Growth of Newly Planted Water Tupelo Seedlings After Flooding and Siltation

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Abstract. In central Mississippi, outplanted water tupelo seedlings survived and grew well after shallow flooding (up to 8 cm) from late February through June 1. Submersion of the seedlings, flooding until late in the growing season, reflooding, and moderate siltation reduced growth. Flooding caused changes in certain soil properties, but these changes did not seem to be the major cause of growth reductions. ***Forest Sci. 16: 250-256.***

Additional key words. Redox potential, Alligator clay, *Nyssa aquatica* L.

WATER TUPELO (*Nyssa aquatica* L.) is a valuable timber species in swamps which cover more than 4 million acres in the Midsouth. The swamps are usually flooded from January or February until late May or early June, and in wet years the water may not leave until midsummer. These wet conditions have discouraged attempts to regenerate water tupelo after logging, and extensive swamp areas in the Midsouth now need planting.

Before a successful planting program can begin, information is needed on the effects of flooding and siltation during the growing season. This paper describes responses of newly planted seedlings to controlled flooding and siltation under field conditions.

Previous studies have determined the general response of water tupelo to flooding. Applequist (1960) and Klawitter (1963) investigated flooding effects by reconstructing the history of existing stands. They found that growth rate was positively correlated with the supply of available moisture during the growing season. They also concluded that extended flooding during the growing season was harmful.

In greenhouse studies, Briscoe[1] found that submersion of first-year seedlings reduced growth more than flooding the soil only, and that the reduction increased with duration of submersion. Water at temperatures of 5° and 35° C was more damaging than that at 20° C.

Hosner and Boyce (1962) in a greenhouse study with first-year seedlings found that water tupelo, green ash (*Fraxinus pennsylvanica* Marsh.), pumpkin ash (*Fraxinus profunda* (Bush) Bush), and pin oak (*Quercus palustris* Muenchh.) in saturated soil significantly outgrew seedlings of the same species in nonsaturated soil. Other species studied were either not affected or their growth was significantly reduced by soil saturation. Hosner *et al.* (1965) studied the effects of four soil moisture regimes (saturated to wilting point) upon nutrient uptake of four species. Tissue nutrient concentrations were generally low for seedlings subjected to saturated soils and high for those subjected to the wilting point regime. The authors concluded that moisture treatments apparently affected

[1] Briscoe, C. B. Diameter growth and effects of flooding on certain bottomland forest trees. Unpublished dissertation on file at Sch. Forest., Duke Univ., Durham, N. C. 1957.

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growth more than nutrient absorption.

Hook[2] and Hook and Stubbs (1967) studied the response of water tupelo and swamp tupelo (*N. sylvatica* var. *biflora* (Walt.) Sarg.) to six water regimes under controlled conditions. They found that seedlings grew about twice as fast in moving as in stagnant water. Under some regimes, lenticels proliferated; and the authors suggested that these structures may function in gas exchange between the atmosphere and roots. Carbon dioxide concentrations were higher and oxygen concentrations lower in stagnant than in moving water. High carbon dioxide (31 percent) and low oxygen (1 percent) concentrations reduced growth.

Silker (1948) measured responses of water tupelo to flooding under field conditions. He planted seedlings along margins of reservoirs, where flooding depth could not be controlled. Water tupelo was well adapted to flats in the zone intermittently covered by water; above this zone seedlings grew well only on seepage areas. Prolonged submergence of the plants during the growing season caused dieback, but the trees sprouted after the water level was lowered.

Methods

In the present study, water and siltation levels were controlled on 66 plots which were 21 m² and surrounded by levees (Fig. 1). Depth and duration of flooding were experimental variables.

The study area is on the Delta Experimental Forest about 4½ miles north of Stoneville, Mississippi. The soil type, Alligator clay, is commonly found in swamps.

Merchantable timber, mostly willow oak (*Quercus phellos* L.), was removed from approximately 4 acres with conventional logging equipment. The remaining trees and stumps were sheared close to the groundline, and they were removed from the area along with tops and small limbs.

FIGURE 1. *The study plots.*

A series of levees was then constructed to delineate six rows of 11 plots. The plot area occupied approximately 1½ acres near the center of the clearing. Soil for the levees was brought from outside the study area. Levees were about 1 m high and 4 m wide at the base. They were completed in September 1967 and allowed to settle until February 1968. To deter seepage, a layer of bentonite clay was applied to levees surrounding plots assigned to the deep flooding treatments. An irrigation system was installed to bring water from a nearby lake.

