FORESTED WETLAND RESTORATION AND "NUISANCE" PLANT SPECIES MANAGEMENT ON PHOSPHATE MINED LANDS IN FLORIDA[1]

by

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Abstract. Florida regulations require that "nuisance" species, including the native primrose willow (*Ludwigia peruviana*) and cattail (*Typha latifolia*), be limited to less than ten percent of the cover on reclaimed wetlands. Controlling these two species is expensive and may be unnecessary. It is hypothesized that shade-tolerant trees can grow through, overtop, and shade out these shade intolerant "nuisance" species. This study, conducted on reclaimed phosphate mined lands in central Florida, compared tree growth in primrose willow stands and in cattail stands versus with the nuisance species removed (cut or herbicided). It also examined the effects of a developing tree canopy on primrose willow. Growth of baldcypress (*Taxodium distichum*) was greater with primrose willow removal, but growth was substantial in the presence of primrose willow. Popash (*Fraxinus caroliniana*) and red maple (*Acer rubrum*) height growth was greater in the presence of primrose willow than when the primrose willow was removed by careful application of triclopyr herbicide. In three to four years, half or more of the baldcypress, popash, red maple and water hickory (*Carya aquatica*) were able to grow through and overtop the 2.3-2.7 m tall primrose willow. The developing canopy of the trees reduced the leaf area index of primrose willow. Cattail had only a small effect on baldcypress or pondcypress (*Taxodium ascendens*) height growth, and half or more of these trees overtopped the 2 m tall cattail in five or six years. However, popash did not compete well with cattail at a site with standing water throughout the year. Four wetland tree species were able to compete successfully with primrose willow, and baldcypress and pondcypress competed well with cattail. Thus costly control of primrose willow and cattail is probably not necessary for reestablishing forested wetlands on phosphate mined lands in Florida when well adapted trees are planted and site conditions allow vigorous tree growth.

Introduction

Primrose willow (*Ludwigia peruviana*) and cattail (*Typha latifolia*) are two wetland species native to Florida (Ramamoorthy and Zardini 1987; Dressler et al. 1987). However, due to their invasiveness, the Florida Department of Environmental Protection-Bureau of Mine Reclamation (FDEP-BMR) lists these native species as "nuisance" species. This designation is legally important in the reclamation of forested wetlands on phosphate mined lands, because one success (release) criterion on many FDEP-BMR permits limits "nuisance" species to less than 10% of the total cover (FDEP-BMR, personal communication).

To comply with this criterion, a combination of herbicide application, mowing and hand labor has often been required to control primrose willow and cattail. Are these control measures necessary ecologically or just legally or aesthetically? Such efforts are not only expensive but may damage desirable plants as well as the targeted "weeds." On forested wetlands, an alternative approach may be possible.. Our own observations and those of others (Richardson et al. 1994; Clewell and Raymond 1991; Hawkins and Ruesch 1988; Miller et al. 1988; Clewell 1981) suggest that several tree species can grow through, overtop, and shade out the "nuisance" species. Thus, it could be more cost-effective to plant a sufficient number of shade tolerant trees and be patient.

With regard to the competitive effects of primrose willow on tree growth on phosphate mined lands, Clewell and Raymond (1991) stated that primrose willow's canopy might even have a beneficial nurse crop effect. As for cattail, Rushton (1988) detected no differences in the heights (after one year) of baldcypress (*Taxodium distichum*) seedlings grown on reclaimed clay settling ponds whether the sites were cleared of cattail or not at the time of planting.

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Clewell (1981) observed vigorous green ash (*Fraxinus pennyslvanica*) growing in a cattail stand, and suggested that densely planted ash might grow through, overtop, and replace cattail. Erwin et al. (1985) observed that cattail appeared to initially reduce baldcypress and Florida maple (*Acer saccharum floridanum*) seedling survival, but seedlings that survived this competition appeared to have high growth rates. Miller et al. (1988) observed that planted trees initially seemed to be overcome by cattail but later became visible as the trees grew taller. They also observed that previously dense cattail thinned dramatically under the expanding crowns of Carolina willow (*Salix caroliniana*) and that red maple grew well beneath the willow canopy.

The first objective of this study was to determine how primrose willow and cattail affect growth of several wetland tree species. The second, and longer term, objective was to determine if these tree species could overtop and shade out the primrose willow and cattail.

