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The Effect of Salinity and Waterlogging on Growth and Survival of Baldcypress and Chinese Tallow Seedlings

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ABSTRACT

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Growth, biomass, and survival of four-month-old baldcypress (*Taxodium distichum* (L.) Rich.) and Chinese tallow (*Sapium sebiferum* (L.) Roxb.) seedlings were examined in an experiment varying water levels (watered, flooded) and salinity levels (0, 2, and 10 ppt, plus a simulated storm surge with 32 ppt water). All seedlings survived to the end of the experiment except for those flooded with 10 ppt water. Baldcypress survived two weeks whereas Chinese tallow survived for 6 weeks in 10 ppt water. Height growth of both species was unaffected by flooding with 0 and 2 ppt water, but heights of plants watered with 10 ppt water were significantly lower. Diameter growth was much more variable. Baldcypress final diameters were greater in flooded treatments than in drained treatments. Chinese tallow diameters were greater in drained treatments. Root and shoot biomasses were not significantly different among treatments for baldcypress, but were two to five times less in flooded treatments for Chinese tallow. Baldcypress is more tolerant of flooding. Chinese tallow can survive longer at higher salinities, thus increasing its chances of survival in coastal areas where salinity levels are rising.

ADDITIONAL INDEX WORDS: Wetlands, salt tolerance, flooding, swamps, coastal forests.

INTRODUCTION

In the southeastern United States, many coastal forested wetlands are being subjected to increased levels of flooding and salinity as a result of subsidence and sea level rise (Salinas *et al.*, 1986; Conner and Day 1988). Current evidence indicates that global sea levels will rise 3 to 124 cm by the year 2100 (Wigley and Raper 1993). A 1 m rise in sea level would flood 30 to 90% of coastal wetlands in the southeastern United States (Smith and Tirpak, 1989). While sea level rise is a slow process leading to changes in tree environment over decades, salinity levels can increase rapidly in freshwater forests during storm surges (Little *et al.*, 1958). The U.S. east coast is expected to enter a 20 to 40 year cycle of intense hurricane activity within the next decade (Tibbetts, 1993). Hurricane storm surges can carry salt water into coastal forests, killing trees (Hook *et al.*, 1991; Conner, 1993). Damage is especially noticeable in areas where anthropogenic features retain salt water (Moss, 1940).

Flooding is a natural occurrence in forested wetlands, and forest productivity peaks when annual flooding occurs during the dormant period (Gosselink *et al.*, 1981). The effect of flooding depends on duration with short-term flooding during the growing season having little effect on mature trees. Extended flooding during the growing season will kill many bottomland trees (Bell and Johnson, 1974). There is extensive literature available on flooding effects on tree species (see Hook and Scholtens, 1978 and Kozlowski and Pallardy, 1984). However, there is little information on the effects of salt water flooding. When nursery grown baldcypress (*Taxodium distichum* (L.) Rich.), water tupelo (*Nyssa aquatica* L.), and green ash (*Fraxinus pennsylvanica* Marsh.) seedlings are flooded with salt water, their stomata close rapidly and photosynthetic rates decline (Pezeshki, 1987; Pezeshki and Chambers, 1986; Pezeshki *et al.*, 1986, 1988, 1989).

Interest in global warming, sea level rise, and increased storm activity in recent years has shown that there is a need for a better understanding of the response of coastal tree species to increased flooding and salinity. The objective of this study

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was to determine survival, height and diameter growth, and biomass accumulation of baldcypress and Chinese tallow (*Sapium sebiferum* (L.) Roxb.) when subjected to flooding and various salinity levels. These two species were chosen for study because the former is one of the dominant forested wetland species in the southeastern United States (WILHITE and TOLIVER, 1990), and the latter is becoming increasingly more common in wetland areas of the southern United States (JONES and MCLEOD, 1989; HELM *et al.*, 1991, CONNER and ASKEW, 1993). Chinese tallow was introduced from China and has escaped from cultivation.

METHODS

Baldcypress and Chinese tallow seeds were collected from Hobcaw Barony near Georgetown, South Carolina, and stratified according to SCHOPMEYER (1974). After stratification, the seeds were planted in plastic nursery pots 15 cm in diameter and 20 cm tall filled with a potting mix of three parts composted bark and one part sand and a slow release fertilizer (Osmocote 14-14-14). The pots were placed in an outdoor facility and watered daily until treatment began. Upon germination, seedlings were thinned to one per pot and allowed to grow for four months, at which time the baldcypress and Chinese tallow seedlings averaged 69 ± 9 cm and 68 ± 10 cm tall, respectively. Plants were randomly assigned to one of eight treatments (15 plants per treatment, replicated 3 times) and basal diameters and heights recorded. Treatments consisted of: flooded with 0 ppt water (F0), watered with 0 ppt water (W0), flooded with 2 ppt water (F2), watered with 2 ppt water (W2), flooded with 10 ppt water (F10), watered with 10 ppt water (W10), flooded with a simulated storm surge of 32 ppt (FS), and watered with a simulated storm surge (WS).

