THE VOLUNTEER COMPONENT IN REFORESTATION OF MINED LANDS[1]

M. M. Larson[2] and J. P. Vimmerstedt[2]

Abstract.--Volunteer trees were inventoried in three, 30-year-old stripmine plantations, each located on a distinctly different type of minesoil and each containing subplots planted with white pine (Pinus strobus), black locust (Robinia pseudo-acacia), white ash (Fraxinus americana), and yellow-poplar (Liriodendron tulipifera) after mining. Volunteer trees were those that seeded-in later. Near-neutral minesoil derived from glacial till and sandstone had the greatest number of volunteers/acre at 929 trees, followed by 698 trees/acre on acidic shaly sand minesoil, and 516 trees on calcareous limestone and clay minesoil. Mean basal area/acre of volunteer trees was 13 ft^2 on the calcareous clay minesoil as compared to 26 ft^2 on each of the other two plantations. The six most numerous volunteer species were: black cherry (Prunus serotina) (31.3% of total volunteer trees), black locust (19.3%), white ash (12.4%), hawthorn (Crataegus sp.) (12.1%), red maple (Acer rubrum) (8.2%), and elm (Ulmus sp.) (7.1%). The number of volunteer trees varied with the species planted on plantation subplots, but relationships often differed among individual volunteer species in these plantations. As examples, subplots planted with black locust contained high numbers of black cherry volunteers on near-neutral and acid minesoils. Subplots planted with white pine had the fewest volunteers, except on calcareous clay minesoil where a significantly large number of white ash volunteers were found. Volunteer trees outnumbered planted trees at a 7:4 ratio, all plantations combined, but planted trees accounted for 72 percent of the total basal area and dominated the subplot stands. The importance of the volunteer component in these stands is expected to increase, although the species composition of future stands is unclear.

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[2]M. M. Larson is a Professor and J. P. Vimmerstedt is an Associate Professor, School of Natural Resources, The Ohio State University and the Ohio Agricultural Research and Development Center, Wooster, OH 44691. Salaries and research support provided by State and Federal Funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University. Manuscript No. 258-87.

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INTRODUCTION

Nearly all land stripmined for coal in the Appalachian Region is eventually invaded by volunteer tree species unless cropped, grazed, or otherwise managed in a way that prevents the establishment of tree seedlings. Even when mined areas are planted with trees, regardless of species, volunteer trees appear sooner or later.

Many species of trees are known to invade plantations on mined lands. After a time, invader or volunteer trees often become numerous and, in some cases, outnumber planted trees (Ashby et al. 1980, Davidson 1981). The volunteer component may consist of species with little economic importance such as hawthorn or sassafras (*Sassafras albidum*), or it may contain valuable species such as ash, maple, black cherry, and oak (*Quercus* sp.) (Haynes and Klimstra 1975, Stiver 1949, Vogel 1977).

This paper examines the results of a study of volunteer trees on 30-year-old minesoils planted with four different tree species following mining. Results reported here are partly based on data published earlier in bulletin form (Larson 1984). Also, some ecological factors that appear to govern the establishment and growth of volunteer species on mined areas are discussed.

DESCRIPTION OF RESEARCH

Plantations and Field Work

Three 30-year-old plantations, each located on a different minesoil type in East-Central Ohio, were used in this study. The location, number of subplots inventoried, and minesoil description of each plantation are given in table 1. The greatest distance between any two plantations is less than 50 miles. These plantations were established by the Central States Forest Experiment Station in cooperation with the Ohio Reclamation Association, Ohio Division of Forestry, and several coal companies.

Each plantation consisted of several subplots which were either 70 ft x 70 ft (0.11 acre) or 105 ft x 105 ft (0.25 acre). Each subplot was planted to a single tree species. Only subplots originally planted to either white pine, yellow-poplar, white ash, or black locust and which had 160 or more surviving trees at 30 years were selected for study. This insured that moderate amounts of planted trees were present on subplots selected for study of volunteer species.

The number and diameter of all volunteer and planted trees by species were measured on a 41.7 ft x 41.7 ft (0.04-acre) sample plot located in the center of each plantation subplot. Natural reproduction of planted species was included in the volunteer inventory, except for black locust reproduction found inside subplots planted with black locust (see Results and Discussion section).