Methods

The research was conducted in central peninsular Florida (Polk County) at several reclaimed phosphate surface mines on regraded overburden soils. To evaluate the effects of primrose willow and cattail competition on tree growth, two stands of primrose willow (P1 and P2 Sites) and a stand of cattail (C1 Site) were selected on reclaimed wetlands. A third primrose willow stand (T1 Site) was used in a study of the effects of tree canopy development on primrose willow.

Primrose Willow Competition. At each primrose willow site, the stand was mowed during the dry season with a tractor drawn mower and eight replicate blocks of paired plots were located within similar hydric regimes. Within each block, a plot was randomly selected to be the weeded plot and the other plot to be the untreated check plot. The primrose willow in the untreated check plots was allowed to regrow, and the primrose willow in the weeded plots was repeatedly mowed with a gasoline powered trimmer at the P1 site or herbicided at the P2 site.

P1 Site. This primrose willow stand was on a reclaimed, seepage wetland at the IMC-Agrico Clear Springs Mine (11 km southeast of Bartow). On 12 May 1989, five baldcypress (*Taxodium distichum*) trees, grown in 15 cm diameter pots, were planted 2 m apart in each plot. The primrose willow in the weeded plots was mowed three to four times during each growing season with a motorized trimmer through 1992. The weeded plots were mowed for the last time at the end of March 1993 and then herbicided two times with triclopyr (Garlon^R 3A) between April and early August 1993, after which weed control efforts ceased.

Baldcypress heights were measured at the time of planting and each subsequent winter. Primrose willow height was measured near each tree after the sixth growing season. Diameter at Breast Height (DBH) at 1.4 m and crown diameters (average of two perpendicular measurements) were measured at the end of the fourth and sixth growing seasons.

P2 Site. This stand of primrose willow was on a reclaimed wetland along McCullough Creek at the Mobil Fort Meade Mine (3 km northwest of Fort Meade). On 10 November 1992, five trees each of baldcypress, popash (*Fraxinus caroliniana*), and red maple (*Acer rubrum*), grown in 35 cm x 10 cm sacks, were planted 2 m apart in each plot. The primrose willow in the weeded plots were herbicided three to four times each growing season with triclopyr (Garlon^R 3A). During these sprayings, the trees were protected with plastic bags.

Tree mortality was assessed in June of 1993. Dead trees were then replaced to assure sufficient numbers of trees for the growth comparisons in subsequent years. The replacement trees were planted later and thus were smaller at any given time than the original trees, but this was accounted for in the data analysis. Tree heights and basal diameters (at 15 cm height) were measured at the time of planting and at the end of each subsequent growing season. Primrose willow height next to each tree was also measured. Tree growth at the P2 site was more complicated to analyze than at the P1 site, because the more dense and more tangled primrose willow at the P2 site leaned on the saplings, causing some trees to be bent in the untreated plots. Tree heights were measured to the highest point above ground, which was not always the apical bud in bent trees. Therefore, data from the untreated plots are presented as averages of the straight trees alone and also as averages of the straight plus bent trees combined.

Tree Canopy Effects (T1 Site). The effects of the developing canopy of three tree species on primrose willow were studied by planting the trees relatively close together (1.2 m apart vs. the usual 2 m) and observing the trees and the primrose willow. The T1 primrose willow site was in a reclaimed flood plain wetland near McCullough Creek at the Mobil Fort Meade Mine (3 km northwest of Fort Meade). Similar to the other studies, the primrose willow was mowed in August 1993 and allowed to resprout. Three replicate blocks were located within similar hydric regimes ("wet", "medium", or "dry") which were related to distance from the stream. Four plots within each block were randomly assigned to be either a baldcypress, popash, water hickory (*Carya aquatica*), or check plot. On 22 September, 1993 each tree plot was planted with 35 trees (grown in 35 cm x 10 cm plastic sacks) in a 5 x 7 arrangement with 1.2 m between trees. The check plots were flagged in the same 5 x 7 arrangement for comparing primrose willow measurements.

Tree heights and basal diameters (at 15 cm) were measured each year. The primrose willow height was also measured next to each tree. Leaf area index of the primrose willow was measured by counting the number of leaves coming into contact with a vertical pole placed midway between trees (Bonham 1989, Frank and McNaughton 1990).

Cattail (C1 Site). The stand of cattail was in a reclaimed wetland at the Mobil Fort Meade Mine, 2 km north of Fort Meade and 3 km east of U.S. Highway 17. Overburden at the site had been graded in 1991 and planted with a variety of tubeling trees between September 1991 and February 1992. The trees (mostly baldcypress and pondcypress, *Taxodium ascendens*) that had been previously planted by Mobil Mining and Minerals Corporation were located, mapped, and marked with tags and flagging.

