. Vegetation control can be costly and laborious. Large amounts of herbicides are used annually in forest management to reduce vegetation that competes with trees for growing space, nutrients, water, light, and other essential components. Using herbicides to control weeds is economical, but may not always be environmentally acceptable. One alternative is to establish nitrogen-fixing (legume) ground covers, which may suppress the more competitive weeds and enrich the soil. This practice has been used successfully in agronomic systems for many years, but has received little attention in forestry until recently (Haines *et al.* 1978, Van Sambeek and Rietveld 1982).

It is generally agreed that grasses compete more vigorously for growth components than do legumes. The primary benefit of grass cover is erosion control during regeneration. Legumes, on the other hand, because of their less branched and shallower root systems, enhance soil ameliorative processes that improve tree growth. Additionally, legumes that complete most of their growth during the cool part of the year and form a dense mat on the soil surface do a good job of reducing weeds. Because of this, using nitrogen-fixing plants in regenerating tree stands may reduce the need for chemical weed control. Even if not eliminating the use of herbicides, legumes could increase growth of the regenerating trees sufficiently to decrease the number of years weed control will be needed (Van Sambeek *et al.* 1986).

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Legumes can use atmospheric nitrogen, which is unavailable to non-nitrogen fixers. When the legumes decay, the accumulated nitrogen they release becomes available for uptake by neighboring plants in addition to weed control and erosion control. Nitrogen fixers may also (1) add organic matter, which may increase the availability of other nutrients, as well as nitrogen; (2) improve the soil physical environment by decreasing bulk density and increasing moisture retention; and (3) reduce soil-borne diseases (Fox 1965).

Many of the benefits attributed to legumes in forestry are hypothesized rather than proven. Most of the forestry literature deals with opportunistic evaluations of unplanned comparisons in man made situations combined with speculations about future potential for planned use of the nitrogen-fixing species in management programs (Haines and DeBell 1979). With few exceptions my report is no different. The purpose of this paper is to present information on nitrogen fixers, mostly herbaceous legume species, whose use in hardwood plantations and natural stands as ground covers may reduce herbicide use. I draw extensively upon results reported in the proceedings of a workshop (Haines 1978).

NITROGEN-FIXING PLANTS IN ARTIFICIAL REGENERATION

More information is available on the value of nitrogen-fixing covers in plantations than in natural stands. Much of the work has been reported relatively recently and may yet lead to the establishment of a successful operational system. Management inertia, however, prevents the introduction of such systems into forestry. That inertia is caused by a variety of factors including (1) the cheapness and operational flexibility of applying inorganic nitrogen fertilizer and insecticide, (2) the economic uncertainty of nitrogen-fixing systems, and

(3) an absence of technology transfer that describes the companion establishment of nitrogen-fixing plants and tree seedlings.

Several criteria should be considered when choosing plants to be used for ground cover in young plantations. Legumes selected must grow well with minimal site preparation. Establishment and growth must be sufficient to meet the objectives of weed control and nitrogen enrichment. Species with the broadest range of utility in forestry will probably be those that have decumbent stems and that grow during the cool season, thereby not adversely affecting tree growth. Weed control results from a dense vegetation mat produced by climbing or decumbent stems. Species with upright stems and low profiles usually give poor results.

Van Sambeek and Rietveld (1982) demonstrate that seeding cool-season legumes, both with and without chemical weed control around coestablished black walnut (*Juglans nigra*) seedlings, can accelerate tree establishment and growth in intensively managed plantations (table 1). Plots of walnut seedlings planted with covers of hairy vetch (*Vicia villosa*), crownvetch (*Coronilla varia*), sericea lespedeza (*Lespedeza cuneata*), Korean lespedeza (*Lespedeza stipulacea*), and a mixture of crimson clover + Korean lespedeza (*Trifolium incarnatum*) were compared to naturally revegetated plots at two sites after 3 years in southern Illinois. Seedling survival was reduced by crownvetch and to a lesser extent by sericea lespedeza and Korean lespedeza. Tree growth on plots seeded with hairy vetch without chemical weed control was almost equal to tree growth on naturally revegetated plots with chemical weed control. The ability of the six cover types to suppress non-leguminous forbs, grasses, and woody plants for the first 3 years was ranked as follows: Crownvetch > hairy vetch > sericea lespedeza > crimson clover + Korean lespedeza > Korean lespedeza > naturally revegetated.

In another study, five legumes (three *Trifolium* spp. and two *Vicia* spp.) were tested in a 2-year-old sycamore (*Platanus occidentalis*) plantation (Haines *et al.* 1978). After 4 years, total height and volume of sycamore in the legume-containing plots exceeded that in the check plots by more than twofold and threefold, respectively. Two of the clovers (*Trifolium subterranean* and *Trifolium incarnatum*) also provided the best weed control, maintained a low profile, and did not shade or climb around the young sycamore trees.

