INFLUENCE OF SEEDING LEVEL UPON PLANT COMMUNITY DYNAMICS ON RECLAIMED MINED LANDS IN PENNSYLVANIA[1]

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Abstract: Current mined land reclamation focusing on dense herbaceous cover may result in low plant species diversity and adversely affect survival of planted tree seedlings. Reducing the amount of grasses and legumes by alternate seeded and unseeded strips may reduce competition among seeded herbaceous plants, invading species, and planted woody species. During 1991-93, we evaluated plant community development at six sites reclaimed in the bituminous coal region in north-central Pennsylvania. One-half of each site received full seeding, and the other half was strip seeded. The full seeding treatment (high-competition) consisted of areas completely (100%) planted with a herbaceous seed mixture. The strip seeding treatment (low-competition) consisted of alternate seeded and unseeded strips, which resulted in 50% of the area being planted with the herbaceous mixture. We visually estimated the amount of plant cover during each growing season by sampling 0.5- by 1.0-m (0.5 m^2) plots in each treatment at each site. Survival of six species of native hardwood seedlings planted in the treatments was determined by examining each seedling after each of two or three growing seasons. Plants from the seed mixtures and other plants invaded the unseeded strips within 2 to 3 years. Seeded annuals were present only in the first growing season, whereas seeded perennials were present in all years and increased in each successive growing season. Species richness and percent cover of invading species varied by site, and the sites reclaimed in 1991 had more invaders than sites reclaimed in 1992. Survival of all six species of hardwoods was higher in low-competition treatments compared to high-competition treatments on sites reclaimed in 1991 and 1992. This study provided evidence that a 50% reduction in planted herbacous cover resulted in increased survival of native hardwood species.

Additional Key Words: reforestation, competition, plant community development.

Introduction

Revegetation of mined lands currently focuses on establishing dense herbaceous cover to stabilize soil and control erosion and sedimentation. Recontouring, liming and fertilizing, seeding with grasses and legumes, and mulching is the most cost-effective way to satisfy current regulatory requirements and recover bond monies. Grasses and legumes are commonly used in reclamation because of their vigor, availability of seed sources, and reported success in erosion control (Ashby et al. 1988).

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Sites reclaimed with grasses and legumes are characterized by low species diversity and often lack woody vegetation. Previous research has shown that dense herbaceous cover may reduce the survival and growth of tree seedlings (Ashby 1990, Ashby et al. 1988, Davidson et al. 1984, Hughes and Garthe 1989, Smith 1980, Vogel 1980). Wade (1989) found that planted grasses used in reclamation are very competitive and impede the invasion of native species.

Competition among plants may be an important factor in community development on reclaimed mined lands. More information on the effects of grasses and legumes on survival of planted tree seedlings is needed in areas of western Pennsylvania where management of reclaimed mined lands may involve reforestation using native hardwoods.

The objectives of our study were to (1) describe and compare the development of herbaceous cover at sites treated with full seeding (100%) and strip seeding (50%), (2) determine plant community composition (consisting of species in seed mixtures, contaminants in the seed mixtures, and invaders from adjacent areas) within and among sites and among years, and (3) compare survival of six species of hardwoods under full and strip seeding treatments.

Methods

Six study sites, three each in 1991 and 1992, were established in the bituminous coal region of western Pennsylvania. At each site, we created two levels (low and high) of herbaceous cover. Herbaceous mixtures were seeded in April and May of 1991 and 1992. High competition treatments were planted using a seed drill with all ports open so that the area was completely (100%) seeded. Low competition treatments were planted using a seed drill with half of the ports plugged so that the area consisted of alternating seeded and unseeded strips, which resulted in 50% of the total area being seeded. Planted seed mixtures varied by site. The seed mixture planted on the Brandy Camp (1991) and Harmony (1991) sites consisted of oats (Avena sativa) L., perennial ryegrass (Lolium perenne) L., timothy (Phleum pratense) L., birdsfoot trefoil (Lotus corniculatus) L., and alsike clover (Trifolium hybridum) L. The seed mixture planted on the Brockport (1992) and Clearfield (1992) sites consisted of oats, perennial ryegrass, timothy, red top (Agrostis alba) L., birdsfoot trefoil, and alsike clover. The seed mixture planted on the Kylertown I (1991) and Kylertown II (1992) sites consisted of buckwheat (Fagopyrum sagittatum) Gilib., oats, K-31 tall fescue (Festuca arundinacea) Schreb., timothy, red top, birdsfoot trefoil, alsike clover, and red clover (Trifolium pratense) L.