Treatment began on July 20, 1992, with inundation of treatments F0, F2, F10, and FS and initiation of daily watering of treatments W0, W2, W10, and WS. Flooded treatments were located in 140 × 80 × 30 cm plastic tanks with water circulated among the three tanks of each treatment by pumping. Water levels were kept at approximately 5 cm above the soil surface to simulate increased water levels due to sea level rise. Watered treatments were located on an adjacent gravel bed and were watered to saturation daily using hoses connected to the flood treatment tanks.The use of watered seedlings helped separate the confounding effects of salinity and flooding. The FS and WS treatments were allowed to grow using 0 ppt water until September 21, 1992, when they were surged with 32 ppt water. This surge was designed to simulate a typical hurricane surge that might occur in coastal forests. Upon mixing with fresh water in the FS tanks, salinity was 21 ppt, similar to that observed in wetland forests on Hobcaw Barony after the passage of Hurricane Hugo in 1989. Flooding of the FS seedlings and watering of the WS seedlings with 21 ppt water continued for 48 hours. Fresh water was then surged through the tanks to simulate heavy rainfall. Salinity dropped to 9 ppt with the surge. Natural rainfall events and continued adding of freshwater over a period of 7 days lowered salinity to 2.5 ppt, where it remained to the end of the study.

On October 26, 1992, seedlings were harvested from all treatments for biomass determination. Basal diameter and heights of the seedlings were also recorded. Seedlings were separated into root and stem components, dried at 40 °C to a constant weight, and weighed. Treatment means for biomass and growth parameters were compared using analysis of variance. When significant differences occurred among treatments, Scheffe's F-test (SNEDECOR and COCHRAN, 1980) was used to determine which treatments differed. The data were analyzed using Statview II for the Macintosh (FELDERMAN *et al.*, 1987).

Saltwater solutions were prepared using Instant Ocean Synthetic Sea Salt with major ionic components of Cl (47%), Na (26%), SO_4 (6%), Mg (3%), Ca (1%), and K (1%) as percentage by dry weight. Salinity values were monitored using a YSI Model 33 meter. Fresh or salt water was added as needed to maintain the flooding depth and salinity.

RESULTS

All seedlings of both species survived to the end of the experiment except for those flooded with 10 ppt water (F10 treatment). Baldcypress seedlings died within two weeks of flooding in the F10 treatment, whereas it took up to six weeks for the Chinese tallow seedlings to die. Although there was no mortality in the FS tanks, both species were exhibiting tip die-back at time of harvest.

Even though seedlings survived the FS treatment, heights were not measured due to the difficulty of determining where the living stem ended. Excluding the F10 and FS treatments, height growth of both species was generally greater in

Table 1. *Diameter and height measurements of baldcypress and Chinese tallow seedlings (± SE). For treatment abbreviations and statistical symbols see caption of Figure 1.*

Species	Treatment	Diameter (mm)		Height (cm)	
		Begin	End	Begin	End
Baldcypress	F0	5.08 (0.13)A	11.61 (0.42)A	68.09 (1.28)A	99.44 (1.76)A
	F2	5.07 (0.14)A	11.60 (0.44)AB	68.73 (1.34)A	94.07 (1.67)A
	F10	5.08 (0.16)A	AD*	68.51 (1.54)A	AD
	FS	5.22 (0.16)A	10.73 (0.35)AB	66.46 (1.42)A	TD**
	W0	5.29 (0.16)A	9.72 (0.30)AB	68.96 (1.11)A	113.56 (2.03)B
	W2	5.13 (0.17)A	9.75 (0.31)AB	70.16 (1.24)A	109.53 (1.97)B
	W10	5.50 (0.15)A	9.14 (0.22)B	70.53 (1.35)A	94.16 (1.58)A
	WS	5.25 (0.17)A	9.58 (0.29)AB	67.20 (1.30)A	106.87 (2.22)B
Chinese tallow	F0	6.74 (0.14)a	13.23 (0.60)b	64.20 (1.25)b	112.67 (2.28)ac
	F2	6.62 (0.12)a	11.88 (0.47)b	65.27 (1.47)ab	110.67 (2.71)a
	F10	6.76 (0.11)a	AD	68.33 (1.52)ab	AD
	FS	6.88 (0.13)a	12.52 (0.42)ab	67.93 (1.40)ab	TD
	W0	7.11 (0.15)a	13.64 (0.20)a	71.47 (1.55)ab	143.04 (2.47)b
	W2	7.02 (0.13)a	13.96 (0.20)a	67.09 (1.28)ab	139.47 (2.49)b
	W10	7.27 (0.15)a	12.62 (0.18)a	72.44 (1.60)a	123.04 (1.88)c
	WS	6.87 (0.15)a	12.78 (0.18)ab	69.44 (1.28)ab	136.67 (2.28)b

