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A STUDY OF RED CEDAR PLANTATIONS IN NORTH CENTRAL OKLAHOMA

By

MICHEL AFANASIEV
Department of Forestry

OKLAHOMA AGRICULTURAL EXPERIMENT STATION
Oklahoma A. & M. College, Stillwater
W. L. Blizzard, Director Louis E. Hawkins, Vice Director

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By MICHEL AFANASIEV
(Associate Forester)

Red cedar *(Juniperus virginiana L.)* occupies a prominent place in forests and forest plantations in Oklahoma. It is found practically throughout the State. In western Oklahoma it often forms pure, open stands. In the eastern part of the State, red cedar is one of the minor components of the the existing forests. Through extensive planting and equally extensive natural dissemination, it has become one of the most widely distributed species in Oklahoma.

Red cedar thrives on a variety of soils, which explains at least in part its wide popularity in forest and ornamental plantings. It is used very extensively in protective plantations around fields and farmsteads. Millions of seedlings of red cedar are needed in Oklahoma for horticultural and forestry purposes.

The value of red cedar wood is universally recognized. In addition to its well-known uses in form of fence posts and lumber, red cedar serves also as a Christmas tree in many Oklahoma homes. This use sets it apart from other native trees in this region as a possible source of early income from the plantation.

Because of red cedar's value and its ability to grow on poor, "unproductive" land, the Experiment Station in 1941 began a study of the possibility of utilizing this species as a source of income on idle acres.

The original plan of investigation called for establishment of several plantations of red cedar and pine in the vicinity of Stillwater, with a total area of some 100 acres. Wartime difficulties in securing labor forced the complete abandonment of all but one of the plantations established in 1941. However, in the winter and spring of 1942-43, it was found possible to establish a second plantation. This bulletin reports observations made on the red cedar portions of these plantations.

The first plantation established in 1941 is located approximately 6 miles west of Stillwater, the second, started in the winter of 1942-43 is 3 miles north of Stillwater. Hereafter the plantations will be referred to as plantations 1 and 2, respectively.

DESCRIPTION OF THE PLANTATIONS

Plantation 1 is located on an east slope. Considerable part of the plantation is underlaid by a layer of sandstone. The latter forms a hardpan located at various depths below the surface. At the west end of the plantation the permeable layer of soil and subsoil is at least two feet deep. At that depth the soil texture is extremely heavy, with clay content up to 58 percent.

Toward the east end of the plantation, the soil becomes light and shallow with the hardpan at depths of from 8 to 15 inches below the surface. Heavy water erosion in the north central and northeastern parts of the plantation brought the hardpan to within 4 and 6 inches from the surface, and in a few limited places even exposed it completely. Presence of hardpan within the planting depth caused considerable difficulty when the trees were being planted.

The planting of red cedar on this site was made March 15, 1941. The planting stock consisted of 200 1-2 and 665 1-1 plants of local red cedar, and 371 1-1 trees of the Platte river variety of red cedar. All trees were grown from seed in the Experiment Station Nursery near Stillwater. The trees were planted in rows located along the contour lines and spaced 6 feet apart. The average distance between the trees in rows was 7 feet, with the exception of 8 rows in the middle of the plantation in which red cedar was set 4 feet apart.

The plantation was abandoned soon after its establishment due to lack of labor and equipment during the war. However, when, despite lack of care, high survival became apparent, it was decided to keep the plantation for further observations. From that time on, one cultivation a year was carried out and a fire lane around the plantation has been maintained continously. In the summer of 1944 the plantation was sprayed with lead arsenate to eliminate bagworms which were found on red cedar in fairly large numbers.

TABLE I.--Relation of Soil Texture and Color to Growth of Red Cedar.