One-year-old tree seedlings were hand-planted in each high-competition treatment and in the unseeded component of each low-competition treatment in May and June of 1991 and April and May of 1992. Seedlings were planted immediately following seeding of herbaceous mixtures. Species planted in 1991 were black birch (Betula lenta) L., black locust (Robinia pseudoacacia) L., quaking aspen (Populus tremuloides) Loeve & Loeve, red oak (Quercus rubra) L., and red maple (Acer rubrum) L. Species planted in 1992 were black cherry (Prunus serotina) Ehrh., black locust, quaking aspen, red oak, and red maple.

After the first growing season, deer exclosures were constructed around one-half of each site, resulting in a randomized split-split plot design with two replications per site. Determining the effect of deer browsing on tree seedling survival involves long-term study. Therefore, only survival data of seedlings inside the deer exclosures are presented in this report.

Percent cover of each plant species and all plant species combined was ocularly estimated (Barbour et al. 1987) by sampling in 0.5- by 1.0-m plots. Twenty-four plots were measured in each high-competition and low-competition treatment. The low-competition treatments consisted of seeded and unseeded components, each 0.8 m in width. Plant cover was measured at sites established in 1991 during August and September of 1991, July and August of 1992, and July and August of 1993. Plant cover was measured at sites established in 1992 during July and August of 1992 and July and August of 1993. The 0.5- by 1.0-m sampling plots were oriented so that separate

measurements were made in the seeded and unseeded components of the low-competition treatment. Seeded components were referred to as "seeded low-competition," whereas unseeded components of the low-competition treatment were referred to as "unseeded low-competition." Species not part of the prescribed seed mixture were contaminants in the seed mixture or invaders from surrounding areas. We did not determine which species were contaminants or invaders.

Each tree seedling inside the deer exclosures was examined and recorded as alive or dead after each growing season. Survival was determined in September of 1991, 1992, and 1993 on sites planted in 1991. Survival was determined in September of 1992 and 1993 on sites planted in 1992.

We used analysis of variance (ANOVA) techniques to test for year and seeding treatment differences in the amount of plant cover. Least-squares means procedures were used for multiple comparison tests among seeding treatments within each year (Neter et al. 1990).

Results and Discussion

Because of differences in climatic conditions between 1991 and 1992 (Washburn et at. 1992), we present separate results for sites reclaimed in 1991 and 1992. Thus, analytical comparisons among years and seeding treatments were also conducted separately for sites reclaimed in 1991 and 1992.

Herbaceous Cover - 1991 Sites

Seeded perennial cover (grasses and legumes) increased significantly ($p<0.05$) in high- and low-competition treatments at all three sites from 1991 through 1993 (fig. 1). The increase in seeded perennial cover appeared to be more pronounced between 1991 and 1992 compared to 1992 and 1993. As expected, seeded perennial cover in the unseeded component of the low-competition treatments was significantly lower ($p<0.05$) than in the high-competition and in the seeded component of the low-competition treatments (fig. 1).

Seeded annual cover (grains and forbs) was present in 1991 and consisted of oats or oats and buckwheat. These seeded annuals were absent on all three sites in 1992 and 1993.

