USDA FOREST SERVICE
RESEARCH PAPER **NC-198**

GROWTH RESPONSE of speckled alder and willow to DEPTH OF FLOODING

M. Dean Knighton

North Central Forest Experiment Station
Forest Service, U.S. Department of Agriculture

Knighton, M. Dean.

1981. Growth response of speckled alder and willow to depth of flooding. U.S. Department of Agriculture Forest Service, Research Paper NC-198, 6 p. U.S. Department of Agriculture Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota.

Growth and survival of speckled alder and willow were determined for two growing seasons with continuous flooding at different depths. Growth was at least four times greater when the water table was below the root crown than when it was 15 cm above. Mortality increased with flooding depth and was greatest for alder.

KEY WORDS: *Alnus rugosa*, *Salix*, inundation, flooding, growth, survival, management, Minnesota, wildlife impoundments.

North Central Forest Experiment Station
Forest Service — U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota

Manuscript approved for publication March 16, 1979

1981

GROWTH RESPONSE OF SPECKLED ALDER AND WILLOW TO DEPTH OF FLOODING

M. Dean Knighton, *Plant Ecologist,*
Grand Rapids, Minnesota

An aggressive wildlife management program on the Chippewa National Forest in north-central Minnesota has led to the establishment of more than 45 wildlife impoundments in recent years; 105 more are planned. Similiar impoundments are part of forest wildlife management programs on several National Forests in the north-central States.

These impoundments are constructed specifically to increase the available area of deep marsh habitat (Mathisen 1970). Water levels are manipulated to favor a host of game and nongame birds, and small mammals. This requires maintenance of shrubs that Harris and Marshall (1963) indicated would die-out within 2 to 4 years after flooding. The depth of flooding that kills the plants is not known, nor do we know what depth of drained soil is needed for good growth. Also, we do not know the extent to which the physical and chemical properties of the soil, and water, alter shrub response to flooding.

Reviews of the information available on the flooding tolerance of woody species were made by Gill (1970, 1977) and Tattar (1972). Most studies have been case histories of flooded plant communities associated with river flood plains or those in the zone of fluctuating water levels of reservoirs. There are few studies where water level was specifically controlled to assess the response of woody species; none have considered the prevalent species of willow and alder present in the north-central States.

The present study examined the response of speckled alder (*Alnus rugosa* (Du Roi) Spreng.) and several willows (*Salix* spp. L.) to depth of flooding. All are known for their tolerance to temporary flooding (Hall and Smith 1955, Broadfoot 1967), and are prominent members of wetland communities in North America (Parker and Schneider 1974, White 1965).

METHODS

Rooted stems of speckled alder and willow were collected from wildlife impoundments in north-central Minnesota and transplanted into tanks where water level could be controlled. The shrubs were grown through two growing seasons under five water regimes. Survival and net woody increment were measured to assess shrub response. Water chemistry and temperature were monitored routinely and were maintained at levels observed concurrently in wildlife impoundments. Volunteer competing vegetation was permitted to grow without interference to simulate field conditions, and at the end of each growing season it was clipped and its dry weight was determined for each insert tank.

Six galvanized stock watering tanks (3.0 m long by 90 cm wide by 60 cm deep) were buried to within 5 cm of their tops within a fenced enclosure near the Forestry Sciences Laboratory, Grand Rapids, Minnesota (approximately 47°32′N, 93°28′W) (fig. 1). Five smaller tanks (61 cm long by 46 cm wide by 38 cm deep) fabricated from 16-gauge galvanized sheet metal were inserted into each stock tank. The insert tanks rested on individual platforms at 7.5 cm height intervals; different heights were randomly located in each tank. Holes 6.4 mm in diameter were drilled into the sides and bottom of each insert tank to permit ready movement of water. The side holes were spaced on 5-cm centers and the bottom holes were spaced on 10-cm centers.