Eight replicate blocks of paired (weeded and untreated) plots were located within similar hydric regimes and cattail densities. Weeded plots were initially cut with machetes in early May 1994 and were maintained three to four times each growing season by cutting resprouts below the water surface with pruning shears. Cattails in the untreated check plots were not cut, but allowed to continue growing. In each plot, five baldcypress and five popash trees, grown in 35 cm x 10 cm plastic sacks, were planted among the existing trees no closer than 1.5 m apart at the end of May 1994. Thus the cattail removal treatment began in the second year for the trees planted in the winter of 1991-92 rather than at the start of the experiment as with the trees planted in 1994.

Trees heights, stem diameters (at 50 cm height to assure being above water), and crown diameters were measured at the end of each growing season. Tree heights were measured vertically from the ground to the highest growing point. Cattail height and water depth were also measured next to each tree.

Statistical Methods. All parameters in both the primrose willow and cattail experiments were statistically analyzed by the SPSS (1988) package using the non-parametric, Mann-Whitney comparison (Mann and Whitney, 1947). The statistics compare only those trees that remained alive throughout the experiment.

Results

P1 Site. There was very little difference in baldcypress height between the two treatments in the first three years (Figure 1). Tree height was actually slightly greater (difference significant at $P<0.05$) in the presence of primrose willow the first year, but growth was enhanced by primrose willow removal in subsequent years. By the sixth year, the compounding of yearly growth enhancement had led to a 25% greater height with primrose willow removal ($P<0.01$). Nevertheless, baldcypress height growth was substantial in the presence of primrose willow. The trees in the untreated check plots averaged 5 m tall after the sixth year, over 2m taller than the primrose willow canopy. Baldcypress trees in the untreated check plots first began to surpass the average primrose willow height of 2.7 m (Figure 2) by the end of the second year, when 18% of the trees were taller than 2.7 m. The percentage of trees taller than 2.7 m increased to 48% after the third year, to 60% after the fourth year, and to 85% after the sixth year.

Primrose willow competition had a greater effect on stem diameter and crown diameter than on tree height.

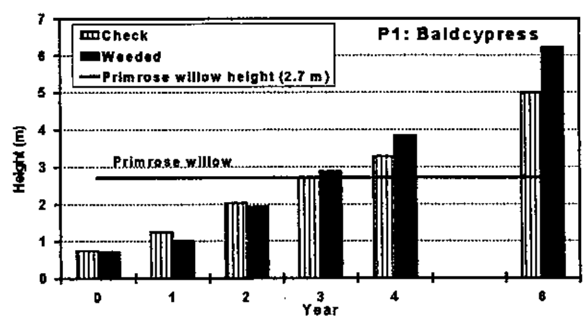

Figure 1. Yearly height of baldcypress as affected by primrose willow competition at the P1 site.

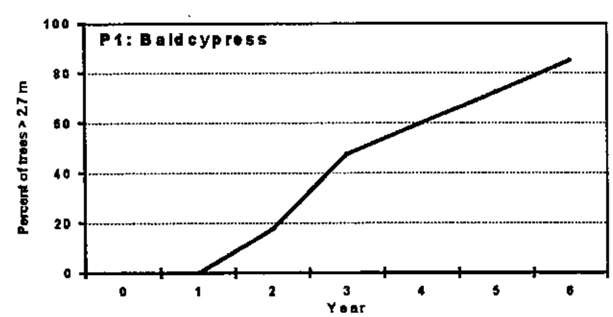

Figure 2. Percent of baldcypress trees taller than the primrose willow canopy (2.7 m) at the P1 site

Baldcypress diameters at breast height (DBH) after the sixth year averaged 8 cm with primrose willow as compared to 12 cm in the weeded plots (P<0.01) (Figure 3). After the fourth year, baldcypress trees in plots containing primrose willow had developed an average crown diameter of 109 cm as compared to 145 cm in the weeded plots (P<0.01) (Figure 4). After the sixth year, baldcypress in the primrose willow plots had developed an average crown diameter of 144 cm as compared to 189 cm in the weeded plots (P<0.01). There was no difference in percent survival of baldcypress after six years between the treatments (weeded plots had 100% tree survival and untreated check plots had 98% tree survival).