Soil Sample	Average height of trees*	At Depth of 18 Inches				At Depth of 30 Inches			
		Sand %	Silt %	Clay %	Soil Color	Sand %	Silt %	Clay %	Soil Color
25-15	69.8	43	30	27	Bright red	35	34	31	Bright red
29-41	64.0	39	36	25		36	37	27	Reddish brown
6-4	63.1	41	37	21	Bright red	42	34	24	Bright red
5-14	60.0	41	32	27	Grayish brown	40	31	29	Dark tan
25-26	59.4	37	36	27	Light reddish	35	34	31	Reddish; some mottling
17-18	59.0	41	32	27	Reddish; slightly mottled	35	35	30	Dark tan
17-35	57.1	28	36	36	Light gray; some mottling	32	37	31	
17-4	56.9	37	30	33	Bright red	49	22	29	Bright red
17-29	55.6	37	32	31	Medium gray	33	36	31	Gray; some mottling
9-28	54.6	33	28	39	Gray	39	30	31	Ash gray
17-24	54.0	37	26	37	Brownish gray	34	35	31	Reddish gray; mottling
15-41	51.5	47	26	27	Brownish gray	43	30	27	
9-35	46.3	29	32	39	Dark gray	37	30	33	Ash gray

* Average height of trees growing on a plot 10.5 x 9 feet in the center of which soil samples were taken.

The trees in plantation 2 occupy a site of poor quality on the top of a low ridge. The soil on this site is variable in thickness, but generally much more uniform than in plantation 1. The average clay content at a depth of 18 inches is from 30 to 35 percent. At a depth of 30 inches the average clay content is 30 percent with somewhat less variation than in the upper 18 inches of soil (Table I). The site as a whole is poor. Prior to planting it bore a sparse stand of poor grass and showed signs of water and wind erosion.

The original planting on this site was done between January 30 and February 12 of 1943. A total of 1472 1-1 red cedars were planted at that time in 32 rows of 46 trees each. The following discussion is based on the behavior of 1320 trees (30 rows of 44 trees each), the remaining trees forming the border rows of the plantation.

The present stand of red cedar in plantation 1 consists of the original trees only, all planted in 1941. On the other hand, approximately 26 percent of trees in plantation 2 are replacements, planted in 1943, 44, and 45.

Survival

By far the largest loss of red cedar in plantation 1 was observed in the second half of the first summer in the field (1941). Mortality among the 1-2 stock was 14 percent. During the same period, local red cedar planted as 1-1 stock lost 3.8 percent and the 1-1 red cedar of the Platte river variety lost 4.6 percent. Observations in the other red cedar plantation (2) and the reports of other workers tend to justify a widely accepted practice of planting 1-1 red cedar in preference to older and larger stock. The loss of trees after the first growing season was negligible.

Mortality among trees in the second plantation followed a similar pattern in two respects: mortality was highest among the older (1-2) stock and most of it occurred during the first season in the field.

On April 17, 1943, approximately 10 weeks after planting, 19.4 percent of trees were found to be dead or dying. These were replaced immediately, bringing the total number of all trees planted in the spring of 1943 to 1576.

The high mortality in the original stand during the first ten weeks occurred principally in four rows. Since these rows were the only ones planted on February 5, 1943, it is quite possible that the quality of work performed on that date was partly responsible for the excessively high mortality.

Although most losses during the first season occurred within three months after planting, dying off of young trees continued at a high rate throughout the summer. The total percentage of dead plants among the original 1320 at the end of the first season was 29.4 percent. Late planting of 256 trees in April resulted in a loss of 28.1 percent. The first year loss among all trees in plantation 2, set in the spring of 1943, was 29.2 percent.

Losses suffered during the season of 1943 were replaced February 15, 1944, when 205 3-year-old trees were planted. These replacements suffered a loss of 64.4 percent during the first season.

The high mortality among the 1944 replacements can be attributed to the age of the planting stock. Both weather conditions and the corresponding availability of soil moisture were more favorable during the planting operation of 1944 than in 1943, judging by the distribution and the amount of precipitation during the critical months of planting and immediately following planting. Precipitation during the months of February, March, and April of 1943 was .81, 1.65, and 1.08 inches, respectively. In 1944, the corresponding figures were 1.13, 2.11, and 4.68 inches. The longest period without rain in these three months of 1943 was 19 days (25 days if a trace of rain on February 10 is disregarded). In the corresponding months of 1944, the longest dry spell lasted 14 days. Moreover, planting in 1944 was immediately followed by light rain, while in 1943 one planting operation was followed by 16 days of dry weather.

