# REVEGETATING SURFACE-MINED LANDS WITH HERBACEOUS AND WOODY SPECIES TOGETHER[1]

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Abstract.--Herbaceous cover is required for erosion control on surface-mined lands even where forests are to be established. Where planted with trees, herbaceous species usually cause an increase in tree seedling mortality and retard tree growth, especially in the first few years after planting. Trees seem to be affected most by competition for moisture because their survival is least affected where spring and summer precipitation is abundant. Tree survival often is reduced most by dense stands of some legumes, especially crownvetch, flatpea, and sericea lespedeza; but in some plantings, growth of surviving trees was later increased in the legumes. Planting trees in existing stands of herbaceous cover usually resulted in poor survival. Herbicides or scalping to control competing cover is suggested, but there is little supporting data from research and experience. Planting trees and seeding herbaceous species in alternate strips appear feasible for combination plantings on areas where the appropriate seeding and fertilizing equipment can be used.

## INTRODUCTION

Much of the early effort to revegetate surface-mined lands in the eastern United States was with trees planted on spoil banks that were ungraded, unamended, and not seeded to herbaceous vegetation. The establishment of herbaceous vegetation for erosion control usually was not emphasized, especially on area-type stripping in the interior coal provinces where much of the sediment from the erosion that did occur was trapped in the valleys between the ridges of ungraded spoil. Besides, foresters had learned from experience and research that planting trees with herbaceous cover, such as in old fields, usually hindered tree establishment and growth.

Beginning in the 1960s more emphasis was given to the use of herbaceous vegetation. Emphasis on its use for erosion control coincided somewhat with the increased contour surface mining activity in the Appalachian region where runoff and erosion from steep slopes caused serious sedimentation problems in streams. Greater use of herbaceous species was also induced by legal requirements for grading and the development of land uses such as pasture. At the same time interest in tree planting was discouraged by legal, social, and economic pressures.

Within the past few years, interest in planting trees has been renewed partly in response to Federal regulations that encourage, imply, or require planting of woody species. At the same time herbaceous species must be sown to protect the mined land from erosion, but where planted with herbaceous vegetation, the survival and growth of tree and shrub seedlings may be jeopardized by interference from the herbaceous cover. This interference often is attributed to competition for nutrients, moisture, and light; it also may be due to allelopathic effects, or combinations of all these factors.

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Obviously, where tree planting is desired or required as a post-mining land use, the mine operator or reclamation contractor would like to establish herbaceous cover and trees as quickly as possible and obtain bond release in the minimum permissible time. Thus there is need for information on the probable success of establishing woody plants and herbaceous cover together. In this paper I will discuss some recent experimentation and observations of planting both types of vegetation together.

## PLANTING METHODS AND RESULTS

Methods used for establishing woody plants in association with herbaceous cover include: (1) planting or seeding trees, and at the same time seeding herbaceous cover either (a) on the entire area or (b) in strips between tree rows, (2) seeding herbaceous cover first and planting or seeding trees later, and (3) planting or seeding trees first and seeding herbaceous cover later. Each method has advantages and disadvantages depending on climatic and weather conditions, plant species selected, season that area is ready for planting, terrain or other minesoil characteristics, available labor, available seeding and planting equipment, and approval by regulatory agencies.

Experiments with these methods have been or are being conducted by the U. S. Forest Service, U. S. Soil Conservation Service, Tennessee Valley Authority, Southern Illinois University, University of Kentucky, and University of Tennessee. Undoubtedly, similar work is being done by other agencies, universities, and some mining companies, but I am not familiar with it.

### Planting trees and seeding herbaceous species at the same time

Seeding of herbaceous species with this method may be (1) a solid seeding, i.e., done on the entire area to be planted with trees or (2) in strips that alternate with strips left unseeded and planted to trees.

#### Solid seeding--

In 1968, a field study was begun by the Forest Service on two nearly level strip-mine sites in southeastern Kentucky (Bell County) to measure the effect of herbaceous cover on tree survival and growth. We found that, after 10 years, the legumes seeded concurrently with tree planting actually favored tree growth. Grass alone, however, suppressed tree growth. In this study, 1-0 seedlings of cottonwood, sycamore, loblolly pine, and Virginia pine were planted concurrently with four cover treatments: (1) a control (not seeded to herbaceous species or fertilized); (2) not seeded, but fertilized with N at 60 lb/acre and P at 43 lb/acre; (3) fertilized and broadcast seeded to grass (weeping lovegrass at 4 lb/acre, Ky-31 tall fescue at 16 lb/acre); and (4) fertilized and broadcast seeded to a grass-legume mixture (weeping lovegrass at 2 lb/acre, Ky-31 fescue at 12 lb/acre, common sericea lespedeza at 20 lb/acre, and Korean lespedeza at 10 lb/acre). Simazine 4G at 100 lb/acre was applied to treatments 1 and 2 to prevent initial establishment of herbaceous cover.[3] The minesoils (spoils) in this study were mixed shale and sandstone overburden materials that varied in pH from about 5.0 to 8.0. Lime and mulch were not applied on any treatment (Vogel 1973). Precipitation in most years of this study has been near normal, with generally favorable moisture conditions during the growing season.