The early benefits of leguminous ground covers may decline later on because cover plants will normally be shaded out as the forest stand develops. However, enough viable seed may be stored in the duff to allow the nitrogen-fixing plants to reestablish themselves when the stand is thinned or harvested. There may also

Table 1.—*Survival and height of black walnut seedlings coestablished with various ground covers with and without weed control*[1]

Cover type	Survival: Without herbicide	Survival: With herbicide	Height: Without herbicide	Height: With herbicide
	Percent	*Percent*	*cm*	*cm*
Hairy vetch	81	86	135	163
Crimson clover	69	78	88	154
Natural	72	89	76	142
Sericea lespedeza	67	97	103	156
Crownvetch	25	75	64	130
Korean lespedeza	69	86	58	145

[1] *Information on file at the Forestry Sciences Laboratory, Southern Illinois University, Carbondale, IL.*

be extended benefits from the nitrogen-fixing plants after they are gone. Legumes planted in a rubber tree (*Hevea braziliensis*) plantation died out after 6 years of growth, but increases in rubber yields continued for 20 years (Broughton 1977).

NITROGEN-FIXING PLANTS IN NATURAL REGENERATION

The nitrogen-fixing plants with the greatest potential for use as ground covers are the native or naturalized nitrogen-fixing plants normally found in forests. Several such species occur in the Ozark forest (table 2). Although these leguminous species occur throughout the Ozark region, they may be scarce on many sites. Native legumes that occur without much assistance should be encouraged.

The utility of most native and naturalized legumes has not been examined in terms of nitrogen-fixing capabilities or weed suppression. Therefore, we do not know if enough native nitrogen-fixing plants can be grown to significantly influence annual nitrogen production and the type of weed competition. Sufficient interest, seed supplies, and seed sources are needed to examine these important questions.

In clearcuts, various plants compete vigorously with each other for resources needed for growth. Under these conditions, if nitrogen-fixing plants are not already in the understory, they might not develop or be of value to the developing stand. Several silvicultural practices show promise for increasing the legume component in natural stands. One of the most

Table 2.—*Natural and naturalized legume plants in the ground cover of Ozark forests*[1]

Plant	Height	Stem type	Habitat	Distribution
	Inch			
False indigo	36-38	Brushy	Moist bottoms	Widespread
Hog Peanut	—	Clumbing	Low, moist, damp areas	Widespread
Groundnut	—	Climbing	Low ground; bottoms	Widespread
Milk vetch	<20	Upright, branching	Upland woods	Widely scattered
Partridge pea	24	Upright	Disturbed areas; open woods	Widely scattered
Butterfly pea	—	Erect or trailing	Bottomland sites	Central Ozarks
Beggers ticks (tick clover)	30-36	Erect or trailing	Dry open woods; cherty sandy acid soils	Widely scattered
Milk pea	—	Low trailing	Dry cherty; open sandy soil	Widely scattered
Lespedeza	40-48	Erect or trailing	Open wood, cherty soils	Widespread
Black medic	20	Low branching	Waste grounds	Widely scattered
Sweet clover	36-48	Erect or trailing	Waste grounds	Widespread
Prairie clover	36	Erect	Open woods; bluffs; glades	Widespread
Prairie turnip (scurf pea and Sampson snakeroot)	36	Erect	Acid or alkaline soils; open woods	Widespread
Sensitive briars	—	Low trailing	Waste ground; open woods	Widespread
Wild beans	8-72	Climbing or trailing	Upland low areas	Widely scattered
Pencil flower	20	Erect	Open woods; dry soils	Widely scattered
Catgut (goat's rue)	20	Erect	Dry acid soils	Widely scattered
Clover	—	Erect	Waste ground	Widespread
Wood vetch	12-60	Spreading or climbing	Cherty or sandy soil	Widely scattered

[1]*Crawford, H.S.; Kucera, C.L.; Ehrenreich, J.H. 1969. Ozark range and wildlife plants. Agric. Handb. 356. Washington, DC: U.S. Department of Agriculture, Forest Service. 236 p.*

beneficial forest practices for increasing legume production is prescribed burning. Low intensity site preparation techniques such as clearing and burning stimulate legumes; high intensity techniques reduce them (Stransky 1976). The increased soil disturbance favors more competitive species.

Most legumes are intolerant of dense shade. An effective canopy of nitrogen-fixing plants cannot be maintained beneath dense stands and perhaps little time should be wasted in the attempt.

CONCLUSION

Changing the weed composition or coestablishing the vegetative competition at the time of establishment is one way to avoid or limit the need to use herbicides. Low intensity site preparation tends to encourage legumes; increased disturbance favors more competitive species such as grasses. There is evidence that legumes planted with tree crops in plantations can provide weed control, improve tree nutrition, and increase wood volume. Despite success, few forest managers are using this alternative. There is no evidence to support the use of legumes as ground covers in natural stands.

Many gaps in knowledge remain to be filled. We cannot merely assume that there is a payoff because biologically fixed nitrogen is good. Research is needed to sort out the many attributes and problems associated with using biological systems (legumes) for weed control

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Presents herbaceous legumes as an alternative to herbicides in forestry. Discusses benefits associated with the capability of legumes to control weeds and promote the growth of young trees.

KEY WORDS: Nitrogen fixing, pesticides, seedling growth, natural stands.