Plant cover of contaminant and invader species was virtually absent at Brandy Camp and Kylertown I in 1991, but increased in 1992 and 1993 (fig. 1). Considerable amounts of contaminant and invader cover were present at Harmony in all 3 years. The amount of contaminant and invader cover at the Harmony site was higher than at the other two sites. High amounts of contaminant and invader cover at Harmony was probably due to greater immigration of seed from adjacent forest communities.

The number of species of contaminant and invader plants increased in all treatments at all three sites from 1991 through 1993 (table 1). Compared to climatic conditions in 1991, conditions during 1992 and 1993 were more favorable to plants, allowing for increased numbers of contaminant and invader species. Higher numbers of contaminant and invader species were present in unseeded component of low-competition treatments compared to high-competition and low-competition seeded components in 1992 and 1993. This was expected due to lower amounts of plant cover and therefore less competition in the unseeded component of the low-competition treatments.

The Harmony site had considerably more contaminant and invader species in all years, and the number at the Brandy Camp and Kylertown I sites were similar (table 1). Nine species of invasive plants were found at the Harmony site but not at the other two sites. The occurrence of sedges (Carex sp.) and cattails (Typha spp.) at Harmony and not at the other sites was probably due to more small pools of water at the Harmony site.

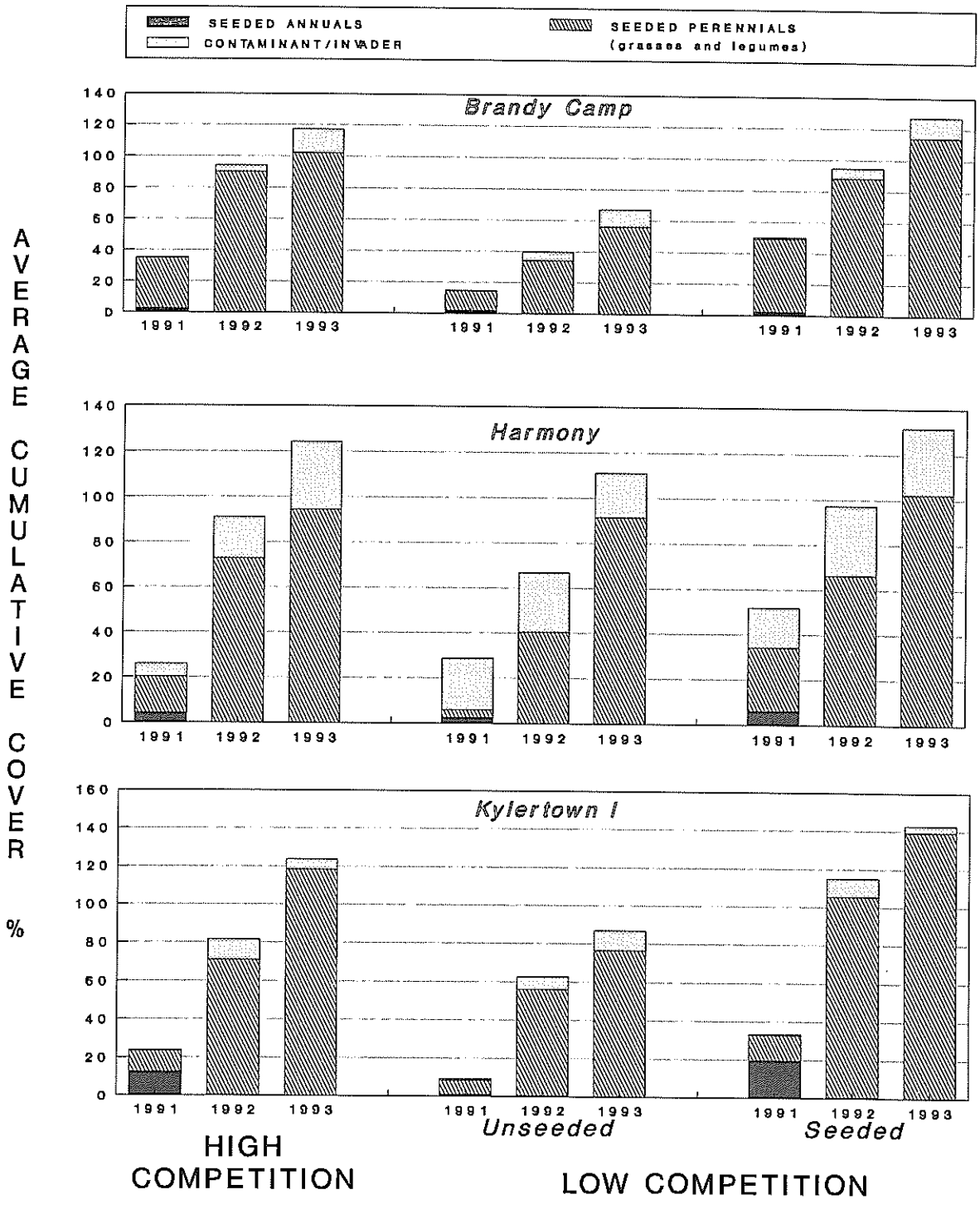


Figure 1. Average cumulative percent cover of seeded annuals, seeded perennials, and contaminant and invader species under two seeding treatments at the Brandy Camp, Harmony, and Kylertown I sites from 1991 through 1993.

Table 1. Number of contaminant and invader species present in high- and low-competition treatments at seeding at three sites reclaimed in 1991.

	Brandy Camp			Harmony			Kylertown I		
	High	Low		High	Low		High	Low	
Year		Unseeded[1]	Seeded[2]		Unseeded[1]	Seeded[2]		Unseeded[1]	Seeded[2]
1991	8	6	7	15	18	15	7	6	4
