ESTABLISHMENT OF TREES IN HERBACEOUS COVER ON GRADED LENZBURG MINESOIL[1]

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Abstract.--The effects of a developing herbaceous cover on tree survival and growth, with and without herbicides, were evaluated on graded, fertilized, remined boxcut spoil in southern Illinois. A pasture mix of tall fescue (Festuca arundinacea Schreb., selection Ky-31), orchardgrass (Dactylis glomerata L., selection Potomac), and alfalfa (Medicago sativa L., selections Arc and Kansas) was sown in the fall 1980 and spring 1981. The herbaceous cover was poorly established in 1981 and well established in 1986. Tree seed of green ash (Fraxinus pennsylvanica Marsh.), black walnut (Juglans nigra L.), and northern red oak (Quercus rubra L.) were planted in fall of 1980 and 1981, and tree seedlings of the same species were planted in spring of 1981 and 1982. Half of the 5,760 tree planting spots were herbicided with Roundup and Princep early in the first growing season after each planting. Survival and growth measurements in 1986 showed slightly better survival of non-herbicided green ash, better survival of hercided black walnut and red oak, and better growth of herbicided trees in all experimental groupings. Survival and growth of trees planted the same season as the herbaceous cover (6-year-old trees) were higher than of trees planted in year-old herbaceous cover (5-year-old trees), except for survival of black walnut from seed. Both tree survival and growth were relatively low on the graded minesoil with herbaceous competition.

INTRODUCTION

Successful reclamation typically includes a revegetation component, be it row crop, pasture, forest, or other land uses. How reclamation is carried out is regulated by State and Federal Agencies. Applicable regulations include grading and establishment of a ground cover for erosion control. Soil compaction associated with site grading in the midwest typically increases the need for erosion control because of decreased rates of water infiltration and increased rates of runoff.

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Tree planting was often the only type of reclamation prior to the Surface Mining Control and Reclamation Act of 1977 (PL 95-87), with millions of trees successfully planted (Ashby et al. 1978). Ground cover was rarely used and tree seedlings commonly established and grew well. Less success has attended many post-law tree plantings, leading to widespread concern among reclamation personnel that today's emphasis on ground cover limits tree survival and growth.

Because of their vigor, available seed, and widespread use, pasture grasses and legumes are commonly used for ground cover in reclamation plantings. These species are especially detrimental to survival and growth of trees. Our study focused on testing whether trees of green ash, black walnut, or red oak planted initially with pasture species would be more successful than those planted later in developing herbaceous cover. Other studies are being carried out to find those herbaceous species which are especially effective for erosion control and which do not compete excessively with tree seedlings.

MATERIALS AND METHODS

This study was carried out on spoil that had been remined in the late 1970's by Freeman United Coal Mining Company's Fidelity Mine in southern Illinois. Cast overburden from a boxcut was graded to a mound about 1.5-km (1-mile) long with a minimal, but still substantial amount of grading. Minesoil bulk densities measured on the study site ranged from 1.60 to 1.90 g/cm^3 (Norland 1982). The rooting medium has been classified as Lenzburg gravelly silty clay loam with an average 15% north-facing slope. Minesoil samples generally had a pH above 7.0 with occasional acidic "hot spots". Available phosphorus (Bray P_1) and potassium tested very low, and reserve phosphorus (Bray P_2) high. Plant foliar analyses showed only P to be deficient.

In August-September 1980 a section of this mound was broadcast fertilized with 112 kg/ha (100 lb/A) each of ammonium nitrate and triple super phosphate and sown with 0.2 hectoliters/ha (1.5 bushel/A) oats (Avena sativa L.) as cover crop, and with a pasture mix of inoculated Arc alfalfa (11.2 kg/ha or 10 lb/A), Ky-31 tall fescue (11.2 kg/ha), and Potomac orchardgrass (4.5 kg/ha) in accordance with provisions of the federal surface mining act. Because of poor establishment during a continuing severe drought in 1980, the area was resown with each species at half-rate in March 1981. Kansas rather than Arc alfalfa was used in the spring.

A 4-ha (10-acre) study site planted to ground cover was divided into 40 tenth-ha (quarter-acre) plots and planted to a total of 5,760 trees in the same seasons as the pasture species, either concurrently or 1 year later. Each plot had 12 rows of 12 trees each on a 2.5-m (8.2-ft.) spacing with one-fourth of the green ash, red oak and black walnut rows planted successively in fall 1980, spring 1981, fall 1981, and spring 1982. Rows were completely randomized per plot. Recently-collected seed of all species was planted in the fall, and seedlings in the spring. Multiple seed per spot were planted based on expected germination percentages.

