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# BLACK ROCK FOREST PAPERS

## SUPPLEMENTAL IRRIGATION OF 75-YEAR-OLD HARDWOODS

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# INTRODUCTION

During the summers of 1956, 1957, and 1958 four plots in the Harvard Black Rock Forest were irrigated. This report describes the observed differences between the diameter growth of the trees on the irrigated plots and trees on eight adjacent control plots.

The average annual rainfall in southeastern New York is 41 inches (13). At West Point, New York, the average weekly rainfall for the four summer months of May, June, July and August was 0.89 inches over a 35 year period (11).[1] The Harvard Black Rock Forest lies immediately north of the United States Military Reservation at West Point. The rainfall during these months may not be evenly distributed (11); rather it may be concentrated in a few weeks, with droughty conditions prevailing the remainder of the time.

The practice of irrigation in agriculture is probably as old as the earliest civilizations. According to Mead (8) the first irrigation by Anglo-Saxons in the United States was in Utah in 1849. In the more humid regions of the United States, irrigation received little attention until rather recently. Quackenbush and Thorne (9) review the results of tests in the eastern United States that had been conducted through 1956. They do not report any tests in forests.

Rudolph (12) has noted the effect of irrigation water containing cannery waste upon the growth of several species of trees. Little, Lull, and Remson (6) report on the flooding of forest land with waste water from the processing plants of Seabrook Farms in southern New Jersey and its effect on vegetation.

A considerable literature exists regarding the availability to plants of water in the soil ranging from field capacity to the wilting point. Much of this literature is concerned with the effects of varying amounts of soil moisture upon plant production rates. Stanhill (12) has reviewed some 80 papers dealing with the subject, and finds that about 80 percent of the investigations indicate that plants produce more if the level of soil moisture is near field capacity. Lewis, Work, and Aldrich (5), reporting on the growth of pears in inland Washington, found that maximum fruit size was obtained with the soil moisture at 75 percent or more of field capacity. Glowa (2) reports that the grass and trees on the nearby United States Military Reservation can be maintained in good condition if irrigation provides the equivalent of one inch of rain per week during the summer months.

## Description of Site and Stand

The plots were located on a six percent slope facing northwest. The elevation is approximately 600 feet above sea level. The soils are mapped as Rockaway very stony loam (3), and are underlain by a deposit of glacial till (1). Approximately 100 feet southeast of the line of plots there is a sharp steepening in slope. Bedrock outcrops are common on the steep slope.

The trees on the plots apparently came up following a clear-cutting in 1881. In 1932 a light thinning was made in the area. This was followed by a heavy thinning in 1953 that removed some 50 percent of the basal area of the canopy trees. In addition, all regeneration and lesser vegetation was cut back to the ground, so that the appearance of the stand following the 1953 operation was park-like. In 1953 and 1954 one half the area was treated with chemicals to prevent the development of undergrowth from cut stumps.

At the time the plots were established in 1956 one half the area was essentially free of undergrowth. On the other half the stump sprouts had made a dense undergrowth that was up to 10 feet high.

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1 Numbers in parenthesis refer to literature cited.

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The trees, all dominants and co-dominants, were in the 60 to 70 foot height class when the plots were established. For all plots combined, the diameters averaged 10.3 inches, and basal area per acre averaged 55.3 square feet. The species composition is given in Table I.

Table I. Species Composition of All Plots

| Species | Number of Trees | | |
|---|---|---|---|
| | Sprayed Plots | Irrigated Plots | Unsprayed Plots |
| Red Oak | 10 | 11 | 9 |
| White Oak | 3 | 0 | 3 |
| Chestnut | 0 | 3 | 3 |
| White Ash | 4 | 2 | 1 |
| Hickory | 3 | 0 | 1 |
| Sugar Maple | 1 | 1 | 0 |
| Red Maple | 2 | 0 | 5 |
| Yellow Poplar | 1 | 1 | 1 |
| Hemlock | 1 | 0 | 0 |
| Total | 25 | 18 | 23 |

## Plot Layout and Treatment

Three sets of four 50-by-50-foot plots were laid out on a line parallel to the break in slope. The four plots in each set were formed by quartering a 100-by-100-foot square. A fifty-foot isolation strip was left between the sets of plots. One set of control plots was laid out in the area treated with chemicals (later referred to as Sprayed Plots), and one set in the area where the undergrowth had been allowed to develop (referred to as Unsprayed Plots). The Irrigated Plots were located in the sprayed area between the two sets of controls.