The herbaceous vegetative cover in the two seeded treatments (3 and 4) averaged about 70 percent after the first year. Cover was 95 percent by the third year and consisted mainly of Ky-31 fescue in treatment 3 and sericea lespedeza in treatment 4. In the two unseeded treatments herbaceous cover ranged from 10 to 25 percent after 3 years and consisted of native and seeded species. Herbaceous cover has gradually increased in density in the unseeded plots and after 10 years consisted mainly of sericea lespedeza that has seeded-in from adjacent plots.

Except for sycamore, survival of the trees was not seriously affected by either type of seeded vegetative cover. Fifth year survival of all tree species was least in the grass-legume seeding (treatment 4) where it averaged 65 percent for cottonwood, 41 percent for sycamore, 86 percent for Virginia pine, and 81 percent for loblolly pine (Table 1). Apparently, sericea lespedeza

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[3]This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by the appropriate State and/or Federal agencies before they can be recommended.

CAUTION: Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife--if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

contributed to the greater mortality of trees by overtopping and smothering the smaller and weaker seedlings.

Table 1.--Fifth year survival of trees.

| Tree Species | Cover[a/] Treatment | Percent[b/] Survival |
|---|---|---|
| Cottonwood | 1 | 71 |
| | 2 | 73 |
| | 3 | 71 |
| | 4 | 64 |
| Sycamore | 1 | 67 |
| | 2 | 81 |
| | 3 | 50 |
| | 4 | 41 |
| Virginia pine | 1 | 91 |
| | 2 | 92 |
| | 3 | 88 |
| | 4 | 86 |
| Loblolly pine | 1 | 92 |
| | 2 | 90 |
| | 3 | 93 |
| | 4 | 81 |

[a/]1 = None, 2 = fertilizer, 3 = fertilizer + grass, 4 = fertilizer + grass + legume

[b/]Based on 288 trees (6 reps, 48 trees/rep)

In the first three years, the growth of trees, especially hardwoods, was suppressed by the herbaceous cover in both seeded treatments. By the end of the fifth year, the growth of trees still was suppressed in the seeding with grass only. But, in the cover treatment seeded to both grasses and legumes (treatment 4), the growth rate of trees was exceeding that in all other treatments, although the trees still were not as tall as those in the unseeded treatments (Table 2).

Table 2.--Average height of trees planted with and without herbaceous ground covers.

| Species | Cover Treatment[a/] | Height after: | | |
|---|---|---|---|---|
| | | 3 yr | 5 yr | 10 yr[b/] |
| | | feet | | |
| Cottonwood | 1 | 7.0 | 11.4 | 23.7 |
| | 2 | 7.6 | 12.5 | 24.5 |
| | 3 | 3.4 | 6.4 | 17.0 |
| | 4 | 4.1 | 10.4 | 25.8 |
| Sycamore | 1 | 5.2 | 8.5 | 18.0 |
| | 2 | 5.5 | 9.0 | 18.7 |
| | 3 | 1.9 | 3.3 | 11.4 |
| | 4 | 2.1 | 6.9 | 19.2 |
| Virginia pine | 1 | 2.7 | 4.8 | 10.5 |
| | 2 | 2.9 | 5.6 | 14.2 |
| | 3 | 2.1 | 4.1 | 12.4 |
| | 4 | 2.2 | 5.1 | 14.9 |
| Loblolly pine | 1 | 3.0 | 5.6 | 12.3 |
| | 2 | 3.3 | 5.8 | 15.3 |
| | 3 | 2.1 | 4.1 | 13.5 |
| | 4 | 1.8 | 4.7 | 15.8 |

[a/]1 = no treatment; 2 = fertilizer applied (60 lb/acre N and 43 lb/acre P); 3 = fertilizer and grass ('Ky-31' fescue and weeping lovegrass); 4 = fertilizer, grass, and legumes (sericea and Korean lespedezas).