Statistical Analysis

The relationship between plantation location (main differences being minesoil type) and planted tree species to number and basal area of volunteer species on sample plots was analyzed by the method of least-squares for unequal subclasses (Harvey 1960). This type of analysis permitted calculation of residual correlations between dependent variables after treatment effects were removed.

A second statistical analysis of volunteer data was also carried out in which the density of planted trees, which varied from sample plot to sample plot, was included as a covariate. This procedure, in effect, allowed evaluation of plantation location and planted species effects without bias due to differences in density of planted trees on sample plots.

However, comparison of the first analysis without covariates to the second analysis with covariates revealed few differences, as indicated by similar probability levels of the F-tests. Unless otherwise stated, the results that follow are based on the analysis without covariates.

RESULTS

The number of volunteer trees varied greatly between the three plantations (table 2). Plantation 2 (near-neutral minesoil) had the most volunteers at 929 trees/acre, which was 44 percent greater than the number found in Plantation 1 (calcareous minesoil) and 25 percent greater than that of Plantation 3 (acid minesoil).

Within each plantation, the total number of volunteers (all species combined) varied with the particular species planted on subplots after mining (table 2). Plantations 2 and 3, with near-neutral and acid soils, were similar in that greatest numbers of volunteers were found on black locust subplots (1,192 and 975 trees/acre) and fewest volunteers on white pine subplots (550 and 375 trees/acre). In contrast, the white pine subplots of Plantation 1 (calcareous) had the most volunteers (855 trees/acre) and yellow-poplar subplots fewest (257 trees/acre). In many instances, however, individual volunteer species exhibited sharply different trends with respect to the planted species, and these data are presented later.

Volunteer trees outnumbered planted trees on all three plantations (table 2), with an overall mean of 715 volunteers/acre to 401 for planted trees. However, planted trees had a total mean basal area/acre of 55.7 ft^2 compared to only 21.8 ft^2 for volunteers. The planted species were the major dominant trees on all subplots, and their performance was evaluated in an earlier report (Larson and Vimmerstedt 1983).

A total of 20 volunteer species was found in the plantations. Plantation 1 (calcareous) had the fewest, 7 species, compared to 13 species on Plantation 2 (near-neutral) and 15 species on Plantation 3 (acid).

When data of the three plantations were combined, the six most numerous volunteer species were, in order: black cherry, black locust, white ash, hawthorn, red maple, and elm (table 3). These accounted for 90 percent of the total number of volunteer trees inventoried.

As a rule, each volunteer species was relatively abundant in only one of the three plantations (table 3). Furthermore, each volunteer species often exhibited a different distribu-

Table 1.--Location and minesoil description of three 30-year-old plantations selected for study of volunteer tree species.

Plantation	Nearest Town	Subplots[1/]	Minesoil pH	Minesoil Description
1	Georgetown	14	7.0 (calcsreous)	Coarse limestone and clay
2	Alliance	14	6.5 to 7.8 (near neutral)	Glacial till,silty shale loam to sandy loam
3	Dundee	20	3.8 to 5.5 (acid)	shaly sand and stony sand

[1/]Number of subplots inventoried for planted and volunteer trees.

Table 2.--Mean number and basal area of both volunteer trees and planted trees found on sample plots located in planted subplots of Plantations 1, 2 and 3.

Plantation and Species Planted	Volunteer Trees[1/2/] Number	Volunteer Trees[1/2/] Basal Area	Planted Trees[2/] Number	Planted Trees[2/] Basal Area
	no./acre	ft^2/acre	no./acre	$ft.^2$/acre
Plantation 1 (calcareous)				
White Pine	855 abc	20.0 ab	345 bcd	52.8 bcd
Yellow-Poplar	257 d	16.0 ab	450 abcd	67.5 abc
White Ash	412 cd	7.8 b	625 a	48.0 bcd
Black Locust	538 bcd	8.5 ab	538 ab	19.3 d
(mean)	(516)	(13.1)	(490)	(46.9)
Plantation 2 (near-neutral)				
White Pine	550 bcd	23.5 ab	383 bcd	85.0 ab
Yellow-Poplar	900 abc	23.7 ab	412 bcd	48.3 bcd
White Ash	1,074 a	38.2 ab	500 abc	37.5 cd
Black Locust	1,192 a	19.0 ab	357 bcd	105.3 a
(mean)	(929)	(26.1)	(413)	(69.0)
Plantation 3 (acid)				
White Pine	375 cd	28.0 ab	260 d	86.0 ab
Yellow-Poplar	680 abcd	20.5 ab	320 cd	62.5 bcd
White Ash	768 abcd	17.8 ab	357 bcd	24.3 cd
Black Locust	975 ab	39.0 a	268 d	31.5 cd
(mean)	(700)	(26.3)	(301)	(51.1)