All metal surfaces were coated with Sherwin-Williams Wash Primer Green (Catalog No. P60 G2)[1] mixed with Catalyst Reducer (Catalog No. R7 K 44)

---

[1]*Mention of trade names does not constitute endorsement of the products by the USDA Forest Service.*

Figure 1.—*Stock tank and insert tank installation at the Forestry Sciences Laboratory, Grand Rapids, Minnesota.*

and followed by one coat of Sherwin-Williams C + M enamel. This provided a stabilized chlorinated rubber finish recommended by the manufacturer for surfaces exposed to excessive moisture. The coating was intended to prevent zinc toxicity that might develop from the galvanized metal.

In early May 1977, the insert tanks were filled with soil from four wildlife impoundments. The soils were common wetland series, Nebish, Shooks, Swatara, and Beltrami, and ranged in texture from sandy-loam to silt-loam. These soils had an organic surface horizon 1 to several cm thick. In addition, an organic soil from a fifth impoundment and an upland mineral loamy-sand subsoil were used. All five insert tanks in a given stock tank were filled with one soil in a manner that reconstructed the natural horizons.

A 200-liter drum adjacent to each stock tank was used for a reserve supply of water. The drum was connected to the stock tank through a float-valve that maintained a constant water level in the stock tank providing five water levels in relation to the shrub root crown: +15 cm, +7.5 cm, 0 cm, –7.5 cm, and –15 cm.

Alder and willow transplants were collected in early April 1977, from the seasonally flooded edge of the three wildlife impoundments (table 1). The buds showed no signs of swelling at this time. The willow transplants were later identified to species after leafing out, but the alder could be identified readily without leaves. All alder samples were collected at

Table 1.—*Willow transplants collected from wildlife impoundments in north-central Minnesota, by species*
(In number)

Impoundment	*Salix gracilis*	*Salix discolor*	*Salix Bebbiana*	*Salix* spp.
Ketchum	11	14	2	3
Bear Brook	6	12	12	0
Ball Club	30	0	0	0

the Bear Brook impoundment. In most cases the roots were less than 15 cm deep and the plants were 1 to 1.5 m tall. The transplants were kept in plastic bags at 2 to 4°C until May 10, 1977, when they were pruned, weighed, tagged, and planted in the insert tanks. After pruning, the transplants were 50-60 cm tall. The pruning was done to give more uniform initial weights, to reduce initial leaf area as an aid in establishment, and to encourage branching.

Four shrubs, one from each of the three willow sites and the alder site, were planted in the corners of each insert tank. To allow the transplants to become established, flooding was delayed until June 10, 1977, when the stock tanks were filled with water. All transplants leafed out and appeared to be established and vigorous before flooding.

The stock tanks were filled with water from Cuba and Ketchum wildlife impoundments (3 tanks each). The chemical composition of the water in these impoundments represents the extremes of surface water chemistry present in north-central Minnesota (table 2). Water conductivity, pH, and total phosphorus concentrations were monitored in the stock tanks at 2- to 3-week intervals through each growing season. When the water chemistry changed significantly from values measured concurrently in the two impoundments, water in the tanks was exchanged for fresh water from the impoundments. Exchanges

Table 2.—*Mean and standard error of several properties of the water used to represent extremes found in north-central Minnesota on 14 sampling dates during 1977*

Water properties	Source: Cuba	Source: Ketchum
Conductivity (mhos at 25°C)	68.4 ± 18.4	326.0 ± 45.7
pH	6.1 ± 0.4	6.8 ± 0.3
Calcium (ppm)	6.9 ± 1.64	48.6 ± 8.55
Total nitrogen (ppm)	3.8 ± 2.0	1.52 ± 1.66
Total phosphorus (ppm)	0.47 ± 0.14	0.15 ± 0.28

were made in July 1977 and May 1978. Apparently the change in water chemistry in the tanks was dilution by precipitation.

Water temperature and dissolved oxygen (DO) concentration were also measured at 2- to 3-week intervals in the stock tanks. DO was controlled at 3 levels (2 tanks per level) during the growing season: (1) stagnant, (2) aerated once each week, and (3) aerated 3 times each week. Tanks were aerated with a water pump, garden hose, and nozzle to circulate water through the nozzle and back into the tank under pressure. This procedure saturated the water with oxygen in less than 3 hours but aeration was continued for 7 to 8 hours each time.