[b/]Nine years for the pine species.

By the tenth year after planting (9 years for the pine) trees in the cover treatment that had been seeded to the grass-legume mixture (treatment 4) were growing at a faster rate and were taller than trees in any other treatment. In plots seeded only to grass (treatment 3) the growth rate and height of trees, especially hardwoods, still lagged behind trees in the other cover treatments. Pine trees planted in the control plots had made the least growth. This may be partly due to minesoil nutrient deficiency as indicated by the better growth of pine in treatment 2 that was fertilized with N and P.

A probable explanation for the growth pattern of trees in the seeded treatments is that during the first 2 to 3 years after planting, the herbaceous cover in both treatments 3 and 4 was predominantly grass. But, in the third year, sericea lespedeza, one of the seeded legume species, became the dominant cover plant in treatment 4; and thereafter, the growth of trees was accelerated by nitrogen that was fixed by the legume plants. Trees growing in cover that remained predominantly grass (treatment 3) were suppressed because the grass was competing with the trees for nitrogen.

Similar results on spoils in northern Alabama were reported by TVA scientists (Bengtson and Mays 1978). They found that loblolly pine fertilized with nitrogen for two or three years after planting grew faster initially than pine that had been seeded with sericea lespedeza but not fertilized with nitrogen after the first year. But after 6 years, the pine in the lespedeza were growing as well as or better than the pine that received the second and third applications of N fertilizer. Survival of pine seedlings was excellent in all cover treatments.

In a Forest Service experiment in western Kentucky, 8 hardwood species and 4 cover treatments were planted on a leveled mined site in 1976. Spoils were predominantly gray shale with pH about 7.0. The ground cover treatments were similar to those used in our eastern Kentucky study but different legume species were used. Survival varied greatly for the various tree species; but when averaged over all species, first year survival was best in the control plots (43 percent). Survival was 31 percent on the fertilizer alone and the fertilizer plus herbaceous species treatments. There was only a sparse herbaceous cover established in the plots, thus the differences in survival were seemingly due to the fertilizer application. In the third year, sericea lespedeza, that apparently had been sown by the mining company a year prior to our planting, became so dense that it was nearly impossible to walk through it let alone find any trees.

In an identical planting made the following year (1977) on a nearby site, overall tree survival the first year was less than in the previous planting. A moderate to good ground cover of red clover, birdsfoot trefoil, and annual lespedeza was established that increased in density for the next couple of years. Survival in this planting was as follows:

| Cover Treatment | Percent Survival 1977 | 1978 | 1979 |
|---|---|---|---|
| Control | 28 | 20 | 17 |
| Fertilizer | 25 | 19 | 18 |
| Fertilizer and legumes | 20 | 13 | 8 |
| Fertilizer, legumes, and grass | 18 | 12 | 5 |

In this latter planting tree survival was affected more by the herbaceous cover than by fertilizer. Other factors, too, probably contributed to poor tree survival in the western Kentucky plantings, especially periods of hot dry weather in the summer that normally are longer in duration and more intense than those in eastern Kentucky. Because of summer droughts, spring seeding in western Kentucky of even herbaceous vegetation often is discouraged in preference to fall seeding.

An experiment in Pennsylvania to evaluate the effect of 6 grasses and 3 herbaceous legumes on the survival and growth of red pine seedlings was begun in 1976 by personnel of the Big Flats Plant Materials Center (PMC) of the U. S. Soil Conservation Service.[4] The plantings were in Tioga County on (1) subsoil (spoil) material on a strip mine backfilled to the original contour and on (2) a similar area covered 8 to 10 inches deep with topsoil. One-half of each test area was treated with lime at 2 ton/acre plus 10-10-10 fertilizer at 400 lb/acre; the other half was not treated. A similar experiment was made in 1977 in Indiana County where red pine and unrooted hybrid poplar cuttings were evaluated on a topsoiled site only.

Results of these studies showed that, after 2 years, tree survival and growth did not differ significantly due to the influence of the different herbaceous species or amounts of herbaceous cover when averaged across all treatments (Table 3). Tree survival and growth were influenced more by topsoiling and by application of lime and fertilizer than by the herbaceous cover. Survival of red pine was 74 percent in the topsoil plots and 60 percent in the subsoil plots. In both topsoil and subsoil plots, tree survival was greater on the areas that were not limed and fertilized.

[4]Interim report by USDA Soil Conservation Service, Plant Materials Center, Big Flats, New York.