Seedlings were grown in a nursery from seed collected near Minter City, in north-central Mississippi. Seeds were stratified in moist sand at 2° to 4.5° C for approximately 4 months before sowing in April 1967. The seedlings were lifted during the first week of February 1968 and planted ⅔ m apart in six rows of five seedlings per plot. At that time, heights of seedling tops averaged 46 cm and diameters at the root collar averaged 6 mm. Standing water was drained from the plots prior to planting. Flooding treatments were started 2 weeks after planting. The water was not disturbed after it was pumped onto the plot, hence it was stagnant throughout the study.

Treatments

The study was divided into three concurrent phases. The first phase measured the effects of three flooding depths—0 to

[2] Hook, D. D. Growth and development of swamp tupelo [*Nyssa sylvatica* var. *biflora* (Walt.) Sarg.] under different root environments. Unpublished dissertation on file at Univ. Libr., Univ. Ga., Athens. 1968.

8 cm above groundline (shallow), 15 to 25 cm above groundline (moderate), and 10 to 15 cm above the tallest seedlings (deep)—and three durations of flooding—until June 1, July 1, and August 1. The second phase measured the combined effects of flooding and siltation. Flooding was to either 15 to 25 cm above the groundline, or to 10 to 15 cm above the tallest seedlings. Siltation was to one of two depths: 8 to 10 cm above groundline (shallow) or 15 to 20 cm above groundline (deep). Flooding was terminated on half the plots on June 1 and the other half on July 1. The impact of reflooding during the growing season was determined in the third phase. Plots were flooded to 10 to 15 cm above the tallest seedlings until June 1, drained, then reflooded for 1 or 2 weeks beginning on July 1 or August 1.

To simulate siltation, sand was shoveled onto the plots immediately after planting and spread uniformly to the desired depth. On these plots flooding depth was measured from the top of the sand. Flooding depths were adjusted daily, and after the flooded phases were completed all plots were kept free of weeds.

Treatments, plus an untreated control, were replicated three times. Groups of plots for each phase were systematically selected, but within phases treatments were factorially arranged in a completely randomized design.

Measurements

Heights and diameters at the groundline were measured after planting and at the end of the growing season on the interior four rows of seedlings in each plot. Heights were measured to the nearest centimeter and diameters to the nearest millimeter. Where sand was added, its upper surface was taken as groundline for measurement purposes.

On each plot, soil temperatures 2.5 cm below the soil surface were measured with mercury-bulb thermometers. Water temperatures were measured approximately 15 cm below the surface in deep-flooded plots and 2.5 cm below the surface in other plots. Oxygen content of the water was determined with a Sargent[3] oxygen analyzer at the same depth and time as temperatures were taken.

Analyses

Soil samples were collected during October 1967 and during May and September 1968 from the 0- to 15-cm layer of each plot in the first and third phases, and the control. Soil from the first and third collections was air-dried, and ground to pass a 2-mm sieve in preparation for chemical analyses. Wet soil from May 1968 collection was sealed in glass jars and stored for 5 months at 2° to 5° C prior to analyses.

Leaves from all seedlings in each plot were collected in early November, dried at 70° C, and ground. Sufficient leaves for individual-plot analysis were obtained for all treatments except deep flooding until August 1, deep flooding until July 1 with siltation 15 to 20 cm deep, and reflooding on August 1 for 2 weeks. Leaves from all three replicates of each of these treatments were composited.

Ammonium and nitrate nitrogen were extracted from soil with acidified sodium chloride, and concentrations were determined on a Kjeldahl apparatus by methods four and five of Sims *et al.* (1967). Total nitrogen in leaves was determined by normal Kjeldahl procedures. Exchangeable potassium and calcium were extracted with slightly acid ammonium acetate and analyzed by emission spectrophotometry (Jackson 1958). Phosphorus was extracted with Bray's #2 solution and analyzed by absorption spectrophotometry (Southern Reg. Soils Res. Comm. 1965). Leaf samples were ashed at 550° C, and phosphorus, potassium, and calcium contents determined by the same analytical procedures as for soil. Soil pH was measured electrolytically.

Redox potentials were read on a pH meter with a millivolt scale; a platinum electrode and a saturated calomel electrode were used. Before any measurements were made, the platinum electrode was

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[3] Mention of a trade name is solely to identify equipment used and does not constitute endorsement by the USDA Forest Service.

cleaned electrolytically by the method of Redman and Patrick (1965). Air-dry soil samples of 80 g of soil were mixed with 80 ml of distilled water, and redox potential was measured after 5 minutes. The electrodes were inserted directly into wet samples in the jars and equilibrated 30 minutes before readings were taken.