Each of the six stock tanks represented one replication of the five water level treatments in a completely randomized block design. Analysis of variance was used to determine significant differences. An additional but less sensitive test of effect of DO levels was also made in a factorial analysis of variance with two replications. All tests were made with $\alpha = 0.05$ or less.

The 2-year wet-weight increment and the 2-year dry-weight (48 hours at 80°C) increment of woody tissue were used as estimates of growth in separate analyses. Pretreatment ovendry weight of each shrub was estimated using regression equations derived from the relation of final wet-weight to dry-weight (table 3). The regression equation is $Y = A + BX$ where Y = pretreatment ovendry weight and X = pretreatment wet-weight with the appropriate coefficients. Wet-weight and dry-weight increments were determined by subtracting pretreatment weights from post-treatment weights.

Alder, and the willows from the three impoundments were tested separately. When weight increments were less than zero they were set equal to zero to avoid the suggestion of negative growth. A test for correlation between original shrub weight and final shrub weight was made to determine if covariance analysis was needed to adjust for disparities in original shrub weights. Differences between treatment means were tested using the Least Significant Difference method.

Table 3.—*Coefficients and 95 percent confidence intervals for the equations*[1] *used to predict pretreatment dry weight (gm) of shrub woody tissue*

	Coefficients and confidence intervals		
Shrub	**A**	**B**	**r**
Alder	8.18 ± 12.94	0.512 ± 0.060	0.98
Willow (all sites)	5.606 ± 2.339	0.45 ± 0.016	0.99

[1]Equations are derived from the relation of final wet weight to dry weight.

Results

Net growth of all shrubs was severely reduced when the water level was at or above the root crown (fig. 2). These differences were not visible during the first growing season but became readily apparent as the second season progressed. The foliage on the flooded shrubs became chlorotic and sparse, and some new stems were dead by early August. Original shrub size did not alter the response to flooding. This was evident from a lack of correlation between original and final weights of individuals. Apparently treatment effects were so overwhelming that any advantage a shrub might have had due to original size, was eliminated. Original branches that died were collected and their weights were added to the final weight of the individual. Some dead branches sloughed off through natural causes such as weight of the winter snowpack, wind, and insect feeding, and were not found. This resulted in negative net growth for some individuals despite prolific adventitious rooting.

Mortality became apparent during the second year of flooding with alder being most sensitive (table 4). All shrubs survived the first growing season with at least a few leaves. Most of the mortality became

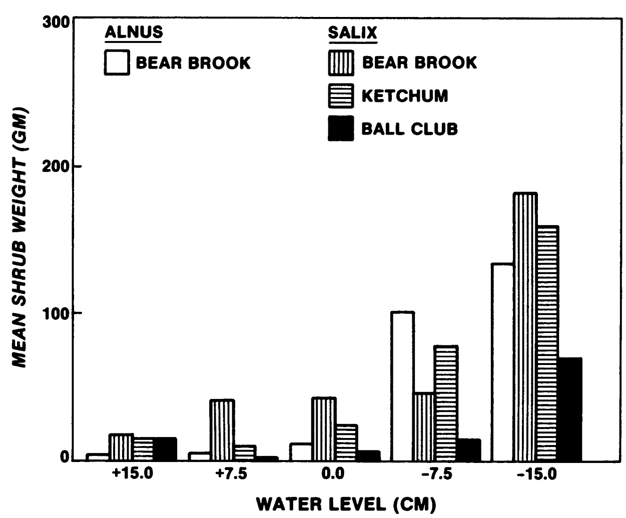

Figure 2.—*Net 2-year wet-weight increment of woody tissue at five levels of flooding. Water level is in relation to root crown.*

Table 4.—*Shrub mortality (i.e., no evidence of above-ground living tissue) after two growing seasons of continuous flooding at different water levels*

(In percent)

	Mortality				
	Water level relative to root crown (cm)				
Shrub	+15.0	+7.5	0.0	–7.5	–15.0
Alder	33	33	16	0	0
Willow					
Ketchum	16	0	0	0	0
Bear Brook	16	0	0	0	0
Ball Club	0	16	0	16	0

apparent when shrubs failed to leaf out at the beginning of the second growing season; moreover, some shrubs that did leaf out died later as the season progressed.