**Table 3.--Percent survival of red pine in herbaceous species; second year. (Data from Big Flats PMC, SCS.)**

| Herbaceous Species | Survival % |
|---|---|
| A-67 Weeping lovegrass | 68 |
| Tioga deertongue | 69 |
| Reuben's Canada bluegrass | 70 |
| Commercial redtop | 73 |
| Pennlawn red fescue | 65 |
| Lathco flatpea | 61 |
| Empire birdsfoot trefoil | 66 |
| Chemung crownvetch | 62 |
| Ky-31 tall fescue | 65 |
| Control | 72 |

Although they did not benefit the trees, lime and fertilizer were beneficial for the establishment of herbaceous species, especially on the subsoil. The herbaceous species produced the most ground cover on limed and fertilized topsoil plots; the cover varied from 85 to 100 percent. Cover on the untreated subsoil varied from 0 to 25 percent.

In the 1977 PMC planting, first year survival of hybrid poplar was not significantly affected by the different herbaceous species or amount of cover. Survival of red pine was reduced by a drier-than-usual spring and may have been affected by species with the greatest density, especially by Lathco flatpea in the unlimed and unfertilized plots.

Results of another Pennsylvania experiment indicated that first-year survival and growth of several hardwood tree species were not affected where planted concurrently with various herbaceous species or mixtures of species. In most seedings, the herbaceous cover was considered inadequate for erosion control, but survival of trees was not adversely affected even where they were planted into an established herbaceous cover. Abundant precipitation in the establishment year was credited as the major reason for tree success in all vegetational covers (Carlson 1979).

Wheeler (1976) made observations of several mined areas in Pennsylvania that had been planted with trees in association with seeding of grasses or legumes. On some sites the planting and seeding had been done at the same time. On others, grasses such as perennial ryegrass were sown in the fall previous to planting of trees. Wheeler's observations indicated that a cover of grass did not adversely affect most trees planted at or near the same time that seeding was done. In some plantings, however, some legumes appeared to reduce survival of most tree species. Deer damage to trees was apparent where legumes had been sown.

In a Tennessee study, pitch and Virginia pine seedlings raised in containers (tubelings) were planted with and without a grass cover on intensively amended spots called minisites and on untreated minesoils. The minisites were prepared by mixing pine bark, vermiculite, lime, and fertilizer with minesoil augered from the planting spots. Grass cover caused an increase in the first year's mortality of pine seedlings on both untreated and minisites, but mortality was much greater on the control sites. During the first winter, however, frost heaving of the tubelings on the bare, ungrassed control sites was so severe that, by spring, tree mortality was greater on the bare area than on the grassed areas. A few tubelings frost heaved also on the bare minisites but none heaved on the grassed minisites (Woods et al. 1978).

In southeastern Kentucky, it was shown that herbaceous ground cover established with European alder caused increased moisture stress and thereby contributed to increased mortality of the alder seedlings (Albers and Carpenter 1979).

A large experiment was begun in 1980 by Ashby and others at Southern Illinois University to evaluate techniques for the establishment of woody plants in association with herbaceous cover. First year results were not available when this paper was prepared.

Strip seeding--

Establishing woody and herbaceous species together is possible by sowing the herbaceous species in strips that alternate with unseeded strips planted to trees or shrubs. Ideally, the unseeded strips will remain free of herbaceous vegetation long enough to permit tree establishment, yet the ground cover in the intervening seeded strips will provide adequate erosion control. Also, only the seeded strips need to be fertilized thus reducing possible adverse effects of fertilizer on newly planted tree seedlings. For best erosion control the strips should run on contour. Establishing cover in strips will be easiest to accomplish on land where appropriate equipment can be used to till a seedbed and place fertilizer and seed in strips of uniform width.

In a demonstration in eastern Kentucky, we successfully established hybrid poplar by planting unrooted cuttings in 3-foot wide strips that alternated with 5-foot wide strips that were tilled, fertilized, and seeded to a grass-legume mixture . The strips were on contour on a gently sloping site. The seed mixture included weeping lovegrass, Ky-31 fescue, birdsfoot trefoil, Korean and sericea lespedezas, and red clover. In the first year the herbaceous vegetation in the 5-foot strips covered 60 to 70 percent of the total site. Cover was predominantly weeping lovegrass. The unseeded tree strips were nearly free of herbaceous cover. By the third year, the unseeded strips, too, had become nearly covered with herbaceous vegetation that spread from adjoining strips, but the trees had grown well above it. The herbaceous cover was then a mixture mostly of birdsfoot trefoil, lespedeza, and fescue. Unfortunately, comparative plantings were not made in a solid seeding or with no seeding.