Initial heights and diameters were used as covariants in testing the effect of treatments on seedling growth. Survival percentages were transformed to arcsin values and the effects of treatments (within each phase) were tested by factorial analysis of variance. Treatment means were compared at the 0.05 level. The control plots were not included in any of the statistical analyses.

Results and Discussion

Soil Properties

Flooding caused some changes in the soil properties (Table 1). Available nitrogen was slightly higher during than before flooding. In submerged soil, virtually all nitrates were absent; nitrogen was available in the ammonium form.

On phase-1 plots, extractable phosphorus increased about 30 percent during flooding. On phase-3 plots, it increased about 150 percent. Differences in content of extractable ferrous iron, which was not measured in the present study, could be the cause of the variable increase in extractable phosphorus (Redman and Patrick 1965).

Exchangeable potassium and calcium contents were lower under flooded than nonflooded conditions. Losses were about the same regardless of flooding depth, and there were no appreciable differences by study phase.

The soil pH was about 5.2 before treatment, 6.4 during flooding, and 5.6 two months after drainage. The increase in hydroxyl ions was probably the result of ammonium production and the reduction of iron and other compounds (Redman and Patrick 1965).

Redox potential before flooding averaged about 270 mv. During flooding, it ranged from −30 mv in the shallowly and moderately flooded plots to −81 mv in the deeply flooded plots.

The pH and extractable phosphorus content 2 months after the last plots were drained were somewhat higher than they were before flooding. The other nutrients

TABLE 1. Chemical properties of Alligator clay under flooded and nonflooded conditions.

Soil property	Before flooding (October)	During flooding (May)
Extractable nitrogen (ppm)	33	37
Phosphorus (ppm)	128	237
Potassium (ppm)	462	273
Calcium (ppm)	4700	4400
pH	5.2	6.4
Redox potential (mv)	270	−52

TABLE 2. Soil and water temperatures by flooding depth (n = 3). (In degrees Centigrade)

Measurement date	Flooding depth					
	Shallow[1]		Moderate[1]		Deep	
	Water	Soil	Water	Soil	Water[2]	Soil[1]
4/17	23	20	22	19	20	18
5/7	29	23	27	20	20	19
5/21	31	2(	29	22	20	20
6/17	32	30	30	28	28	28
7/9	27	27	28	28	26	27
7/18	32	31	30	30	30	30
8/1	34	32	33	32	31	32

[1] At 2.5 cm below surface.

[2] At 15 cm below surface.

had returned to about the preflooding levels.

Soil temperatures until July in the shallowly and moderately flooded plots were lower than water temperatures (Table 2). Soil and water temperatures were about equal in the deeply flooded plots in all phases. Both temperatures decreased with an increase in flooding depth. Until July, soil temperatures were 3° to 5° C lower in the moderately than in the shallowly flooded plots. For the remainder of the growing season, soil and water temperatures were about the same regardless of flooding depth.

TABLE 3. Effects of flooding depth and drainage date on first-year survival and increase in height and diameter (Phase 1) (n = 3). Average initial height, 49 cm; average initial diameter at root collar, 6.8 mm.

Flooding depth and drainage date	Increase in— Height	Diameter	Survival
	Cm	*Mm*	*Percent*
Shallow			
June 1	52	15	100
July 1	29	9	98
August 1	39	13	100
Moderate			
June 1	27	10	92
July 1	30	9	100
August 1	17	6	95
Deep			
June 1	17	7	93
July 1	− 6[1]	3	87
August 1	−24	−1	32
No flooding	61	16	95

[1] Negative growth is a result of dieback.

Seedling Responses

Nutrient Uptake. Nutrient contents of leaves did not appear to be affected by flooding depth or duration. The average contents—2.34 percent N, 0.13 percent P, 1.36 percent K, and 0.58 percent Ca—are within the range expected from nonfertilized plots (Broadfoot 1966).

Flooding. The seedlings showed a remarkable ability to survive flooding for extended periods (Table 3). Survival was 87 percent or higher on all plots that were flooded from late February until July 1, including those with water 15 to 20 cm above seedling tops. Deep flooding until August 1 reduced survival to 32 percent.

Height growth in plots covered with 0 to 8 cm of water until June 1 was approximately the same as that on the nonflooded control plots. Retention of this depth of water until July 1 and August 1 significantly reduced height growth (Table 3), but did not cause dieback.