Perforated plastic hoses were used to distribute the water. With the existing pressure, one inch of water could be applied in 2 hours and 40 minutes. Water for the irrigation came from a pond in the upland section of the Harvard Black Rock Forest. The water was not treated in any way.

The decision to irrigate or not was based on the amount of rainfall. At the end of each week between May 1 and August 15 the plots were irrigated if less than one half inch of rainfall was recorded during that week. The amount of irrigation was arbitrary: if less than one half inch of rainfall had been recorded the plots received one inch of water. This procedure was based on Glowa's (2) experience.

The rainfall records for 1956 and 1957 were collected by Ross (11). One of his stations was located less than one half mile from the plots. Records for 1958 were collected by the author at the site and checked with those at Stewart Air Force Base which is about seven miles from the plots.

Precipitation during 1956 and 1958 was near normal; during 1957 it was well below normal. This is reflected in the number of irrigations: 1956, five; 1957, 12; and 1958, six. Table II is a schedule of the irrigations for the three years.

Table II. Irrigation Schedule

Dates of Application of 1 Inch of Water

| 1956 | 1957 | 1958 |
|---|---|---|
| May 27 | May 2 | June 28 |
| June 17 | 26 | July 5 |
| July 1 | June 2 | 26 |
| 29 | 9 | Aug 2 |

| | | | |
|---|---|---|---|
| Aug | 7 | 16 | 9 |
| | | 23 | 16 |
| | | 30 | |
| | July | 7 | |
| | | 21 | |
| | | 28 | |
| | Aug | 4 | |
| | | 11 | |
| Number of irrigations | | 5 | 12 | 6 |
| Rainfall recorded | | 13.03 | 5.05 | 12.65 |
| Total water, in inches | | 18.03 | 17.05 | 18.65 |

Observations

Growth was measured as square feet of basal area at a marked level on each tree four and one half feet above the ground. Diameters, from which the basal area was calculated, were recorded to the nearest 0.01 inch with a diameter tape. The measurements were taken before growth started in the spring and after the leaves had fallen in the autumn.

The Unsprayed Plots had the greatest variation in growth from year to year. The Irrigated Plots had the least variation, and the Sprayed Plots were intermediate. The growth by plot and year expressed in square feet of basal area and as a percentage of the basal area on the plot at the beginning of the year, is given in Table III.

Table III.

Growth on Test Plots, 1956-1958

| PLOT | 1956 | | 1957 | | 1958 | | Three Year Total | | B.A. Fall 1958 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $Ft.^2$ B.A. | % | $Ft.^2$ B.A. | % | $Ft.^2$ B.A. | % | $Ft.^2$ B.A. | * % | $Ft.^2$ on plot | $Ft.^2$ per acre |
| Sprayed | | | | | | | | | | |
| 1 | .080 | 2.79 | .099 | 3.36 | .101 | 3.32 | .280 | 9.77 | 3.145 | 54.798 |
| 2 | .090 | 2.90 | .118 | 3.70 | .131 | 3.96 | .339 | 10.92 | 3.442 | 59.973 |
| 3 | .100 | 2.56 | .085 | 2.12 | .106 | 2.59 | .291 | 7.45 | 4.196 | 73.111 |
| 4 | .110 | 3.49 | .136 | 4.17 | .092 | 2.71 | .338 | 10.73 | 3.487 | 60.757 |
| Ave. | .095 | 2.94 | .1095 | 3.34 | .1075 | 3.15 | .312 | 9.72 | | 62.132 |
| Irrigated (and sprayed) | | | | | | | | | | |
| 1 | .090 | 3.38 | .103 | 3.74 | .115 | 4.03 | .308 | 11.56 | 2.972 | 51.784 |
| 2 | .089 | 3.28 | .091 | 3.25 | .105 | 3.63 | .285 | 10.50 | 3.000 | 52.272 |
| 3 | .097 | 5.17 | .108 | 5.50 | .082 | 3.96 | .277 | 14.77 | 2.153 | 37.514 |
| 4 | .114 | 3.12 | .138 | 3.67 | .152 | 3.89 | .404 | 11.07 | 4.055 | 70.654 |
| Ave. | .0975 | 3.74 | .110 | 4.04 | .1135 | 3.88 | .318 | 11.975 | | 53.058 |
| Unsprayed (and unirrigated) | | | | | | | | | | |
| 1 | .094 | 2.60 | .054 | 1.46 | .097 | 2.58 | .245 | 6.78 | 3.860 | 67.257 |
| 2 | .101 | 2.58 | .072 | 1.79 | .122 | 2.94 | .295 | 7.54 | 4.209 | 73.338 |
| 3 | .057 | 1.76 | .051 | 1.54 | .069 | 2.06 | .187 | 5.76 | 3.432 | 59.799 |
| 4 | .099 | 2.94 | .072 | 2.08 | .085 | 2.40 | .256 | 7.60 | 3.623 | 63.127 |
| Ave. | .08775 | 2.47 | .06225 | 1.72 | .09325 | 2.50 | .246 | 6.92 | | 65.880 |