[1/]All species combined.

[2/]Within each column, means not followed by a common letter are significantly different at the 5-percent level, Duncan's new multiple range test.

tion pattern with respect to the planted species on subplots within each plantation. Thus, black cherry volunteers were relatively abundant in number and basal area on all plantation subplots planted with black locust, but particularly numerous (908 trees/ acre) in Plantation 2 (near neutral) (tables 3 and 4). The greatest basal area growth (30.5 ft^2) was attained by black cherry volunteers on black locust-planted subplots in Plantation 3 (acid) (table 4).

Subplots planted with white ash contained moderate to high numbers of black locust volunteers in all plantations and numerous hawthorn volunteers (383 trees/acre) in Plantation 2 (near-neutral) (table 3). Also, red maple volunteers were most numerous on the yellow-poplar and black locust subplots of Plantation 3 (acid), but absent or nearly so in the other plantations.

When subplots planted with black locust were sampled and inventoried, all living black locust trees were classed as "planted" because of the near-impossibility of identifying which trees were planted and which were of sprout or seed origin. Black locust can reproduce by root suckers and produces seed at about age 6 (Fowells 1965). Thus, the amount of black locust volunteers is probably under-reported in tables 3 and 4.

As stated earlier, number and basal area of volunteer trees varied with both plantation and species of planted trees. In general, these relationships were significant even after effects of the amount of planted trees present were statistically removed by covariate analysis. This is not to say that the density (number and basal area) of planted trees did not influence volunteers. Low, but significant, residual correlations between density of volunteer species and density of planted species suggest that the presence of volunteer trees decreased as planted trees increased.

Sample plots that contained a large number of volunteer trees did not necessarily have a proportionately large total basal area for volunteers (compare tables 3 and 4). The coefficient of determination (r^2) between number and total basal area of volunteers was only 0.132 (13.2 percent of the variation accounted for). Thus, both number and basal area measurements are important in the assessment of volunteer species on mined lands.

DISCUSSION AND CONCLUSIONS

In this study, both minesoil type and species of planted trees greatly influenced the amount and kind of volunteer trees that seeded-in on the areas. With regard to minesoil type, highest numbers of volunteers were found in Plantation 2 with near-neutral minesoil derived from glacial till and sandstone. Plantation 3 with acidic shaly sand minesoil had fewer volunteers than Plantation 2, but the total basal area of volunteer trees was nearly identical on both plantations. Plantation 1 with calcareous limestone and clay was least suitable for invasion of volunteer species. The macroclimate of the three plantations is similar and is considered favorable for growth of all volunteer species found in the study.

In a study of problem spoilbanks in Illinois, Lindsay and Nawrot (1981) noted that density of natural vegetation varied according to chemical composition of the minesoil, rather than with time since mining. Also in Illinois, Smith and Klimstra (1987) observed that only scattered growths of dewberry (<u>Rubus flagellaris</u>) and grasses occurred on areas with large surface accumulations of limestone rocks and boulders.

The effect of planted species on volunteers was varied. In fact, each individual volunteer species had a distinct distribution pattern with regard to both planted species and minesoil type. As examples, black cherry was particularly numerous in planted black locust stands on near-neutral and acid minesoils. Planted white pine stands contained relatively few white ash volunteers except on calcareous clay minesoils. Here, the mitigating effect of pine on the high pH soil conditions and/or the clay soil may have aided ash seedling establishment.