A comparison of strip planting with a solid planting was made in Pennsylvania by the Big Flats Plant Materials Center personnel. In 1976, they planted 2-0 red pine seedlings with a seed mixture of weeping lovegrass, Tioga deertongue, and Lathco flatpea. All plots were limed and fertilized; some plots were planted on subsoil and some on a topsoiled area.

After 2 years, tree survival on the topsoiled area was 58 percent in the strip seeding and 43 percent in the solid seeding. The herbaceous cover was predominantly flatpea and was providing adequate erosion control in both strip and solid seedings. In the solid seeding, cover was nearly 100 percent and it was choking out the young trees. In the strip seeding, tree survival had remained the same for 3 years.

On the subsoil area tree survival was higher in the solid seeding (74 percent) than in the strip seeding (64 percent), but the difference was not related to density or pattern of herbaceous cover. The herbaceous cover on both solid and strip seedings was sparse and not providing adequate erosion control even after 2 year's growth.

In a similar experiment begun by the Big Flats PMC in 1977, the survival of hybrid poplar cuttings after 2 years did not differ significantly between strip and solid seeded plots or between two herbaceous mixtures. Some differences in red pine survival may have been related to the different herbaceous mixtures, but positive relationships were not obvious.

Seeding trees and herbaceous species at the same time

Direct-seeding of woody species offers several advantages over hand planting of seedlings. It usually is easier, less costly, and circumvents many of the labor problems associated with planting seedlings. But there are relatively few species of trees and shrubs that have been successfully established on surface mines by direct seeding. Besides, competition from herbaceous cover can be a problem also with the establishment of direct-seeded woody species.

Seeding of southern pines on mine spoils in Alabama and southern Tennessee has been a common practice for many years, but usually without companion seeding of herbaceous species. In a TVA study, grass and fertilizer applied with pine seed were detrimental to pine establishment. The seeding of Bermudagrass, a warm-season species, was more harmful than the cool-season Ky-31 fescue. The growth of fescue usually slows during the hot summer period and allows some pine seedlings to develop in spots with sparse or no grass. Bermudagrass, however, grows rapidly in the summer and chokes out the emerging pine seedlings. Those that survive the first year in Bermudagrass usually are gone after the second year; but mortality of pine seedlings in fescue usually is low the second year. Seeding pine one year with fertilizer, and applying grass seed and additional fertilizer the next year was recommended for establishing a mixed pine-grass cover on areas where erosion is not a serious problem. Where erosion is a problem, Bermudagrass should be established first and pine seedlings planted the second or third year when the vigor of the grass declines due to depletion of nutrients (Bengtson et al. 1973).

Direct-seeding of black walnut and bur oak on mine spoils in the midwest produced satisfactory stands in some of the early experimental tree plantings. Ground cover of volunteer vegetation varied among sites but seldom was it considered dense.

On minesoils in eastern Kentucky, the first year survival of germinated seed of red oak, pin oak, and bur oak was reduced by a cover of ryegrass and sweetclover. Average survival of the three oak species for all treatments of mulch and fertilizer was 50 percent on the control site and about 38 percent on the sites with herbaceous cover. Height of the seedlings was not affected by the grass-legume cover (Tackett and Graves 1979).

Direct-seeding black locust with herbaceous species has been practiced in much of the Appalachian region. Establishment of the locust usually is successful but sometimes does not appear so for two or three years. This was illustrated in one of our experiments.

We evaluated the effect of several herbaceous species on the establishment of seeded black locust. The fertilized and seeded experimental plots were laid out on moderately steep slopes of spoils (pH 5.0 to 7.8) that had received minimum grading. The first year's results showed marked differences in number and height of black locust seedlings among the various herbaceous species (Table 4). It appeared that fast-growing cool-season species, especially ryegrass, were more suppressive than warm season and slow-developing species to the early survival and growth of seeded locust. But in the second year and thereafter, these differences were less pronounced among the grass and legume cover species.