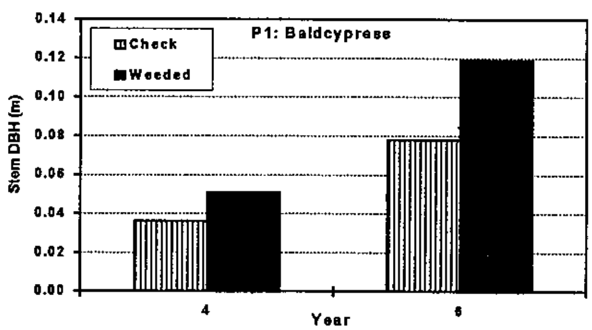

Figure 3. Stem diameter at breast height (DBH) of baldcypress as affected by primrose willow competition at the P1 site.

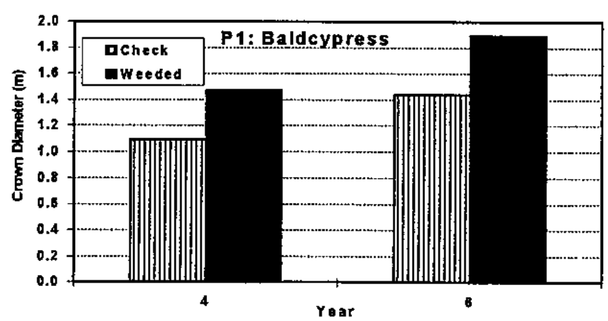

Figure 4. Crown diameter of baldcypress as affected by primrose willow competition at the P1 site.

P2 Site. Survival was determined in June 1993, seven months after planting of trees at the P2 site. Red maple survival was low, but it was greater in the presence of primrose willow (42%) than with primrose willow removed (30%). Popsash survival was 100% with primrose willow and 87% with primrose willow removed. Baldcypress survival was 86% in both treatments.

Dead trees were replaced after the June 1993 survival assessment, and survival determinations in subsequent years included the replacement trees. After the fifth year, survival of baldcypress was greater with primrose willow removed with tryclopyr herbicide (98%) than in the presence of primrose willow (63%). In contrast, herbicide removal of primrose willow reduced survival of popash (untreated check 83%, weeded 50%) and red maple (untreated check 70%, weeded 38%), even though great care was taken to protect the trees from the herbicide spray with plastic bags.

The pattern of baldcypress height growth (Figure 5) and crown diameter expansion (Figure 6) at the P2 site was similar to that at the P1 site, but tree growth was slower at the P2 site. Average height of the baldcypress trees in the unweeded check surpassed the height of the primrose willow in the third year at P1, but not until the fourth year at P2 (compare Figures 1 and 5).

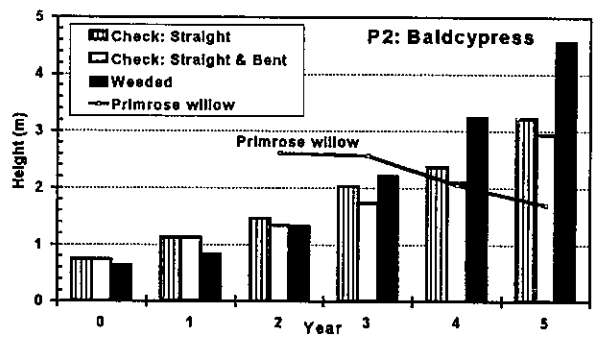

Figure 5. Yearly height of baldcypress as affected by primrose willow competition at the P2 site. Check plot trees grouped into a subset of straight trees only and the entire set of straight trees and bent trees.

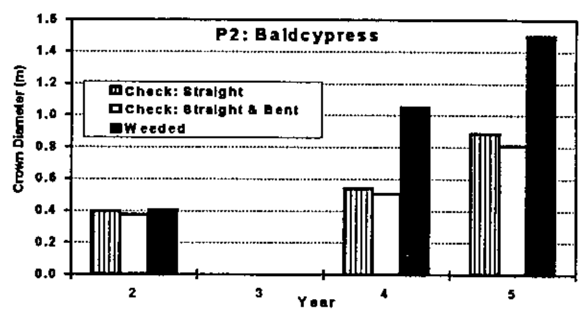

Figure 6. Crown diameter of baldcypress as affected by primrose willow competition at the P2 site. Check plot trees grouped into a subset of straight trees only and the entire set of straight trees and bent trees.