1992	9	13	7	18	30	22	8	15	6
1993	16	17	8	22	31	31	8	16	7

[1] Unseeded refers to the unseeded low-competition treatments.
[2] Seeded refers to the seeded low-competition treatments.

A total of sixty-three species of contaminant and invader plants were found on the six study sites during 1991-93. Nineteen (table 2) of the sixty-three species occurred at two or more sites in two or more years.

Herbaceous Cover - 1992 Sites

Seeded perennial cover (grasses and legumes) increased significantly ($p<0.05$) during 1992-93 in low- and high-competition treatments at Brockport and Kylertown II (fig. 2). However, the increase in seeded perennial cover at Clearfield was not as pronounced as at the other two sites. The smaller increase in seeded perennial cover at Clearfield was due to birdsfoot trefoil not increasing as it did at the other sites (Washburn, unpubl. data). As expected, perennial cover in the unseeded components of the low-competition treatments was significantly lower ($p<0.05$) than in the high-competition and in the seeded components of the low-competition treatments (fig. 2).

Seeded annual cover (grains and forbs) was present in 1992 and consisted of oats or oats and buckwheat. These seeded annuals were absent on all three sites in 1993.

The unseeded component of the low-competition treatments at Brockport and Kylertown II had significant contaminant and invader plant cover in the first growing season (1992), but the amount was markedly reduced in the second growing season (1993). The unseeded component of the low-competition treatment at Clearfield exhibited low plant cover by contaminant and invader species in 1992. This lower amount of contaminant and invader cover were probably due to the lack of available seed sources and because site preparations occurred after germination of invasive annuals.

Invasive plants were less prevalent on the sites reclaimed in 1992 than on the sites reclaimed in 1991. The favorable growing conditions in 1992 resulted in high amounts of seeded plant cover, creating more competition and less opportunity for contaminant and invader species to become established.

