RESPONSE OF RED MAPLE SAPLINGS TO FERTILIZATION AND IRRIGATION ON A DRY SITE: PRELIMINARY RESULTS

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Abstract.--Growth and crown responses of twelve red maple (*Acer rubrum* L.) saplings to fertilization and irrigation were studied in an eight-year-old, naturally regenerated stand, located on a dry site in southeast West Virginia. Fertilizer (NPK) and irrigation were applied in factorial combinations. The saplings were irrigated biweekly throughout the growing season. Soil moisture tension (at 30 cm) was monitored by thermocouple psychrometers, and terminal shoot and lateral shoot elongation (five first order branches per tree) were measured.

First year results showed that in the 1981 growing season, soil under the controls was as moist as that under irrigated trees from bud break to mid July, when most height growth had been achieved. There were neither significant (0.05 level) irrigation effects nor irrigation X fertilizer interaction, but there were significant fertilizer effects. Fertilization significantly (0.01 level) affected diameter growth but not height. Terminal shoot elongation showed no clear patterns among treatments, while the lateral shoot elongation showed a clear difference due to fertilizer, with fertilized trees growing more than 50 percent faster than the controls. It was concluded that crown expansion (branch elongation) was a response mechanism of red maple to fertilization.

Keywords: *Acer rubrum* L., crown expansion, fertilization, soil moisture.

INTRODUCTION

Fertilization is one cultural practice being explored for naturally regenerated hardwoods. However, fertilization of natural hardwoods has produced variable results. Since Auchmoody and Filip wrote their review of "Forest Fertilization in the Eastern United States: Hardwoods" in 1973, a significant number of reports of fertilization of natural hardwoods have appeared. These reports collectively can be related to three major points:

1. Variation in fertilizer response was attributable to species, pretreatment growth rate, site factors (especially soil moisture with generally more positive response on moist sites) (Safford 1973, Stone 1977, Lamson 1978 and 1980, and Boyette and Brenneman 1981).

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2. Fertilization response was often obtained in conjunction with thinning (Stone and Christensen 1974, Graney and Pope 1978, Czapowskyj and Safford 1979, and Lea et al 1979).

3. Few studies examined the tree response mechanisms to explain cause and effect relationships of tree growth variables (Lozano 1974, Auchmoody and Smith 1977).

There is a need for greater understanding of the nature of tree responses to fertilizer and the interaction between fertilizer and other stand-site factors.

The purpose of this study is to examine the interaction of soil moisture and fertilizer on the response of naturally regenerated red maple (Acer rubrum L.) saplings in a mixed hardwood stand. Response mechanisms in terms of diameter growth, height growth, and crown expansion (terminal and lateral shoot elongation) are studied. The data presented will include only first year, preliminary results. It should be pointed out that the aim of the study is neither to recommend irrigation in natural hardwoods nor to recommend a fertilizer rate, but rather to gain a better understanding of the fertilizer response in relation to water supply.

PROCEDURE

The study site is located on Westvaco property in southeast West Virginia in Greenbrier County. The area is in the Ridge and Valley physiographic province, with relatively low annual precipitation of 965 mm (average 1931-1960). The study site is at about 884 m in elevation.

In March 1981, twelve uniformly dominant, single-stemmed red maple saplings in the eight-year-old clearcut were chosen as study trees. They were situated on the upper part of a south facing slope of eight percent and from 2.1 m to 6.7 m apart. The stand attained crown closure at about age five and was dominated by red maple, black locust (Robinia pseudoacacia L.), black cherry (Prunus serotina Ehrh.), northern red oak (Quercus rubra L.), scarlet oak (Quercus coccinea Muenchh.), and chestnut oak (Quercus prinus L.). The stand density was about 14,800 stems/ha above 1.37 m tall. The study trees had a mean height of 3.6 m (SD = 0.48) and mean dbh of 2.56 cm (SD = 0.53).

The soil is Dekalb channery fine sandy loam (Typic Dystrochrepts), well drained and of moderate to rapid permeability (Gorman et al 1977). The profile has a depth of about 10-50.8 cm and 20-40% rock fragments. The soil test results (0-30.5 cm) are as follows:

pH	N	P	K	Ca	Mg
	%	- - - -	-kg/ha-	- - - -	
4.9	0.11	10.1	188	280	57

The soil is thus relatively droughty and low in nitrogen but adequate in phosphorus and potassium.