Table 4.--Vegetative cover and number and height of black locust seedlings in plots seeded to herbaceous species and black locust.[a]

| Herbaceous Species Seeded | | Herbaceous Cover | | Black locust seedlings Number | | Height | |
|---|---|---|---|---|---|---|---|
| | | 1969 | 1970 | 1969 | 1970 | 1969 | 1970 |
| | | % | | on .01 acre | | cm | |
| None (natural seeding) | | 15 | 25 | 54 | 51 | 24 | 98 |
| Birdsfoot trefoil | (8)[b] | 40 | 85 | 18 | 14 | 18 | 59 |
| Kobe and Korean lespedeza | (10) | 45 | 70 | 22 | 24 | 17 | 94 |
| Weeping lovegrass | (5) | 80 | 85 | 24 | 34 | 17 | 79 |
| Sericea lespedeza | (20) | 25 | 55 | 31 | 26 | 15 | 61 |
| Ky-31 tall fescue | (15) | 60 | 75 | 15 | 22 | 13 | 58 |
| Perennial ryegrass | (15) | 70 | 55 | 9 | 23 | 10 | 57 |
| Annual ryegrass | (15) | 70 | 40[c] | 9 | 25 | 7 | 73 |

[a] Seeded in March 1969; evaluated in October, 1969 and 1970. Fertilized with 60 lb/acre N and 43 lb/acre P. Black locust seeded at 3 lb/acre.

[b] Seeding rate (lb/acre).

[c] Mostly plant residue.

## Seeding herbaceous cover first and planting trees later

This two-step concept for afforestation is of special interest mainly because many acres of surface-mined land have been vegetated solely with herbaceous species either for economic reasons or in compliance with regulations that require ground cover for erosion control and aesthetics. But, now, there is increasing interest or requirement to establish woody species on many of the grassed areas. This concept may be the most feasible also for afforesting many of the mined areas being reclaimed under present regulations.

With this concept, the woody species may be planted (1) directly into living herbaceous cover or (2) into herbaceous cover killed or weakened with herbicides, scalping, or cultivation. The second approach seems to hold the best chance for tree planting success because living cover usually is the most competitive with newly planted trees.

Planting trees in living cover--

In an experiment in eastern Kentucky, Plass (1968) planted seedlings of 2 hardwood and 2 pine species into a 2-year-old stand of Ky-31 tall fescue. The fescue had been established without application of fertilizer and the ground cover was described as light to moderate. The established ground cover was removed from one-half of each plot before planting trees, and the volunteer vegetation was grubbed out once or twice during each of the next 4 years. After the 4th growing season, survival of sycamore and sweetgum was not affected by the fescue cover; survival of white pine and loblolly pine was reduced slightly. The height of sycamore and sweetgum was significantly reduced by the fescue cover; height of the pines was reduced, but not significantly so. The results suggest that tree survival and growth would have been more adversely affected in a dense vigorous cover of fescue.

A revegetation demonstration was made in 1965 on a surface mine at about 2800 feet elevation in Bell County, Kentucky. Several hardwoods, conifers, and shrubs were planted in a moderate to dense stand of Ky-31 fescue and Korean lespedeza. Nitrogen-fixing trees and shrubs--European alder, black locust, autumn olive, and bicolor lespedeza--had reasonably good survival and grew rapidly. Other hardwoods--yellow-poplar, sycamore, and red oak--and Norway spruce had poor survival and initially grew slowly. Scotch pine had moderate survival and growth. About 10 years later, a few of the surviving hardwood trees were making acceptable growth, but many had poor form and were growing slowly. In contrast, some yellow-poplar trees that had become established by natural seeding in a stand of European alder were growing more rapidly than most of the artificially planted trees.

Verbal reports on results of plantings in some areas indicate complete failure of all tree species, even the nitrogen-fixers, where planted into established herbaceous cover. A few reports indicate varying levels of success, but success is mostly with black locust, autumn olive, bicolor lespedeza, and to a lesser extent European alder and pine. Developed stands of some herbaceous species such as crownvetch, sericea lespedeza, and flatpea are especially inimical to the establishment of trees.

Planting trees in cover killed with herbicide or scalping--

An alternative to planting trees in established herbaceous cover is to kill or weaken the herbaceous cover before or immediately after planting the trees. One likely method is the application of a non-residual herbicide before planting trees. This method was useful in West Virginia for killing fall-sown rye just prior to spring seeding of perennial forage species. The *in situ* mulch produced by killing the rye was equal to or more effective than applied mulches for conserving soil moisture and reducing erosion (Jones et al. 1975).

Carlson (1979) compared Roundup and paraquat[5] applied in strips with no treatment prior to planting trees on a Pennsylvania strip mine. The Roundup was more effective than paraquat in reducing herbaceous competition. But, in this planting, tree survival was not significantly increased by killing the herbaceous cover. This was attributed to abundant spring and summer rainfall.