Moderate flooding (15 to 25 cm) had significantly greater effect on height growth than shallow flooding. This effect was apparent on plots drained on June 1 as well as those drained later.

Seedlings in shallowly flooded plots were about 14 cm taller and about 4.5 mm

TABLE 4. Effects of siltation depth, flooding depth, and drainage date on first-season survival and increase in height and diameter (Phase 2) (n = 3). Average initial height and diameter, 42 cm and 5.1 mm respectively.

Flooding depth and drainage date	7.5 to 10 cm of sand			15 to 20 cm of sand		
	Height	Diameter	Survival	Height	Diameter	Survival
	Cm	*Mm*	*Percent*	*Cm*	*Mm*	*Percent*
Moderate						
June 1	10	3	87	18	7	95
July 1	12	4	87	9	4	88
Deep						
June 1	−8[1]	3	68	−6	3	62
July 1	−9	1	68	−17	1	30

[1] Negative growth is a result of dieback.

larger in diameter than those in moderately flooded plots. Early in the growing season, seedlings in the shallowly flooded plots had much larger, healthier crowns than those subjected to moderate flooding. Soil temperatures may explain differences in crown vigor. Soil temperatures until early July were 3° to 5° C lower in the moderately than in the shallowly flooded plots. These lower soil temperatures could have reduced metabolic activity in the roots sufficiently to restrict growth. After the soil warmed in the moderately flooded plots, crowns enlarged and growth increased.

Inundated seedling tops did not leaf out until the water was removed from the plots. All durations of deep flooding reduced height growth and caused dieback. Severity of damage increased with duration of flooding.

The treatments that reduced height growth also reduced diameter growth (Table 3).

Siltation and Flooding. At the moderate depth of flooding, survival with siltation averaged 87 percent versus about 96 percent without siltation (Table 4). On deeply flooded plots, survival averaged 57 percent with siltation and 90 percent without.

Siltation in combination with flooding reduced height and diameter growth more than flooding alone, but the two siltation depths did not differ significantly in their effect on height and diameter.

Siltation with moderate flooding caused dieback to about 30 percent of the seedlings; whereas, there was practically no dieback in the moderately and shallowly flooded plots without siltation. Dieback in deeply flooded treatments was about the same (75 percent) with or without siltation.

Reflooding. Two weeks of reflooding were significantly more damaging to seedling survival than 1 week (Table 5). However, the most harmful treatment, reflooding for 2 weeks starting on August 1, still left 75 percent survival, which would be satisfactory in most plantings.

TABLE 5. Effects of date and duration of reflooding on first-season survival and increase in height and diameter (Phase 3) (n = 3). Initial height and diameter, 45 cm and 5.7 mm respectively.

Reflood date and duration	Height	Diameter	Survival
	Cm	*Mm*	*Percent*
July 1			
1 week	2	3	92
2 weeks	−7[1]	2	85
August 1			
1 week	−9	1	90
2 weeks	−8	1	75

[1] Negative growth is a result of dieback.

Seedlings that were reflooded were smaller than those receiving most of the other treatments (Table 5). Date (July 1 and August 1) and duration (1 and 2 weeks) of reflooding did not significantly affect growth. Seedlings had leafed out before they were reflooded, and inundation killed the leaves. Within about a week after the water receded, the seedlings began to leaf out a second time.

Dieback occurred on 80 percent of the seedlings in reflooded plots; it was already evident when the plots were drained in June. The average amount of stem loss was 25 cm per seedling.

Seedlings with dieback sprouted readily just below the lowest dead stem tissue. Usually, a sprout from the uppermost bud on the live stem asserted dominance and became the new leader for the seedling.

Although complete submersion of water tupelos or moderate flooding until late in the growing season reduced growth, planted seedlings appear able to survive and grow under conditions normally encountered in southern swamps.

Reflooding during the growing season, which is largely unpredictable, is damaging if the seedlings are completely submerged. As little as 1 week of submergence kills the leaves.

In the study, all depths of flooding chemically reduced the soil, but seedlings grew well on shallowly flooded plots. Hook[4] reported that swamp tupelo ap-

[4] Hook, D. D. See footnote 2.

peared to have a dual metabolic system in its roots. He found evidence of aerobic and anaerobic respiration in the presence of oxygen, and anaerobic respiration in the absence of oxygen. Perhaps water tupelo roots have a similar system which enables the plant to grow well under reduced conditions such as those of the present study.

Moderate siltation, which often accompanies flooding, reduced growth and could be a problem in water tupelo plantations.

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