Popash and red maple differed from baldcypress in their responses to primrose willow removal. In the third and subsequent years, red maple tended to be taller in the presence of primrose willow than when the primrose willow was removed by application of tryclopyr herbicide, but the differences did not become significant ($P<0.05$) until the 4th and 5th years (Figure 7). Popash had greater height in the herbicided treatment in the 2nd year ($P<0.05$) but greater height in the untreated check in the 4th and 5th years ($P<0.01$) (Figure 8). Crown diameter of red maple tended to be greater, although not significantly so, in the presence of primrose willow in all the years it was measured (Figure 9). Herbicidal removal of primrose willow had no effect on popash crown diameter until the 5th year, when crown diameter was significantly less in the weeded treatment than in the check ($P<0.01$) (Figure 10).

An interesting observation at the P2 site was a decrease in primrose willow height as the baldcypress, popash and red maple overtopped the primrose willow in the fourth and fifth years, indicating a competitive inhibition of primrose willow by the trees (Figures 5, 7, 8).

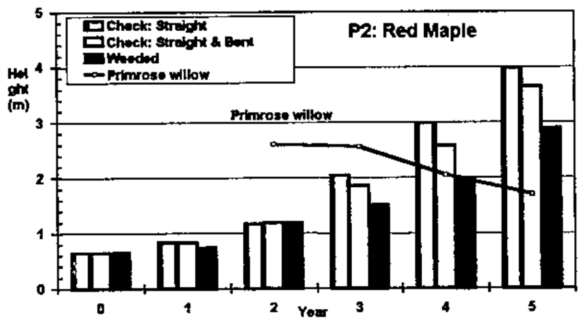

Figure 7. Yearly height of red maple as affected by primrose willow competition at the P2 site. Check plot trees grouped into a subset of straight trees only and the entire set of straight trees and bent trees.

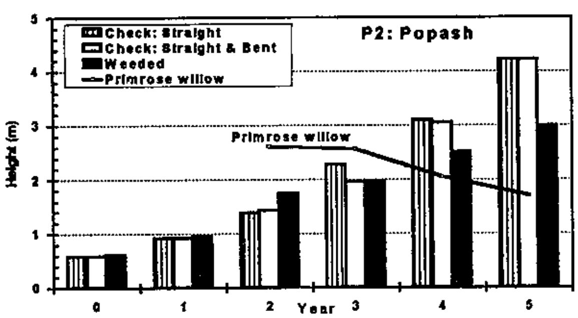

Figure 8. Yearly height of popash as affected by primrose willow competition at the P2 site. Check plot trees grouped into a subset of straight trees only and the entire set of straight trees and bent trees.

T1 Site. As early as the second year more than 50 percent of the popash trees, and about 20 percent of the baldcypress and water hickory trees, had exceeded the average height of the primrose willow (2.3 m) (Figure 11). By the fourth year nearly 100 percent of the popash trees and 70 percent of the baldcypress and water hickory trees were taller than the primrose willow. The trees had begun to exert a competitive effect on the primrose willow as indicated by a reduction in the leaf area index of the primrose willow in the plots with trees relative to the plots without trees (Figure 12). The greater reduction in relative leaf area index of primrose willow by the popash than by the other tree species is consistent with the greater height and crown diameter of popash than water hickory or baldcypress (Figures 13 and 14). Water hickory's height, crown diameter and effect on reduction of primrose willow leaf area index were greater than those of baldcypress but less than those of popash.

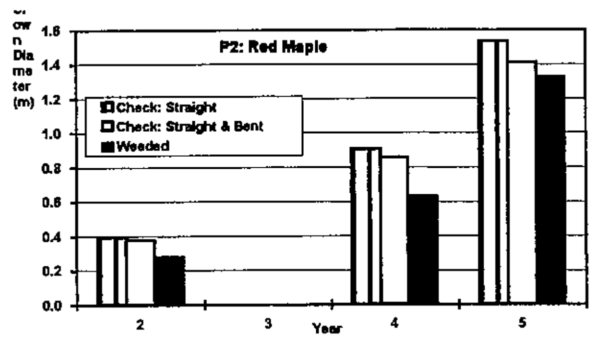

Figure 9. Crown diameter of red maple as affected by primrose willow competition at the P2 site. Check plot trees grouped into a subset of straight trees only and the entire set of straight trees and bent trees.