The loss of trees in plantation 2 during the second season in the field was 2.7 percent of those which survived the first season and 1.9 percent of all trees planted in the spring of 1943.

During the following seasons of 1945 and 1946, mortality among the trees comprising the original plantation declined to .3 percent and .8 percent, respectively. A sharp break in mortality after one year in the field was noted by other workers also. Hayes (6) reports little or no loss of trees of slash and longleaf pines after the first spring.

A similar pattern of heavy mortality during the first season and very light losses after one year in the field was also recorded among the trees planted in other years throughout the period of this study. Mortality figures for 1944 and 1945 plantings were as follows:

	First Season	Second Season	Third Season
1944 Planting	64.4	1.0	0.0
1945 Planting	24.7	2.5	---

Growth

Although red cedar is known to be adapted to a variety of soils, (4), its rate of growth is definitely dependent on soil characteristics.

Nine samples of soil from plantation 1 were examined—three each from places representing poor, medium, and good sites as judged by the average height of trees. Sharp stratification of heights was apparent even from a superficial examination. The "poor" site represents tree heights of 6 feet and less; "medium" site, from 6 feet to 8 feet; and "good" site, trees taller than 8 feet. *

Trees of medium size were located in two cases on deep soil containing 57 percent clay at a depth of two feet. Good growth was concentrated on shallow (8 to 15 inches) sandy soil with hardpan underneath. Trees of poor growth were located either on light soil 4 to 6 inches in depth, or on a deep soil of heavy texture (clay 58 percent).

* The terms "poor," "medium," and "good" are not used here in the absolute sense of these words. With the exception of a small proportion of the trees, the growth of cedar in general has been rather poor, averaging approximately between 7 and 8 inches per year. The average weighted height of all trees in the plantation after 8 years in the field was 7.14 $\pm$ .19 feet, with a range from 3 to 14 feet.

It appears that under conditions existing within this plantation the lack of a deep layer of soil does not necessarily preclude the development of a good root system and the consequent good growth of trees. A layer of soil 8 inches and more in depth seems to have been adequate to maintain a tree until the roots penetrated deeper through hardpan for additional and more stable supply of moisture. Trees on the poor sites, with soil 4 and 6 inches deep, were handicapped from the very start. They were planted directly in hardpan.

Excessively high content of clay even in deep soils appears to be an obstacle in the development of red cedar, just as it is in growth of many deciduous species (1, 3, 5).

The influence of clay content on growth of red cedar can be demonstrated more clearly with trees in plantation 2. All trees in that plantation were planted in the spring of 1943 when they were two years old. At the time of planting, no attempt was made to separate trees according to size, therefore all trees in the plantation lend themselves to comparison in regard to growth and size.

The average height of all these trees at the end of 1946 season was 53 inches, which represents an average annual growth of 11 inches. Variation can easily be traced to variations in certain characteristics of the soil. Figure 1, representing distribution of trees according to height classes, reveals concentration of larger plants in the northern and eastern parts of the plantation and slower growth and higher mortality in the southern part. Data pertaining to the relationship between the rates of growth and the characteristics of the soil are found in Table I. The average height of trees corresponding to any one soil sample represents the heights of trees located within a rectangle 9 x 10.5 feet, from the center of which the soil sample was taken.