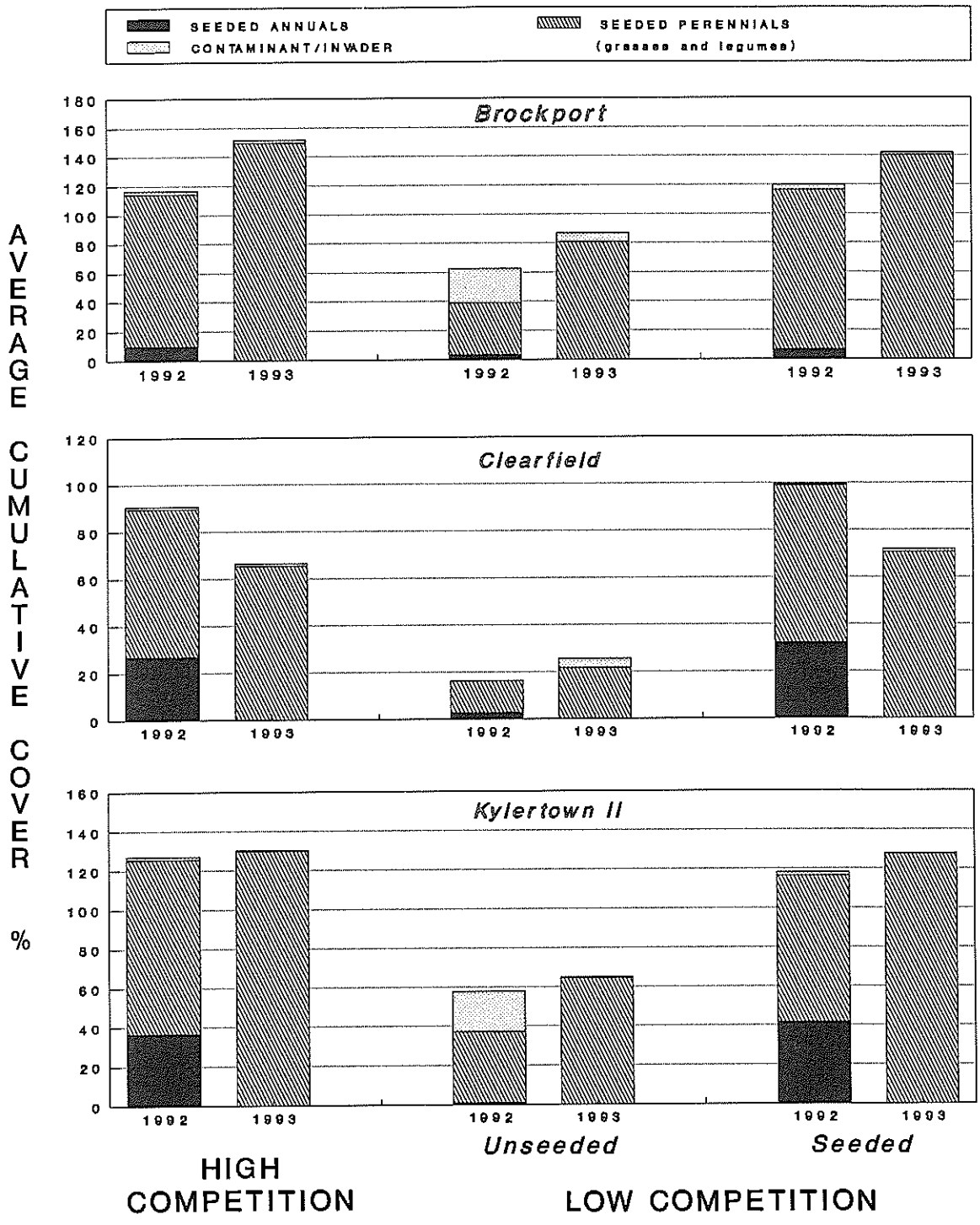


Figure 2. Average cumulative percent cover of seeded annuals, seeded perennials, and contaminant and invader species under two seeding treatments at the Brockport, Clearfield, and Kylertown II sites from 1992 through 1993.

Table 2. Names of 19 contaminant and invader species present in at least 2 years on 2 or more study sites in north-central Pennsylvania.