Irrigation was carried out on this presumably dry site to study the interaction of soil moisture with fertilizer. Irrigation and fertilization, each

at two levels (control and applied) were used in factorial combinations. Individuals of three four-tree groups were marked permanently. Each tree within the group was irrigated and/or fertilized as required. The study used a randomized complete block design with three replications of two irrigation regimes and two fertilizer rates. Fertilizer was applied by hand in March 1981, at a rate of 0.91 kg per tree (10-10-10 grade) in a circular plot of 91 cm radius around the trees. This amounted to field rates of 345 N, 150 P and 285 K kg/ha. All vegetation within the 91 cm circle of each tree was cleared to insure availability of applied nutrients. This cleaning did not amount to a release envisioned in a crop tree release operation where a complete cylinder free from competition is achieved.

The irrigation treatment was applied biweekly, starting on 13 April 1981, before bud break. Thirty liters of water were applied to each irrigated tree at each application; this amounts to about 138 mm of rainfall for the twelve applications during the growing season. Soil moisture tension (at 30.5 cm) was monitored by eight thermocouple psychrometers (Model PST-55) with a dewpoint microvoltmeter HR-33 (Wescor Co., Logan, Utah). The psychrometers were calibrated with standard salt solutions before being buried at the base of the trees. Terminal and lateral shoot elongation and soil moisture tension were observed biweekly each time irrigation was done throughout the growing season until the end of September 1981. The terminal shoot (first order branch) and five lateral shoots (second order branches) in the upper half of the crown of each tree were tagged. Care was taken in selecting only long shoots and not leaf and flower bearing short shoots which would not elongate significantly (Wilson 1966).

At the end of the growing season, total height and dbh were remeasured. Dbh was measured at marked height for accuracy with a diameter tape accurate to 0.0254 cm. Also in the first year, leaf longevity was noted and foliar analysis was done for N, P, and K by standard methods. Ten sun leaves from the upper half of the crown of each tree were collected in September and composite samples, using blades only, for all treatments were used for analysis. Data were analyzed by analysis of variance and treatment means compared by Duncan's new multiple range test (Steel and Torrie 1980).

RESULTS AND DISCUSSION

The first year growth responses of red maple saplings are presented in Table 1 as absolute increment and as relative increment in percent of initial values.

Analysis of variance showed that there were neither significant (0.05 level) irrigation effects nor fertilizer X irrigation interaction. The fertilizer effects were not significant on height growth but were highly significant (0.01 level) on diameter growth and significant on volume growth (in terms of D^2H index), both in absolute and relative growth.

Table 1 further shows a clear trend of different treatment responses of increasing order of control, irrigated < fertilized < fertilized + irrigated. This could mean that although the fertilizer X irrigation interaction was not significant statistically, the additive effects of fertilizer and irrigation were still better than those of either fertilizer or irrigation alone.

Table 1.--Growth responses of naturally regenerated red maple saplings to irrigation and fertilization in Southeastern West Virginia - First Year Results.

Treatment	Height	Dbh	D^2H*
	cm	cm	Index
I. Absolute Growth:			
Control	49.7 a**	0.43 a	11.313 a
Irrigated	41.8 a	0.43 a	13.840 a
Fertilized	60.0 a	0.84 b	25.321 ab
Irrigated and Fertilized	52.7 a	1.09 b	36.919 b
II. Relative Growth (as % of initial values)			
Control	15.3 a	17.9 a	60.7 a
Irrigated	11.5 a	16.6 a	51.7 a
Fertilized	16.5 a	32.5 ab	104.8 ab
Irrigated and Fertilized	13.1 a	41.0 b	127.8 b

* D^2H as volume index with D in cm and H in m.

** Values in the same column with the same letter are not significantly different at 0.05 level using Duncan's New Multiple Range Test.

This is in agreement with generally more positive fertilizer response reported on moist sites and brings out the possible relationship between soil moisture and nutrient availability. Lozano (1974) documented the complementary action of soil moisture and nutrition (mostly nitrogen) in fertilizer and thinning responses of oaks; the diameter response was attributed largely to the favorable conditions for photosynthesis from more available nutrients in combination with a lower moisture stress produced by thinning. Buckner and Maki (1977) observed the additive effects of fertilizer and irrigation in the seven-year growth of yellow poplar and sweetgum planted on two sites.