Somewhat similarly, Ashby et al. (1980) reported that black locust stands in Indiana, Missouri, and Kansas were favorable for invasion. In Illinois, Smith and Klimstra (1987) found only slippery elm (<u>Ulmus rubra</u>) and boxelder (<u>Acer negundo</u>) invaded and were established as part of the canopy of a shortleaf pine (<u>Pinus echinata</u>) plantation planted on an area mined in 1942. These authors also noted that a black locust plantation established in 1945 was dominated by volunteer slippery elm, boxelder, and black cherry in 1976-78.

In this study, the near-absence of white ash volunteers in planted white ash stands suggests an allelopathic relationship. Many of the planted white ash were producing seed at the time of inventory.

Some general observations on the availability of volunteer seed on the plantations were made. First, one can assume that most of the volunteer seed was carried into the plantations by wind or animals. Second, some volunteer white ash probably originated from seed of the planted trees, and black locust volunteers from root suckers of planted trees. Volunteers of white pine and yellow-poplar, the other two planted species, were not found. Third, the uneven distribution of volunteer species in these plantations appears to be related to differences in species composition of nearby stands. The numerous mature hawthorn trees in an old field adjacent to Plantation 2 and red maple trees near Plantation 3 were the probable seed sources for volunteers of these species in these plantations.

In our study, the number of volunteer species and their relative abundance in each plantation varied widely. Overall, black cherry was the most numerous volunteer, due in large part to its superior numbers in Plantation 2. Several other species were also relatively abundant in only one of the three plantations.

Several researchers have listed the most common volunteer tree species found on stripmined land in their areas. In an extensive study in Illinois, Ashby et al. (1978) reported the number of volunteer species in each of five mining

Table 3.--Mean number of trees of the six most abundant volunteer species found on sample plots located in planted subplots of Plantations 1, 2 and 3.

Plantation and Species Planted on Subplots	Volunteer Species[1/]					
	Black Cherry	Black Locust	White Ash	Hawthorn Species	Red Maple	Elm Species
	----------number/acre----------					
Plantation 1 (calcareous)						
White Pine	65 d	245 ab	465 a	20 c	0 b	60 ab
Yellow-Poplar	117 d	75 b	50 b	0 c	0 b	0 b
White Ash	0 d	406 a	0 b	0 c	0 b	0 b
Black Locust	175 bcd	0 [2/]	187 b	0 c	0 b	100 ab
(mean)	(89)	(181)	(176)	(5)	(0)	(40)
Plantation 2 (near neutral)						
White Pine	150 cd	29 b	25 b	167 bc	4 b	33 b
Yellow-Poplar	187 bcd	187 ab	25 b	312 ab	25 b	75 ab
White Ash	383 bc	150 ab	17 b	383 a	0 b	42 b
Black Locust	908 a	0[2/]	0 b	150 bc	0 b	33 b
(mean)	(407)	(91)	(17)	(253)	(7)	(46)
Plantation 3 (acid)						
White Pine	61 d	125 ab	70 b	0 c	72 b	28 b
Yellow-Poplar	105 d	75 b	75 b	0 c	285 a	85 ab
White Ash	125 d	367 a	17 b	8 c	83 b	8 b
Black Locust	417 bc	0[2/]	133 b	0 c	242 a	150 a
(mean)	(177)	(144)	(74)	(2)	(170)	(68)

[1/] Within each column, means not followed by a common letter are significantly different at the 5-percent level, Duncan's new multiple range test.

[2/] Planted and volunteer black locust not differentiated (see text).

Table 4.--Mean basal area of trees of the six most abundant volunteer species found on sample plots located in planted subplots of Plantations 1,2, and 3.