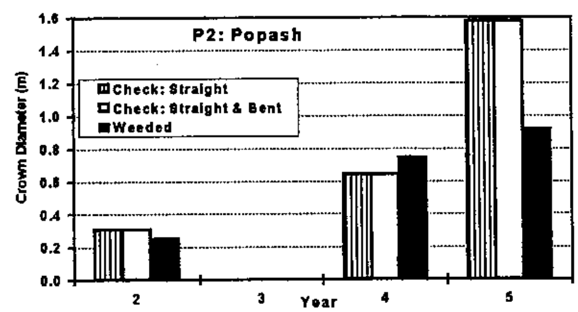

Figure 10. Crown diameter of popash as affected by primrose willow competition at the P2 site. Check plot trees grouped into a subset of straight trees only and the entire set of straight trees and bent trees.

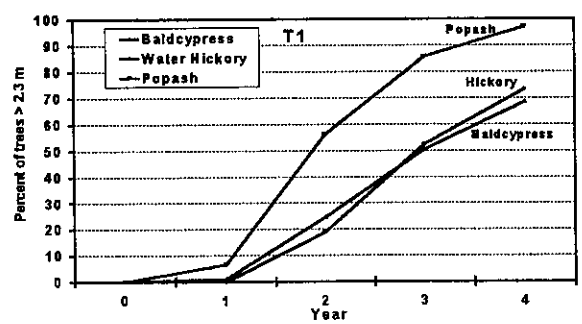

Figure 11. Percent of trees taller than the four year average sitewide primrose willow height (2.3 m) at the T1 site.

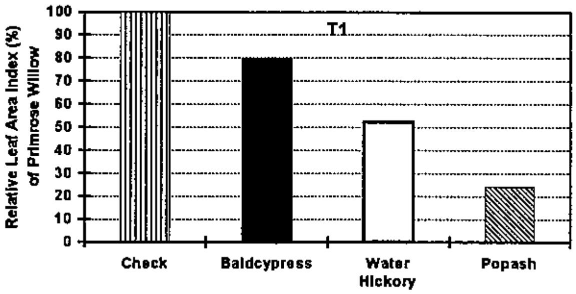

Figure 12. Effect of tree canopy development on relative leaf area index of primrose willow in the 4th year at the T1 site.

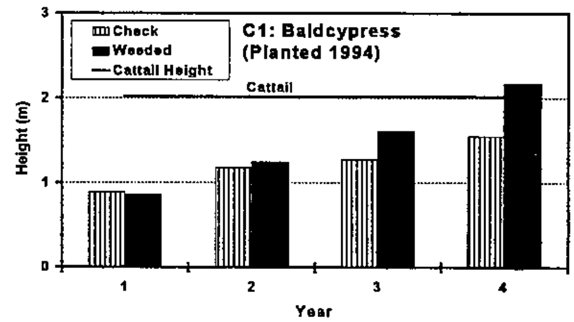

Figure 15. Yearly height of baldcypress as affected by cattail competition at the C1 site.

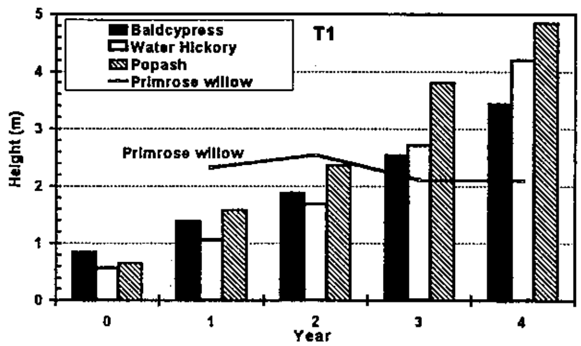

Figure 13. Yearly height of baldcypress, water hickory, and popash in a primrose willow stand at the T1 site.

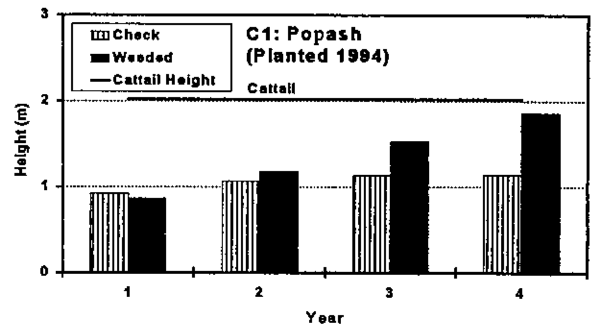

Figure 16. Yearly height of popash as affected by cattail competition at the C1 site.