The non-significant effect of irrigation was rather unexpected on this relatively dry site. To understand the growth response results, we will look at soil moisture regime, terminal and lateral shoot elongation (Figure 1).

The soil moisture tension data (Figure 1-C) shows that the soil was equally moist under the control trees and the irrigated trees until mid July when most shoot growth had been achieved (Figure 1-A and B). This apparently nullified any irrigation effect during this critical period. The soil moisture tension did not exceed negative 400 kPa (-4 bars) until toward the end of July. Bassett (1964) has defined no-growth days as any day in which the mean moisture tension in the surface foot of the soil reached or exceeded -400 kPa when relating basal area growth to growth-day units and to no-growth days. No precipitation data were collected at the site due to the distance involved. However, records at the town of White Sulphur Springs, five miles southeast of the site suggested that the site should have received about 51

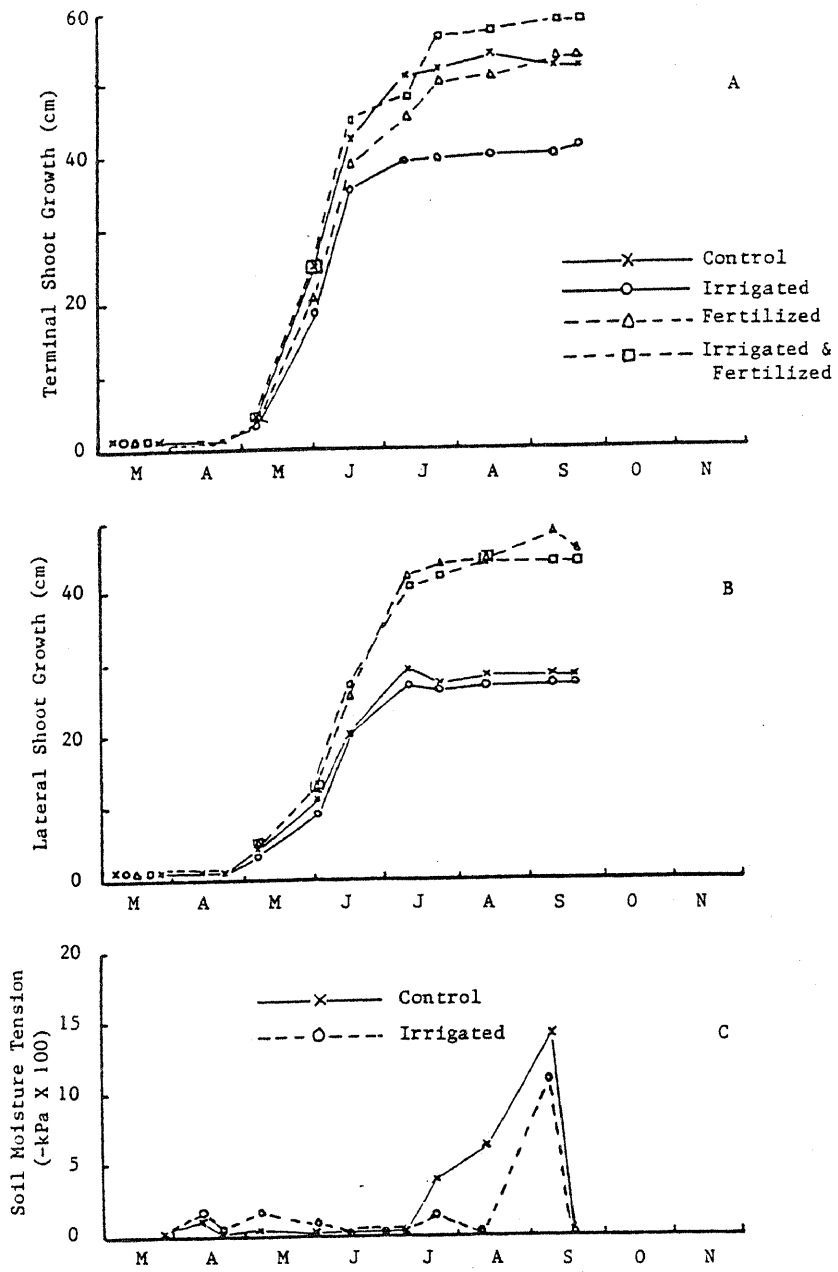

Figure 1.--Terminal and Lateral Shoot Elongation of Red Maple Saplings and Soil Moisture Tension at 30 cm During the 1981 Growing Season, in the Irrigation and Fertilization Experiment in Southeast West Virginia.

mm or more of rain more than the average record (368 mm) for the period May-July. Also, the rain experienced in 1981, in this period was no more than two or three days apart.