In the early spring of the first growing season after planting a mixture, 1.5% each of Roundup (9.4 l/ha with 41% active ingredient [a. i.] glyphosate) and Princep (5.6 kg/ha with 80% a. i. simazine) herbicides, was sprayed on the developing ground cover in a 1.5-m circle around half of the trees. Use of trade names does not constitute endorsement of these products. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Adjacent columns of plots were combined to give 20 paired plots with 24 rows each, and rows of each tree species in the 20 paired plots were randomly selected for spraying. Thus, half of the fall 1980/spring 1981 plantings were herbicided in 1981, and half of the fall 1981/spring 1982 plantings in 1982. Survival counts were taken in 1981, 1982, 1983, and 1986. Height measurements were made in 1986.

Our research objective was to evaluate survival and growth of trees planted in a developing cover of highly competitive herbaceous species. Three specific research questions were:

A. Do tree species successively planted in a developing herbaceous cover differ in their survival and growth?

B. Is establishment, survival, and growth of trees influenced by the use of herbicide?

C. Do trees planted in the fall as seed, or in the spring as seedlings, have better survival and growth?

This study utilized a randomized complete block design. The experimental unit for survival was a planting spot, and for height was a planting row of 12 planting spots. If few trees survived, numerous planting rows with zero height resulted in a mean height lower than the median value for trees of that experimental grouping.

Statistics were calculated by computer using the SAS (Statistical Analysis System) and the PROC GLM (general linear model procedure) to determine significant ($\alpha = 0.01$) differences in a

three-way analysis of variance. Differences between species, treatment, and planting type/season along with main effect interactions were tested.

RESULTS

Establishment of the pasture species was good. After 6 growing seasons tall fescue was recorded in 98% of the tree rows, alfalfa in 85% and orchardgrass in 3%. Although the herbicide treatments were relatively effective and still evident as bare or thinly vegetated circles for numerous seedling- or seed-spots in 1986 after either 6 or 5 tree-growing seasons, herbaceous competition likely still affected the tree seedlings even in the herbicided rows. An indirect effect was that in 1984 a tremendous vole/field mouse population in the herbaceous cover girdled nearly all red oak, stripped bark on the green ash, and chewed the bark on many walnut. The high point of vole population density coincided with a severe growing-season drought period that likely exacerbated the tree damage from voles as the herbaceous vegetation dried up. Growth measurements were not made in 1984 because for many seedlings it was not possible to tell whether they were still alive or not.

Scattered deer browsing was observed on several occasions. Drought effects on the trees and herbaceous cover had also been evident in 1983. Related to these several factors basal sprouting and/or tip dieback were common for all species in all groupings.

Number of surviving trees and mean row height showed significant differences for species, planting method/season, and for their interaction for all ages of trees planted concurrently with, or one year later than the herbaceous cover pasture mix (tables 1 and 2). Herbicide treatment effects in year 6 and year 5 were significant under all treatments except for tree survival when planted later than the pasture mix (table 2). Interaction effects involving herbicide treatment were minor. The apparently inhibitory effects of herbicides on green ash affected the analysis of variance.

Trees from seedling (versus seed) origin had higher survival and mean row heights, as did those herbicided versus non-herbicided (table 1). Green ash had greater survival and mean row height than black walnut or red oak when planted either concurrenly with a pasture mix or 1 year later. Black walnut outperformed red oak when planted in year-old herbaceous cover.

Including Norland's (1982) data from years 1, 2, and 3 it is evident that the number of surviving trees of all species, treatments, and plantings decreased with age under both planting schedules (table 3). The relative decrease in numbers from year 1 to year 6 or 5 was greatest for green ash and red oak seed, and black walnut seedlings. Green ash established and survived less well from seed than the other two species. Fewer green ash survived when herbicided, in contrast to black walnut and red oak. The number of surviving black walnut was greater from seed than seedlings.

DISCUSSION

This study included state-of-the-art reclamation practices as well as utilizing a site reclaimed under the then-applicable State and Federal regulations. Our choice

Table 1.--Percent survival and mean row height after planting for populations of green ash, black walnut, and red oak planted concurrently with a pasture mix or 1 year later.