Shrub root development in the soil was restricted severely by flooding, but adventitious rooting above the soil (in the water) was abundant (fig. 3). When the water level was maintained at the soil surface (at the root crown) a new root system developed in the first 0-5 cm of soil. The deeper old root system appeared dead.

The physical and chemical properties of the water in the stock tanks remained fairly close to properties measured concurrently in the impoundments (fig. 4). Dissolved oxygen showed the greatest discrepancy because it is influenced by wind action and it was not possible to synchronize tank aeration with wind action. Nevertheless, the range in DO maintained in the tanks reflected the variation in field conditions. The study was not designed to evaluate the effects of different soil and water properties on shrub survival and growth. They were included simply to cover the range of these properties that are common in impoundments of the region. No analysis of interaction with these properties was possible except for a weak test of the effect of oxygen saturation which proved to be not significant ($\alpha = 0.05$).

The competing vegetation was primarily sedges (*Carex* spp. L.) and beggar's ticks (*Bidens* spp. L.). Its standing crop biomass in the insert tanks ranged from 0 to 1,200 g/m^2 the first year and 0 to 200 g/m^2 the second year but showed no correlation with water depth. Therefore, effects of competition (if any) on shrub growth were not confounded with depth of flooding.

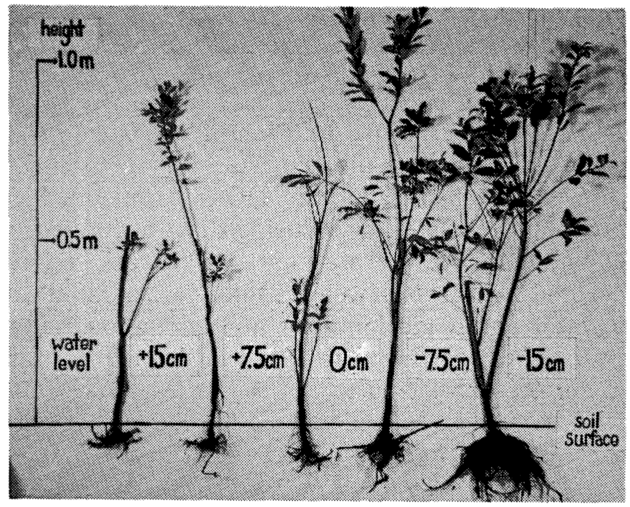

Figure 3.—*Examples of willow after 2 years of inundation at five water levels. Adventitious rooting is apparent on the shrubs to the left.*

Discussion

The species of alder and willow that were studied are tolerant to prolonged flooding of their root crowns; however, shrub growth essentially stops and after two growing seasons significant mortality can be expected. These effects occur regardless of the DO concentration in the surrounding water. This is somewhat surprising because others have found that woody species are not as severely affected by flowing water as they are by stagnant water (Hook *et al.* 1970, Hunt 1951).

The assumption has been that flowing water has a high DO concentration and the plants are able to utilize it. It may be that the DO concentration in the soil rather than the water is of greatest importance, at least with prolonged flooding. This is in spite of adventitious rooting by submerged stems. Apparently, soil DO is limited by the biological oxygen demand and the diffusion rate rather than by the DO concentration of surrounding water (Gill 1977). Zimmerman (1930) suggested the threshold figure of 10 to 11 percent for O_2 concentration in the soil atmosphere; below which injurious effects were produced. It is possible that the DO concentration in the soil atmosphere of the submerged insert tanks never exceeded this threshold although in some cases the surrounding water was saturated. Similar conditions would be expected in soils associated with impounded waters wherein the DO in the water may be maintained at high concentrations by wind action, but the soil atmosphere DO concentrations may be very low (Bouldin 1968).