*Based on B. A. in spring of 1956

The growth on all plots in 1956, a near normal year, was practically the same. In 1957, a relatively dry year with much of June and July without rain (Table II), a considerable difference was recorded between the sets of plots: the Irrigated Plots put on the most basal area, the Unsprayed the least, and the Sprayed Plots were intermediate. In all three years the growth on the Sprayed Plots was intermediate. However, the amount of growth was nearer to that recorded for the Irrigated than for the Unsprayed Plots (Table III). The average basal area growth per acre per year during the three year period was: Irrigated, 1.850 square feet; Sprayed, 1.803 square feet; Unsprayed, 1.427 square feet. Stocking in 1958, in the same order, was 78 trees and 53.058 square feet; 109 trees and 62.132 square feet; 100 trees and 65.880 square feet per acre.

The amount of growth in relation to the basal area on each plot at the beginning of the growing season is given in Table III, and for ease of comparison is expressed as a percentage rather than in square feet.

The differences between the means of the plots for the different years were tested for significance by the "t" test with three degrees of freedom. Table IV is a tabulation of the results. The nature of the terrain and the source of irrigation water did not allow for a more elaborate experimental design. The conclusions drawn are conditioned to a degree by this lack of statistical control.

Table IV. Tests of Significance

| Test | Year | Plot[1] | Mean Growth Ft.[2] | Mean Growth % | Plot | Mean Growth Ft.[2] | Mean Growth % | Difference Ft.[2] | Difference % |
|---|---|---|---|---|---|---|---|---|---|
| Basal | 1956 | Irr. | .03603 | 3.740 | Sp. | .02852 | 2.935 | .00751 | .805 |
| Area | 1956 | Irr. | .03603 | 3.740 | Unsp. | .02408 | 2.470 | .01195 | 1.270 |
| Growth | 1956 | Sp. | .02852 | 2.935 | Unsp. | .02408 | 2.470 | .00444 | .465 |
| per sq. | | | | | | | | | |
| ft. of | 1957 | Irr. | .03877 | 4.040 | Sp. | .02975 | 3.340 | .00902 | .700 |
| B.A. & % | 1957 | Irr. | .03877 | 4.040 | Unsp. | .01688 | 1.720 | .02189 | 2.320** |
| | 1957 | Sp. | .02975 | 3.340 | Unsp. | .01688 | 1.720 | .01287 | 1.620** |
| | 1958 | Irr. | .03754 | 3.880 | Sp. | .03045 | 3.150 | .00709 | .730 |
| | 1958 | Irr. | .03754 | 3.880 | Unsp. | .02442 | 2.470 | .01312 | 1.410* |
| | 1958 | Sp. | .03045 | 3.150 | Unsp. | .02442 | 2.470 | .00603 | .680 |
| Mean | 1956 | Irr. | 1.708 | | Sp. | 1.655 | | .053 | |
| B.A. | 1956 | Irr. | 1.708 | | Sp. | 1.533 | | .175 | |
| Growth | 1956 | Sp. | 1.655 | | Unsp. | 1.533 | | .122 | |
| per plot | | | | | | | | | |
| on an | 1957 | Irr. | 1.917 | | Sp. | 1.908 | | .009 | |
| | 1957 | Irr. | 1.917 | | Unsp. | 1.080 | | .837** | |
| | 1957 | Sp. | 1.908 | | Unsp. | 1.080 | | .828** | |
| | 1958 | Irr. | 1.986 | | Sp. | 1.882 | | .104 | |
| | 1958 | Irr. | 1.986 | | Unsp. | 1.620 | | .366 | |
| | 1958 | Sp. | 1.882 | | Unsp. | 1.620 | | .262 | |
| B.A. | | Irr. | | 11.980 | Sp. | 9.720 | | | 2.26 |
| Growth | | Irr. | | 11.980 | Unsp. | 6.920 | | | 5.06** |
| percent | | Sp. | | 9.720 | Unsp. | 6.920 | | | 2.80 |
| 3 years | | | | | | | | | |