	Survival				Mean Row Height[1]			
	Pl. Conc. (Year 6)		Pl. Later (Year 5)		Pl. Conc. (Year 6)		Pl. Later (Year 5)	
Grouping	%	%	%	%	cm	cm	cm	cm
A Species	20.8		10.0		29.4		17.5	
Green ash		35.8		16.7		40.9		26.1
Black walnut		11.7		10.8		25.1		21.0
Red oak		14.2		2.5		22.2		5.5
B Treatment	20.8		10.0		29.4		17.5	
Non-herbicide		17.5		9.2		21.3		11.8
Herbicide		24.2		11.7		37.4		23.2
C Planting	20.8		10.0		29.4		17.5	
Seed/Fall		6.7		6.7		16.2		11.7
Seedling/Spring		34.2		13.3		42.6		23.3

[1]Mean heights on a per-tree basis for green ash, black walnut and red oak respectively were for year 6--82.5, 51.1, and 39.1 cm; and for year 5, with lower survival--56.6, 61.1, and 22.2 cm.

Table 2.--Analysis of variance (oc = 0.01) for survival and mean row height 1, 2, or 6, and 1 or 5 years after planting for populations of green ash, black walnut, and red oak planted either concurrently with a pasture mix or 1 year later.[1] Treatment was herbicide and non-herbicide. Planting was seed/fall and seedling/spring.

	Number of Surviving Trees					Height	
	Planted Concurrently			Planted Later		Pl. Conc.	Pl. Later
Grouping	Year 1	Year 2	Year 6	Year 1	Year 5	Year 6	Year 5
A Species	*	*	*	*	*	*	*
B Treatment	-	-	*	*	-	*	*
C Planting	*	*	*	*	*	*	*
AB	-	-	*	*	-	-	-
AC	*	*	*	*	*	*	*
BC	-	-	-	*	-	-	-

[1]Data for years 1 and 2 from Norland (1982).

Table 3.--Percent survival and mean row height 1, 2, 3, or 6 and 1, 2, or 5 years after planting for populations of green ash, black walnut, and red oak planted either concurrently with a pasture mix or 1 year later.[1] Seed was fall- and seedlings spring-planted.

		Survival							Height	
		Planted Concurrently				Planted Later			Pl. Conc.	Pl. Later
		Year 1	Year 2	Year 3	Year 6	Year 1	Year 2	Year 5	Year 6	Year 5
Planting	Treatment	%	%	%	%	%	%	%	cm	cm
					Green ash[2]					
Seed	Non-herb.	3.4	0.8	0.0	0.0	22.1	0.8	0.0	0.0	0.0
	Herbicide	4.9	0.8	0.4	0.4	5.8	0.4	0.0	4.2	0.0
Seedling	Non-herb.	96.3	94.2	92.1	75.4	63.8	52.5	36.2	66.2	41.7
	Herbicide	94.5	92.1	89.6	68.8	63.8	63.3	31.2	93.4	62.6
					Black walnut					
Seed	Non-herb.	64.2	40.4	30.8	8.8	53.3	44.2	12.5	20.0	19.0
	Herbicide	70.0	39.6	36.7	21.7	77.1	75.4	22.1	46.8	39.4
Seedling	Non-herb.	91.3	48.3	24.6	2.1	60.8	11.7	1.7	8.1	4.2
	Herbicide	93.6	55.0	38.8	15.0	89.2	46.2	7.1	25.5	21.6
					Red oak					
Seed	Non-herb.	99.6	91.6	42.1	2.9	62.1	24.6	2.1	9.7	4.2
	Herbicide	96.0	86.9	53.8	7.9	79.6	40.4	2.9	16.4	7.8
Seedling	Non-herb.	89.9	68.8	45.8	16.2	60.4	11.2	0.8	24.0	1.9
	Herbicide	89.6	80.4	64.6	29.6	90.4	40.4	5.0	38.4	8.2

[1]Data for year 1, and year 2 planted concurrently, from Norland (1982).
[2]Green ash had 3 seed per seed spot in Fall 1980 and 12 seed per seed spot in Fall 1981. Black walnut and red oak had 3 seed per seed spot both seasons.

of the herbaceous cover pasture mix was based on current industry practice and on research by Grandt and Lang (1958) and others.