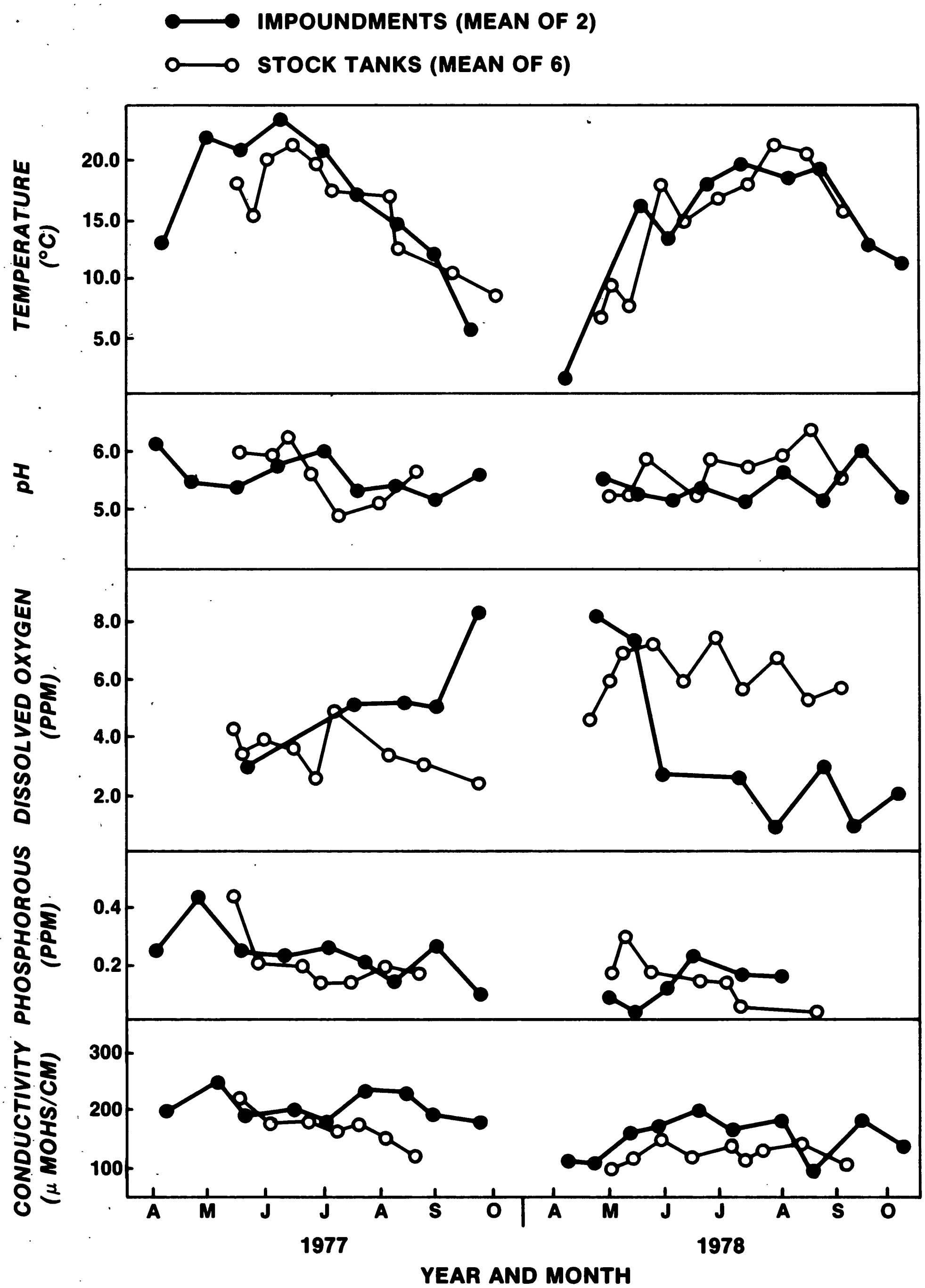

Figure 4.—*Mean water properties in two impoundments and the stock tanks.*

Shrub root development did respond to what may have been available DO in the surface 0-3 cm of soil in the insert tanks when the soil surface, water surface, and root crown were at the same level. A new root mass developed above the old mass and it appeared to be healthy (fig. 5); however, these shrubs had no better growth than more deeply flooded shrubs. The new root mass may have contributed to the higher survival experienced at this level of flooding. Both alder and willow exhibited good growth in as little as 7.5 cm of aerated soil; however, growth is substantially greater in 15 cm of aerated soil.