First year results of an experiment in western Kentucky showed that herbicide applied to a fescue-alfalfa cover was responsible for greater tree survival than in the untreated cover. The herbicide was applied around the pine seedlings after they were planted (Barnhisel 1979).

This past spring, we initiated an experiment in southeastern Ohio with the use of Roundup herbicide for killing a grass-legume cover in strips and spots prior to planting several species of trees. The herbicide was applied about 7 days before the trees were planted. First-season evaluations of tree establishment have not yet been made.

Scalping and similar types of mechanical tillage will also control or reduce herbaceous competition. In one experiment in southeastern Kentucky, European alder seedlings suffered complete mortality the first year where planted in an untreated 2-year-old stand of Ky-31 fescue; but survival was 43 percent where the grass had been mechanically scalped from around the seedlings (Carpenter and Albers).[6]

Annuals for temporary cover before planting trees--

Annual species probably can be effectively used for providing temporary cover and *in situ* mulch prior to tree planting. Summer annual grasses such as foxtail millet, Sudangrass and other sorghums, and pearl millet

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[5]Mention of brand names does not imply endorsement or recommendation for use.

[6]Manuscript in press.

are especially useful for providing quick temporary cover in late spring and early summer. The residue from these crops can provide site protection over winter. The following spring, trees can be planted along with a seeding of perennial herbaceous species. A modification of this procedure is to include, where climatically adapted, Korean or Kobe lespedeza in the summer-annual seed mix. These annual legumes normally reseed and would be present to establish plant cover in the spring and summer after the trees have been planted. Perennial herbaceous species would then be sown in the late summer or fall of the second year.

Winter annuals, such as rye or wheat, sown in late summer or early fall will provide ground cover in the winter. Trees may be planted directly into the cover the following spring, but the herbaceous species may compete strongly with the trees (winter planting of trees also is possible). To reduce competition, the entire cover could be controlled with a non-residual herbicide just prior to planting of trees, and the perennial herbaceous species sown. An alternative procedure is to kill strips of the winter annual crop with an herbicide or scalping. Korean or Kobe lespedeza could be sown on the entire area or only on the strips along with the planting of trees. Perennial herbaceous species could be sown over the entire area in late summer.

Seeding annuals in the spring for temporary cover in conjunction with planting of trees showed no advantage over seeding perennial grasses and legumes as determined in a Pennsylvania study by the SCS Plant Materials Center. In some plots, tree survival was lower in the annual vegetation than in perennial vegetation.

### Planting or seeding trees first and herbaceous species later

This concept normally should provide the least herbaceous competition and the best chance for initial survival of newly planted or seeded tree seedlings. Results of some of the previously described experiments verify this. For example, Bengtson et al. (1973) showed that to obtain adequate stocking, pine seed only should be sown with application of the required amount of fertilizer. Seeding herbaceous species the following year resulted in some reduction in pine stand, but much less so than where pine and herbaceous species were sown at the same time.

Under present regulations, however, this method of planting trees is not likely to be approved because the quick establishment of vegetative cover is required for all land uses. The procedure most nearly approaching this concept is planting trees and sowing herbaceous species in alternate strips as previously discussed.

## DISCUSSION AND CONCLUSIONS

Results of research and experience with planting trees and herbaceous species together indicate that, generally, herbaceous cover causes an increase in mortality of tree seedlings and may retard tree growth, at least in the first few years after planting. Competition between trees and herbs seems to be primarily for moisture because survival of trees was least affected where spring and summer precipitation was most abundant. Besides total precipitation, moisture availability to plants can be influenced by the physical properties of minesoils, duration of dry periods or frequency of precipitation events, air temperature, wind, evaporation, latitude, elevation, aspect, etc.

Competition for nutrients seems to affect tree growth more than tree survival as indicated by apparent nitrogen deficiency and reduced tree growth in grass cover. Tree growth usually is better on nitrogen fertilized areas and in legume cover once trees have grown taller than the herbaceous vegetation.

Density of herbaceous vegetation can influence the degree of competition and thus the survival and growth of trees. For example, in experimental plantings in Illinois, second-year survival of 17 tree species averaged 61 percent in sparse light ground cover (less than 50 percent cover) and 27 percent in a dense heavy cover of sweet clover. Only two tree species (white ash and eastern red cedar) survived well in the dense cover (Limstrom and Deitschman 1951).