Our choice of tree species was based on experience and on review of a relatively extensive reclamation reforestation literature (Ashby et al. 1978, Vogel 1981). Further guidelines were earlier results from direct seeding (Kolar et al. 1981, Philo et al. 1981), expected deleterious effects of herbaceous cover on trees (Vogel 1980), and availability of methods for weed control (Parr 1982, Philo et al. 1983). We expected tree survival and growth to be limited by other possible adverse features of the mine site such as compaction (Limstrom 1960, Philo et al. 1982). Limitations from allelopathy were not specifically known.

We have observed similar good relative success of tall fescue and alfalfa and poor success of orchardgrass at

several mine sites in southern Illinois, and conspicuous mortality of tree seedlings in dense tall fescue or alfalfa cover. When reforestation is a primary objective, less competitive herbaceous species would be desirable.

Specific identification of other possible limiting factors has not been feasible. Severe drought periods in 1983 and 1984, and the vole irruption in 1984 likely were of importance. The severe damage by voles in dense herbaceous cover of our study coincided with industry-wide losses of Illinois and Indiana tree plantings in the same year. A low-growing herbaceous cover would probably be better than tall fescue or alfalfa to increase visibility for predators of voles and other rodents that damage tree seedlings.

Our findings that even a 1-year-old herbaceous cover limits tree survival and growth reinforce Vogel's (1980) recommendation to plant trees at the same time or before the herbaceous species, if the latter have to be used. The numerous excuses to delay tree planting--seedlings not available, planting crews busy, current budget problems--need to be balanced against the greatly increased likelihood of planting failures. Acceptance of the generally favorable effects of herbicides has been reinforced by the results of this study. The effects of herbicide treatment evidently persisted longer than usually reported, with both favorable effects for black walnut and red oak, and the adverse effects for green ash, becoming more evident with time from year 1 to year 6 or 5. One hypothesis is that simazine as a pre-emergence herbicide had greatest effects on survival when trees and herbaceous cover were planted concurrently, and glyphosate as a contact herbicide had greatest effects on survival for trees planted 1 year later within an established herbacous cover. The need for further guidelines on use of herbaceous cover and for use of herbicides when growing trees has been demonstrated.

Our findings also support earlier reports of poor success in planting small-seeded species (ash) from seed (black locust [Robinia pseudoacacia L.] would be a bold exception), and of much better success with large-seeded trees (black walnut, which has been widely studied, and red oak). An ability of fall-seeded black walnut to outgrow seedlings became evident with a developing herbaceous cover. Philo et al. (1981) reported that controlling dense herbaceous vegetation with either herbicides or cultivation has given marked improvement in the survival of direct-seeded black walnut.

Seedlings were clearly superior in establishment and survival of green ash. Although poor ash germination/establishment could be attributed to poor seed, the dying off the trees which did establish from seed was unexpected. Sensitivity of ash to herbicide, or allelopathy, could have been a factor in early mortality from seed. Green ash from fall-planted seed is not recommended for reclamation plantings, and careful attention should be given to possible herbicide damage in use of ash seedlings under present reclamation practices. Green ash had lower percent year 1 survival than red oak or black walnut when machine-planted on graded sites with weed control (Parr 1982). Raisanen (1982), with similar overall survival had higher survival of all three species when herbicided.

An interpretation of the red oak survival data, and to a lesser extent the growth data, is that seedlings planted in the spring with a pasture mix had enough head start to attain more than twice the survival and growth of the plants from seed and seedlings planted a year later. Differential effects of voles in 1984 within the seriously affected red oak population were not observed. A relatively bare circle around the herbicided trees may have inhibited vole activity somewhat.

SUMMARY AND CONCLUSIONS

Herbaceous cover adversely affected establishment and later survival and growth of trees in reclamation. These effects were partially offset by planting trees early relative to the herbaceous cover, and by using herbicides to create a bare area around each tree seedling. Caution is needed in using herbicides with green ash.

Fall seeded green ash is not recommended. Green ash seedlings outperformed black walnut and red oak either when planted concurrently with herbaceous cover, or when planted in 1-year-old herbaceous cover.

The best red oak performance 5-6 years after planting was from seedlings planted with the herbaceous cover, especially with use of herbicides. By years 5 and 6 black walnut performed best with fall-planted seed. Walnut from seed performed equally well when planted concurrently with herbaceous cover or in year-old herbaceous cover. Herbicide application increased walnut survival and height growth. Based on this study, if other site conditions are favorable the best choices for reclamation tree plantings in established herbaceous cover would be fall planting of black walnut seed, and spring planting of green ash seedlings, with as much control of herbaceous cover as possible.

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