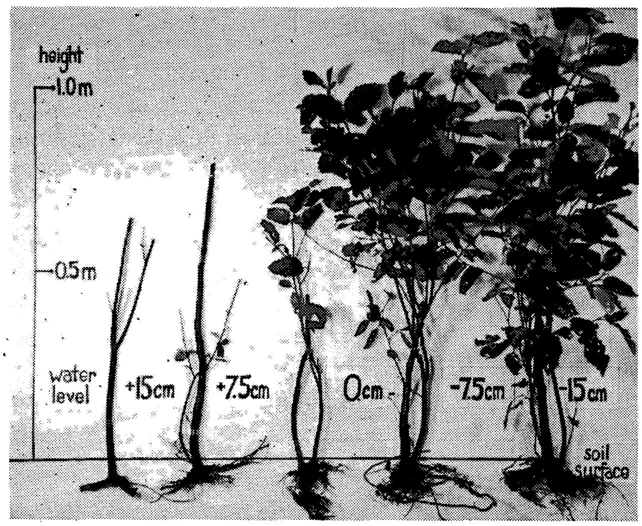

Figure 5.—*Examples of alder after 2 years of inundation at five water levels. A new growth of roots at the soil surface is apparent in the middle shrub and the lower residual root appeared to be dead.*

MANAGEMENT IMPLICATIONS

1. Flooding for 3 or more years may be required to kill enough willow to substantially reduce stem density. The same is true for alder although it apparently is more sensitive.
2. Shrubs growing on <15 cm of drained soil will suffer loss of vigor.
3. Dissolved oxygen content of flood water has no effect on shrub survival and growth.

LITERATURE CITED

Bouldin, D. R. 1968. Models for describing the diffusion of oxygen and other mobile constituents across the mud-water interface. Journal of Ecology 56:77-86.

Broadfoot, W. M. 1967. Shallow water impoundment increases soil moisture and growth of hardwoods. Soil Science Society of America Proceedings 31:562-564.

Gill, C. J. 1970. The flooding tolerance of woody species—a review. Forestry Abstracts 31:671-688.

Gill, C. J. 1977. Some aspects of the design and management of reservoir margins for multiple use. p. 129-182. *In* Applied Biology. Vol. II. T. H. Coaker, ed. Academic Press, New York and London.

Harris, Stanley W., and W. H. Marshall. 1963. Ecology of water-level manipulations on a northern marsh. Ecology 44:331-343.

Hall, T. F., and G. E. Smith. 1955. Effects of flooding on woody plants. West Sandy Dewatering Project, Kentucky Reservoir. Journal of Forestry 53:281-285.

Hook, D. D., Gordon O. Langdon, Jack Stubbs, and Claud L. Brown. 1970. Effect of water regimes on the survival, growth, and morphology of Tupelo seedlings. Forest Science 16:304-311.

Hunt, F. M. 1951. Effect of flooded soil on growth of pine seedlings. Plant Physiology 26:363-368.

Mathisen, John. 1970. Some aspects of man-made impoundments on the Chippewa National Forest. Seminar on Wildlife and Man-made Water Areas. Northern Prairie, Wildlife Research Center. Jamestown, North Dakota, April 15-16, 1970.

Parker, G. R., and G. Schneider. 1974. Structure and edaphic factors of an alder swamp in Northern Michigan. Canadian Journal of Forest Research 4:499-508.

Tattar, T. A. 1972. Effects of inundation on trees. Publication number P-72-4 U.S. Department of Agriculture, Forest Service, Northeastern Area State & Private Forestry, Portsmouth, N.H. 5p.

White, K. L. 1965. Shrub-carrs of southeastern Wisconsin. Ecology 46:286-304.

Zimmerman, P. W. 1930. Oxygen requirements for root growth of cuttings in water. American Journal of Botany 17:842-861.

☆ U.S. Government Printing Office: 1981—766-839/177 Region No. 6