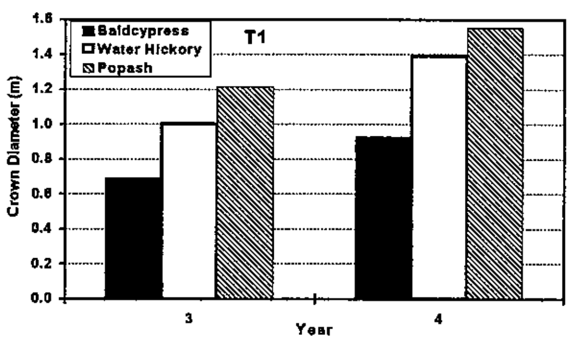

Figure 14. Yearly crown diameter of baldcypress, water hickory, and popash in a primrose willow stand at the T1 site.

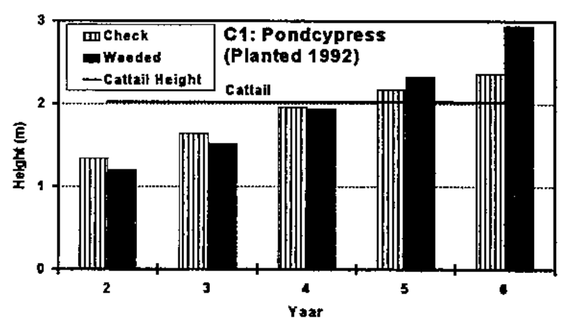

Figure 17. Yearly height of pondcypress as affected by cattail competition at the C1 site.

C1 Site. Cattail removal enhanced the growth of the baldcypress and popash trees we planted in 1994 (Figures 15 and 16). Although the baldcypress continued to grow in height in the presence of cattail, popash height growth in the presence of cattail was practically nil between the 3rd and 4th years. Cattail removal beginning in the 2nd year also enhanced growth of the pondcypress and baldcypress planted earlier by Mobil (Figures 17 and 18).

Nevertheless, these earlier planted trees have been able to grow and to surpass the height of the cattail (Figure 19). Pondcypress grew faster than baldcypress, resulting in nearly 80% of the pondcypress, compared to 50% of the baldcypress, surpassing the 2m height of the cattail by the 6th year.

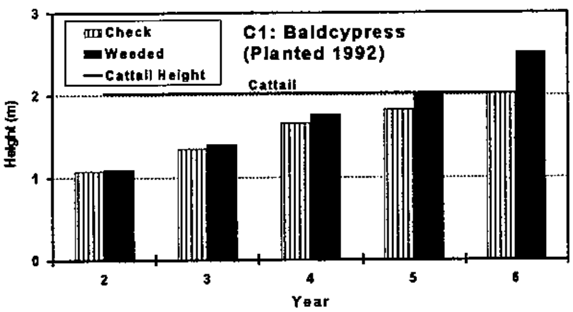

Figure 18. Yearly height of baldcypress as affected by cattail competition at the C1 site.

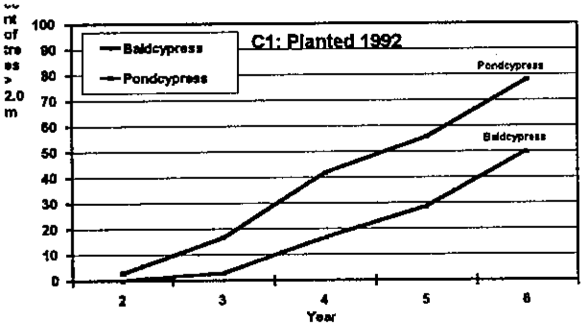

Figure 19. Percent of trees taller than the average sitewide cattail height (2.0 m) at the C1 site.

Discussion

Primrose willow had only a slight effect on heights of baldcypress through three growing seasons at the P1 site. In the first growing season, baldcypress height growth was greater in the presence of resprouted primrose willow than with primrose willow repeatedly mowed. This may have been due to a protective nurse crop effect (protection from heat, wind, predation, etc.) or to an etiolation effect because of shading from the primrose willow. In subsequent years, growth rates were greater with primrose willow removed, so that by the end of the sixth growing season baldcypress height was 25 percent greater, and DBH was 50 percent greater, without primrose willow than with primrose willow competition.

Baldcypress growth at the P1 site was rapid. Even with primrose willow competition, tree height was greater on this reclaimed mine site than was height of comparably aged trees on unmined mitigation wetlands as determined by Denton (1990). DBH was also greater, but crown diameter was slightly less, on this reclaimed mined site with primrose willow than on the unmined wetlands. Baldcypress height, DBH, and crown diameter were all much greater on the weeded P1 plots than on the several mitigation wetlands.