Competition for light, i.e., shading of tree seedlings from sunlight, affects both survival and growth of tree seedlings and may occur more with dense stands of legumes than with grasses. The season when the various plant species make most of their growth may interrelate with shading and competition for sunlight. For example, legumes such as birdsfoot trefoil and red clover make rapid growth in the spring at about the same time as some tree species, such as pine, make most of their growth. Perhaps the dense foliage of these legumes contributes to tree seedling mortality by excluding light from the small seedlings during the time when light is most needed for their growth. Warm-season legumes, such as sericea lespedeza, would not provide dense shade until early- to mid-summer, after the pine have made most of their season's growth. However, shade of warm-season legumes may be detrimental to tree species that continue growth through the summer. Also, warm-season species probably compete more than cool-season species for moisture during periods of summer drought. Obviously, more research is needed to elucidate some of these relationships among species.

Herbaceous species can have indirect effects on tree survival and growth. For example, herbaceous legumes are more attractive than grasses to deer. In areas with large populations of deer, trees planted with legumes, therefore, are more subject to damage by deer browsing. In such areas, the least palatable of the adapted grasses may be the best choice for combination plantings. This may warrant greater use of warm-season grasses because they do not provide green forage in the fall, winter, and early spring when it is most attractive to deer.

Although in some experiments little difference in initial tree survival was noted among several herbaceous covers, some herbaceous species usually are more competitive than others with companion trees. Several legumes--crownvetch, flatpea, sericea lespedeza, and probably red clover--are especially severe competitors where they get a quick start and overtop the tree seedlings. Competition from these legumes is less severe where the trees have a chance to become established first. The establishment of dense stands of these legumes can be slowed by sowing them at a reduced seeding rate. Another option is to sow them only in strips that alternate with unseeded strips planted to trees. Even in strips, the seeding rate should be reduced from that normally recommended for ground cover. In fact, for combination plantings, seeding rates in general should be reduced from those often recommended for ground cover.

One reason given in favor of establishing a dense legume cover in conjunction with afforestation is to keep sunlight from the soil surface and thereby aid development of a rich soil fauna in a shorter period of time. The legume cover can substitute for the closed canopy that would develop from close spacing of trees. Grass does not provide a favorable environment for forest-dwelling soil fauna (Neumann 1973).

There seems to be no "ideal" species or seed mixture for sowing with trees in all situations or all regions. Obviously, species should be adapted to the season of the year when seeding must be done. For seeding in the spring, a mixture of temporary quick cover and perennial herbaceous species may be desirable. Ideally the quick cover species should be one that is not too competitive with trees. Such a species is difficult to define. Perennial ryegrass, for example, is less vigorous and may be preferable to annual ryegrass as a quick cover species for early spring seeding. The density and vigor of cover can perhaps be controlled by the application rate of fertilizer. Nitrogen at no more than 50 to 60 pounds per acre should support adequate growth of grass without excessive vigor. Less nitrogen may be adequate on fertile topsoil. Phosphorus should be applied at rates indicated by soil test, or if not tested, at about 40 to 50 pounds per acre of P.

Summer seedings can take advantage of summer annuals for quick cover. Also, Korean and Kobe lespedeza should be used wherever possible. These annual legumes are probably some of the most compatible with trees.

Fall seeding presents a more difficult situation for establishing herbaceous cover and trees because the cover is already established before tree planting time the following spring. The use of herbicides or scalping to control the herbaceous cover in planting spots or strips may be a feasible solution for planting trees in fall-seeded cover. One problem associated with the use of herbicides in the spring is that the herbaceous vegetation should be actively growing for most effective results. But, by waiting until the herbaceous cover is sufficiently advanced for effective herbicide kill, the ideal period for spring planting of trees is nearly passed. Fall application of herbicide and winter or spring planting of trees is a possible alternative.

A labor-intensive method for conserving soil moisture and reducing immediate herbaceous competition is to apply shredded bark mulch about 4 to 5 inches deep around each tree seedling. This method would probably be feasible only with high value crops such as black walnut.

Allelopathy is another process that may hinder the establishment of trees planted or seeded with herbaceous cover. The possibilities for allelopathic effects are many, but few of the possible combinations have been studied. For example, results of studies at the Ohio Agricultural Research and Development Center showed that daily watering with a leachate from crownvetch foliage was inhibitory to the growth of newly germinated red oak seed, but had no adverse effect on fully developed seedlings (Dr. Merlyn Larson).[7]

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[7] Unpublished data.

It is apparent that knowledge and experience with planting trees in conjunction with herbaceous cover is still in infancy. Various combinations of trees and herbs have worked from time to time, but probably more have failed. We usually can suggest reasons for failure, such as a drought, but find it more difficult to understand the successes. Continued applied and basic research is necessary to find more answers.

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