[1] Irr. = Irrigated Plots
Sp. = Sprayed Plots
Unsp. = Unsprayed Plots

* Significant at 1% level
** Significant at 5% level

## Discussion

The supplemental irrigation of the four plots described here appears to have been responsible for some additional increment. The Irrigated Plots, though less densely stocked than the control plots, added more basal area (a) per acre, (b) per square foot of original basal area, and (c) per tree. The marked difference is between the Irrigated Plots and the Unsprayed Plots. The difference between the Irrigated and Sprayed Plots did not show a significant difference when tested (Table IV).

Inspection of Table IV shows that for the individual years there is an indication that both the Irrigated and Sprayed Plots are growing consistently more than the Unsprayed Plots. At the bottom of Table IV the results of the tests of three years' growth are given. In this test the Irrigated Plots grew significantly more than the Unsprayed Plots. The "t" value for the difference in growth between the Sprayed and Unsprayed Plots was 3.093. For three degrees of freedom a figure of 3.182 would have indicated significance at the five percent level. There was no significant difference between the Irrigated and Sprayed Plots.

It appears that the addition of supplemental water does not change significantly the amount of basal area growth if the undergrowth has been eradicated. During the driest of the three years of the study, 1957, the average growth of the Irrigated Plots (.110 square feet) was not significantly greater than that of the Sprayed Plots (.1095 square feet). In the same year, however, the Unsprayed Plots averaged .06225 square feet which is significantly less than that of either the Irrigated or the Sprayed Plots. On a per acre basis, the growth was 1.917, 1.908 and 1.085 square feet, respectively.

Zahner (14) has described the depletion of soil moisture by a hardwood understory in pine stands in Arkansas. He found (p. 183) that, "Midsummer water loss rates were about 25% percent faster in plots with understory left in place than those with hardwoods eradicated by chemicals." McClurkin (7) has found a correlation between the moisture in the upper four feet of soil and the day to day radial growth of shortleaf pine in northern Mississippi. He points out, however, that the correlation does not account for all the variations observed.

Apparently the water transpired by the lesser vegetation is critical. No estimate of the amount transpired is available in the present case. With Zahner's (14) figure in mind, it is interesting to note that the greater growth on the Sprayed Plots (expressed as a percentage of the basal area on the Unsprayed Plots) is approximately 26 percent per year.

## SUMMARY

The result of supplemental irrigation and undergrowth eradication on a 75-year-old stand of mixed hardwoods is described. Apparently as a result of the irrigation, the trees on the Irrigated Plots grew significantly more than those without irrigation in which the undergrowth had been allowed to develop during two of the three years. During a year with little rainfall (1957) the plots without undergrowth grew significantly more than those with undergrowth. Over the three-year period the trees in the Irrigated Plots grew significantly more than those in the control plots on which undergrowth had been allowed to develop. The difference between plots with and without underbrush did not give a "t" value for a five percent level of significance. The closeness of the figure to the five percent level, however, suggests a strong influence on growth that may be attributed to the undergrowth.

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