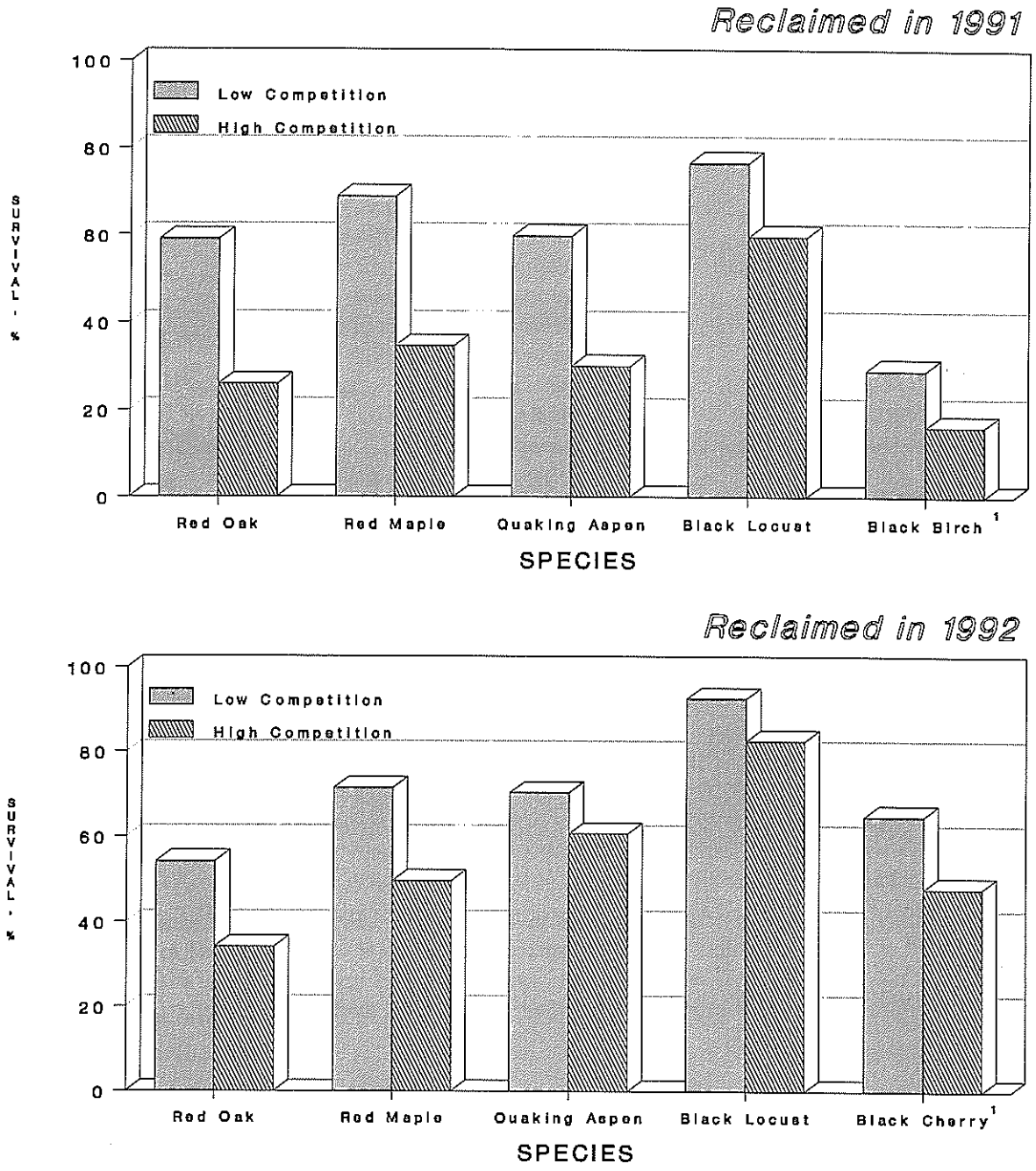
Common Name	Botanical Name
K-31 Tall Fescue	*Festuca arundinacea* Schreb.
Orchardgrass	*Dactylis glomerata* L.
Fall Panicum	*Panicum dichotomiflorum* Michx.
Common Barnyardgrass	*Echinochloa crusgalli* Beauv.
Deertongue Panicum	*Panicum clandestinum*
Yellow Sweetclover	*Melilotus officinalis* Lam.
White Sweetclover	*Melilotus alba* Medik.
Red Clover	*Trifolium pratense* L.
Goldenrod spp.	*Solidago* spp. L.
Curly Dock	*Rumex cripus* L.
Pink Knotweed	*Polygonum pensylvanicum* L.
Common Ragweed	*Ambrosia artemisiifolia* L.
Plantain spp.	*Plantago* spp. L.
Dwarf Cinquefoil	*Potentilla canadensis* L.
Oxeye Daisy	*Chrysanthemum leucanthemum* L.
Common Yellow Sorrel	*Oxalis stricta* L.
Staghorn Sumac	*Rhus typhina* L.
Blackberry	*Rubus* spp. L.
Pin Cherry	*Serotina pensylvanica* L.