* All dead, no measurements taken

** Tops dead, no height measurements taken

watered treatments than in flooded treatments (Table 1). Low levels of salinity (2 ppt) had little impact on height growth of either species in both watered and flooded treatments. Watering with 10 ppt, however, resulted in significantly lower heights. Watering with the higher salinity surge water reduced final heights only slightly. Chinese tallow seedlings outgrew baldcypress by approximately 15 cm in flooded treatments and 30 cm in watered treatments.

Average diameters of Chinese tallow seedlings at the end of the experiment were not very different among treatments (range of 11.9 cm to 14.0 mm). The smallest seedlings were in the F2 treatment, and the largest seedlings were in the W2 treatment. Diameters of baldcypress seedlings were more variable, with flooded seedlings having a greater diameter at the end of the experiment than the watered seedlings.

Although seedling survival was 100% for W0, W2, W10, WS, F0, F2, and FS treatments, shoot and root biomass values were affected by flooding and salinity, especially for Chinese tallow (Figure 1). Root biomass of Chinese tallow seedlings was significantly less ($P \leq 0.05$) for flooded treatments when compared to watered treatments. Root biomass of watered seedlings was 4–5 times that of flooded seedlings, while shoot biomass was only 2 times greater. Root and shoot biomass of baldcypress seedlings was not very different among treatments, although there was some hint of declining values with increased salinity levels.

DISCUSSION

Baldcypress and Chinese tallow are both highly tolerant of flooding with freshwater (Hook, 1984; Jones and Sharitz, 1990), but Chinese tallow exhibited a greater reduction in root and shoot biomass when flooded. Lower root biomass of flooded seedlings was probably the result of root die-off. Flood tolerant species tend to lose their original root system upon waterlogging and subsequently develop succulent soil water roots as Donovan *et al.* (1988) observed with baldcypress. Roots of flooded seedlings in this study were observed to be more succulent than those of watered seedlings. In addition, hypertrophied lenticels were prolific on Chinese tallow stems, indicating a capacity for partial oxygen stress avoidance (Kozlowski, 1984).

In the present study, four-month-old seedlings of baldcypress and Chinese tallow were able to grow fairly well when flooded with up to 2 ppt water. Even though both species were killed when flooded with 10 ppt water, Chinese tallow survived for a longer time than baldcypress before death occurred. Surging with 32 ppt water caused tip die-back, but Conner and Askew (1992, 1993) reported that these species tend to resprout lower on their stem after short-term exposure to salt

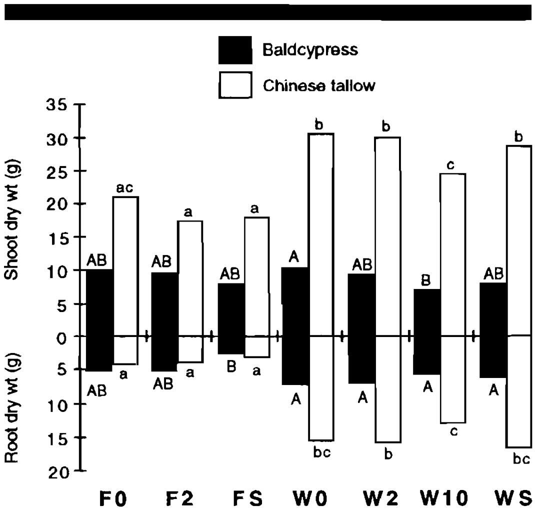

Figure 1. Effects of flooding and salinity on shoot and root biomass of baldcypress and Chinese tallow seedlings. F0 = flooded with 0 ppt water, F2 = flooded with 2 ppt water, FS = surged with 32 ppt water, W0 = watered with 0 ppt water, W2 = watered with 2 ppt water, W10 = watered with 10 ppt water, WS = surged with 32 ppt water. Unlike lower case letters indicate statistical differences at 5% level for Chinese tallow seedlings. Different upper case letters indicate statistical differences at 5% level for baldcypress seedlings.

water. CONNER and ASKEW (1993) also found that Chinese tallow could survive up to five days exposure to 20–27 ppt water. This ability to withstand higher salinity for several days gives Chinese tallow a competitive edge over baldcypress, allowing it to outcompete native vegetation. HELM *et al.* (1991) found Chinese tallow growing in pure stands in poorly drained swales on Bull Island, South Carolina. Further research is needed to address the question of whether Chinese tallow will dominate future coastal forests in the southeastern United States.

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