Terminal shoot elongation (Figure 1-A and Table 2) shows that height growth was essentially accomplished from the beginning of May to the middle of July (about 10 weeks), and there was no clear difference between treated trees and the controls, either by irrigation or fertilizer. This lack of difference may be due in part to a lack of a clear apical dominance in red maple crowns. A dominant shoot may stop being dominant and be overtopped by a nearby lateral. This was, in fact, observed in one fourth of the experimental trees. Consequently, by selecting a terminal shoot and following its elongation, one could not be sure that it will stay dominant. Wilson (1966) observed that upper lateral buds in red maple are not inhibited by the terminal.

The lateral shoot growth (Figure 1-B and Table 2), however, supports the results of Table 1, i.e., there was a difference due to fertilizer, but not to irrigation. Although there was no observable difference in timing of growth onset and growth stoppage, lateral shoots of fertilized trees grew faster than the non-fertilized trees. The development of long lateral shoots is typical of red maple crown development. The framework of long shoots bear the slow growing short-shoots which occupy most of the volume of the crown and bear most of the leaves and flowers.

Gross crown characteristics (number of flushes, lengthening of the live crown, increasing number of secondary and tertiary branches) have been shown as the primary mechanisms of conifer response to fertilization and thinning. For example, in loblolly pine these gross characteristics are more important response mechanisms than individual fascicle or needle traits (Allen 1981). In Douglas fir, fertilization increased branch elongation at all crown heights but thinning alone had no effect on crown width down to whorl 12 (Brix 1981). No such comparable and intensive studies have been done for hardwoods. These conifer studies and observations on black cherry (Auchmoody 1973) lend support to the results of this study, that crown expansion (branch elongation) was a response mechanism of red maple to fertilization. This crown expansion consequently increased diameter growth. The fact that height growth was not increased may be due to the situation in which height growth rate of the experimental trees was probably already at a maximum. In any case in the same tree, seasonal cambial growth begins at about the same time that shoot elongation begins, however, cambial growth continues for some time after shoot elongation ceases (Kramer and Kozlowski 1979, Chapter 3).

Table 2.--Terminal and lateral shoot growth for 1981 growing season, percent foliage retention in October and foliar nutrient analysis of red maple saplings under irrigation and fertilization in southeastern West Virginia.

Treatment	Terminal Shoot Growth	Lateral Shoot Growth	Percent Foliage Retention on 10/8/81	Foliar Analysis N	P	K
	cm	cm	%	- - -	-%-	- - -
Control	51.7 a*	28.5 a	37	1.85	.13	.53
Irrigated	40.7 a	26.9 a	93	1.83	.14	.58
Fertilized	52.7 a	45.7 b	99	1.92	.13	.61
Irrigated and Fertilized	54.0 a	45.5 b	87	1.58	.13	.54

* Values with the same letter are not significantly different at 0.05 level using Duncan's New Multiple Range Test.

The observed expansion as a response to fertilizer helps explain why a fertilizer response is often obtained in conjunction with thinning because fertilized trees need more crown space to respond and this space is provided by thinning. Thinning also improves soil moisture status which in turn increases nutrient availability.

Observations of percent foliage retention in early October and foliar nutrient analysis (Table 2) showed that the fertilized trees tended to retain foliage longer than the controls and did take up the applied nutrients when the effect of growth dilution is taken into account when examining the foliar nutrient percent. The fertilizer response may be due mostly to applied nitrogen as suggested by the soil analysis before treatment. Auchmoody and Smith (1977) attributed foliar response in leaf weight and color in yellow poplar and red oak mostly to nitrogen although phosphorus in combination with nitrogen produced slightly heavier and darker green leaves than nitrogen only.

Because of the variable nature of annual precipitation, it is intended to continue the study for a second or a third growing season. The study will also include twelve more study trees at the site and observations on leaf response mechanisms.

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