Plantation and Species Planted on Subplots	Volunteer Species[1/]					
	Black Cherry	Black Locust	White Ash	Hawthorn Species	Red Maple	Elm Species
	----------ft^2/acre----------					
Plantation 1 (calcareous)						
White Pine	0.26 c	17.73 a	0.74 a	0.07 b	0 a	0.45 a
Yellow-Poplar	0.26 c	7.93 a	0.22 a	0 b	0 a	0 a
White Ash	0 c	5.53 a	0 a	0 b	0 a	0 a
Black Locust	4.49 bc	0 [2/]	0.22 a	0 b	0 a	1.88 a
(mean)	(1.25)	(7.80)	(0.30)	(0.02)	(0.00)	(0.58)
Plantation 2 (near-neutral)						
White Pine	10.50 bc	4.40 a	0.78 a	1.48 b	0.04 a	2.90 a
Yellow Poplar	15.25 b	6.01 a	0.13 a	0.50 b	0.02 a	0.68 a
White Ash	6.75 bc	22.91 a	0.02 a	8.01 a	0 a	0.20 a
Black Locust	15.51 b	0 [2/]	0 a	0.87 b	0 a	0.50 a
(mean)	(12.00)	(8.33)	(0.23)	(2.72)	(0.02)	(1.07)
Plantation 3 (acid)						
White Pine	5.00 bc	17.16 a	2.18 a	0 b	1.75 a	0.30 a
Yellow-Poplar	5.49 bc	6.53 a	2.79 a	0 b	5.00 a	0.22 a
White Ash	5.23 bc	8.36 a	0.09 a	0.50 b	1.26 a	0.05 a
Black Locust	30.49 a	0 [2/]	2.61 a	0 b	3.00 a	0.92 a
(mean)	(11.55)	(8.01)	(1.92)	(0.13)	(2.75)	(0.37)

[1/] Within each column, means not followed by a common letter are significantly different at the 5-percent level, Duncan's new multiple range test.

[2/] Planted and volunteer black locust not differentiated (see text).

districts ranged from 13 to 28, and that each district had a different "most frequently found volunteer species." These species were elm, black cherry, cottonwood (Populus deltoides), oak, and dogwood (Cornus florida). In Ohio, a bottomland site 2 years after mining had volunteer trees of sycamore (Platanus occidentalis), sugar maple (Acer saccharum), elm, yellow-poplar, and white oak (Quercus alba) (Merz and Plass 1952). Common volunteer species on spoils in Indiana were red oak (Q. rubra), elms, green ash (Fraxinus pensylvanica), red maple, sycamore, cottonwood, sassafras, black cherry, black willow (Salix nigra), and red cedar (Juniperus virginiana) (Stiver 1949, Byrnes and Miller 1973). In western Pennsylvania, invader species were aspen (Populus deltoides), fire cherry (Prunus pennsylvanica), black cherry, and red maple (Bramble 1952).

It is apparent from the cited reports and this study that there are many potential invader species. This study concluded that their occurrence on a particular site is largely determined by the following factors: minesoil type, climate, topography, seed source, established vegetation, damaging agents, and time since mining.

Ashby et al. (1978) reported that invasion of volunteers on planted mined areas in Illinois occurred in two stages: first, early invasion by cottonwood and sycamore when areas were open; and second, later invasion by other species after planted trees or early volunteers were established. No such "two-stage" invasion of volunteers was apparent in this study, and pioneer trees of cottonwood and sycamore were nearly absent in plantations.

The early stages of forest succession in the three plantations are evident from the list of volunteer species in table 3. In the future black cherry and the somewhat more tolerant species such as maple, ash, and elm will probably proportionately increase on most areas, especially as black locust trees are overtopped. In every planted type, individual volunteer trees on favorable micro-sites outgrew nearby planted trees. Most volunteers were understory trees, however.

The expected increase in importance of the volunteer component in these planted stands is indicated by a study of still older plantations on mined areas in Pennsylvania. Davidson (1981) evaluated 19 coniferous plantations ranging from 46 to 61 years of age. Volunteer species accounted for one-third of the total volume in plantations. Black cherry outnumbered other volunteer species 2:1. Aspen and red maple were present in more than one-half of the plantations.

The nature of the climax or near-climax succession in the three plantations is unclear. Plantation 2 is in the beech forest type, and Plantations 1 and 3 are in the oak-hickory forest type. Aharrah and Hartman (1973) speculated that coal spoils of Pennsylvania will eventually be revegetated with oak-hickory forests because that is the climax vegetation of the area. In northern West Virginia, most iron ore spoils 85 to 119 years old were dominated by oak species (Tryon and Markus 1953). However, in southern Illinois, Smith and Klimstra (1987) report that vegetative composition on naturally revegetated spoils suggest succession to a flood plain forest rather than to oak-hickory typical of the region.

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