Baldcypress height growth was slower at the P2 site than at the P1 site, but it was still comparable to the mitigation wetlands (Denton 1990). The trees at the P1 site had reached an average height of 2 m by the end of the second growing season, while it required three growing seasons for the P2 trees to reach 2 m in height. However, similar to the P1 site, baldcypress at the P2 site also exhibited greater growth the first year in the presence of primrose willow than with the primrose willow competition removed. There was an additional complication at the P2 site in that the primrose willow there was more dense and tangled than at the P1 site and was more prone to lean on and bend some of the planted test trees. The effect of primrose willow on bending of trees was only slight the first year, but about 40 to 50% of the trees were bent to some degree by the 3rd year. However, the bending effect seems to be temporary and may disappear after the trees overtop the primrose willow. By the 5th year none of the popash trees were bent and only 14% of the red maple and 16% of the baldcypress were bent.

The modest effect of primrose willow on tree height growth indicates that control measures, which are often expensive, may not be necessary in establishing forested wetlands on reclaimed phosphate mined lands. Baldcypress, popash, red maple and water hickory trees were able to grow through and overtop the primrose willow. As the trees have overtopped the primrose willow, their expanding crowns have exerted an inhibitory effect on the primrose willow. The data and our observations indicate that if trees are planted at a sufficient density they will eventually develop a canopy cover that will shade out the primrose willow, thus reducing primrose willow cover as required by FDEP regulations. The presence of primrose willow may even have a temporary beneficial effect on understory development. We observed an abundance of ferns and begonias beneath the shade of the primrose willow at the P1 site, but in the plots where primrose willow was removed, the result was a ground cover of weedy species.

Removal of cattail enhanced the growth of baldcypress and popash. However, baldcypress and pondcypress were able to eventually overtop the cattail at this site without cattail control efforts. In contrast, popash's lack of growth in the presence of cattail between the 3rd and 4th years indicates that popash may not compete as well with cattail as does baldcypress, and popash may not displace cattail without control efforts.

Our general observation has been that wetland trees grow slower in standing water than in better drained conditions, but baldcypress is more tolerant of flooded conditions than popash. For example, standing water was observed seldom at the T1 site, occasionally at the P2 site, and almost continuously at the C1 site. Correspondingly, popash and baldcypress growth was fastest at the T1 site, intermediate at the P2 site, and slowest at the C1 site. Popash grew faster than baldcypress and competed well with primrose willow at the T1 site, but baldcypress grew better than popash at the cattail site.

We found that cattail removal by cutting enhanced popash growth, but removal of primrose willow by spraying with triclopyr herbicide inhibited popash growth. This suggests that the herbicide had a detrimental effect on popash even though we attempted to protect the trees from the herbicide spray by covering the trees with plastic bags and by carefully directing the spray on the weeds and not the trees. However, there may have been some root absorption of herbicide that fell on the saturated soil or standing water. In contrast to popash (and red maple), baldcypress was not harmed by the herbicide at the P2 site, which is consistent with the much greater tolerance of baldcypress to triclopyr herbicide. Normally one would not go to the extent that we did in these experiments to protect the trees from an herbicide effect. The possible detrimental effect of herbicidal treatment on some desirable trees, and perhaps various understory species as well, is another argument for being patient and allowing the trees to grow and shade out primrose willow.

We have observed that elderberry (*Sambucus canadensis*) tends to grow more erect than primrose willow but is able to occupy similar habitat and may have greater wildlife value. The presence of some elderberry intermixed with the primrose willow at the P1 site may have helped prevent bending of trees. In contrast, there was virtually no elderberry at the P2 site. We have begun experiments that will examine the possibility of using elderberry as a forested wetland "nurse crop." It is hypothesized that elderberry will occupy space that otherwise might be inhabited by primrose willow, and the elderberry should provide canopy cover and habitat for shade requiring understory plants, but it should in turn be shaded out by the developing canopy of the taller wetland trees. Carolina willow (*Salix caroliniana*) has also been proposed as a wetland forest nurse crop (Miller et al. 1988), but its taller stature may require a longer time for other wetland tree species to overtop and shade it out compared to elderberry.

Our research results indicate that the expense of chemical, mechanical and manual control of primrose willow and cattail are not necessary when adapted wetland trees are planted and site conditions allow vigorous tree growth. However, we have observed and battled several vine species that do appear to require more intensive control measures, and further research is needed to develop more economical vine management strategies.

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