The number of species of contaminant and invader plants at the Brockport and Kylertown II sites paralleled the results found with the 1991 sites -- that more species were present in the unseeded low-competition components (table 3). Although the Clearfield site had fewer contaminant and invader species in the unseeded component of the low-competition treatment compared to the other two seeding treatments in 1992, the number of species were similar in 1993.

The numbers of species of contaminants and invaders present on sites reclaimed in 1991 increased or remained the same in the high- and low-competition treatments during 1992-93. However, no distinct pattern exists for changes in the numbers of contaminant and invader species present on sites reclaimed in 1992 in the high- and low-competition treatments during 1992-93.

Seedling Survival

Survival of all six species of hardwoods was higher in low-competition treatments compared with high-competition treatments at sites established in 1991 and 1992 (fig. 3). Of the four species that were planted in both 1991 and 1992, black locust exhibited the highest survival whereas red oak exhibited the lowest survival after 2 and 3 growing seasons.



[1] Black birch and black cherry were planted in only one year.

Figure 3. Average survival of six species of native hardwoods planted in low and high levels of herbaceous cover at reclaimed site in north-central PA; survival was determined for seedlings inside deer exclosures after three growing seasons for three sites established in 1991 and after two growing seasons for three sites established in 1992.

Table 3. Number of contaminant and invader species present in high- and low-competition treatments at three sites reclaimed in 1992.

	Brockport			Clearfield			Kylertown II		
	High	Low		High	Low		High	Low	
Year		Unseeded[1]	Seeded[2]		Unseeded[1]	Seeded[2]		Unseeded[1]	Seeded[2]
1992	12	18	11	6	1	5	6	14	5
1993	5	19	5	7	7	4	1	5	3

[1] Unseeded refers to the unseeded low-competition treatments.
[2] Seeded refers to the seeded low-competition treatments.

Conclusions

As expected, the amount of plant cover in the unseeded components of the low-competition treatments, especially the seeded perennial species, was reduced on all six sites during 1991-93. Reduced amounts of plant cover provided space where competition was minimal for invaders, as exemplified by the presence of more species of contaminants and invaders in the unseeded components of the low-competition treatments. The amount of contaminant and invader cover and the number of species of contaminants and invaders increased from 1991 to 1993 on sites reclaimed in 1991. However, no clear pattern existed for the amount of contaminant and invader cover or the number of species of contaminants and invaders on sites reclaimed in 1992. Survival of all six species of hardwoods was higher in low-competition treatments compared to survival in high-competition treatments after two and three growing seasons. The results of the present study indicated that black cherry, black locust, quaking aspen, and red maple may be used in reclamation of mined lands with native species.

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