Statistical analysis shows a definite trend in the relationship between the proportion of clay in the soil at the depth of 18 inches and the heights of trees of the same age. The coefficient of correlation between these two items is $-.67 \pm .103$. Within the range shown in Table I, higher clay content indicates slower growth and smaller trees. Although certain amount of fine soil particles is essential for tree devel-

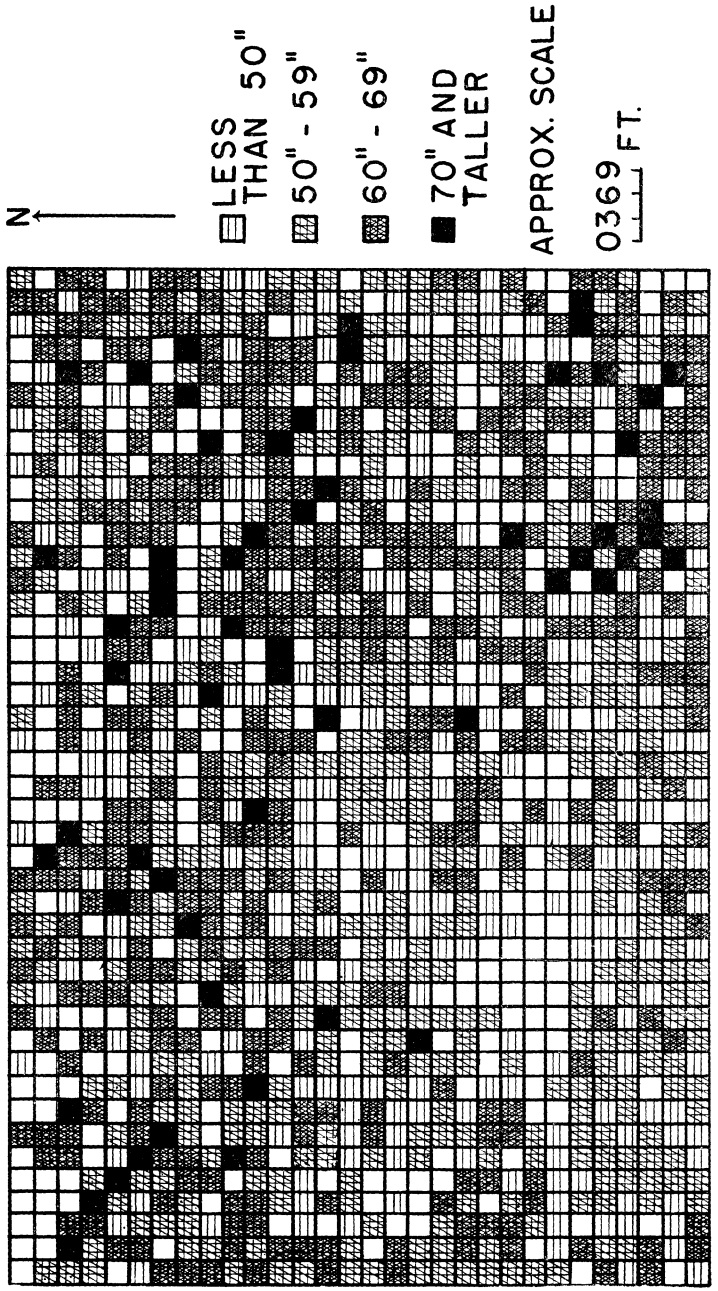

FIGURE 1.—Distribution of trees according to height classes,

opment, the excessive amount of clay was found to be detrimental for growth of red cedar, just as it is for many deciduous and coniferous trees (1, 3, 5, 7).

Variations in the height of trees appear to be connected also with the color of the soil. The most vigorous growth was found on red and reddish soils, while the poorest trees are located mostly on soil of various shades of gray. Correlation between the vigor of trees and the degree of oxidation taking place in the soil, as expressed by local variations in soil color, has also been observed by other workers (3).

Thinning

One of the advantages of using red cedar in preference to other trees on idle land is the fact that the red cedar acquires commercial value in the relatively short time of three to five years. There is normally a good demand for two-year-old transplants of red cedar for grafting many ornamental conifers. In Oklahoma there is a market for small red cedar either for Christmas trees or for ornamental planting. Therefore, it is possible not only to realize a financial return while the the trees are still young, but also to utilize the land more completely by planting a larger number of trees per unit of area.

Study of the returns from a four-year-old plantation and of the effect of heavy thinning on growth of trees was started in plantation 2 in December of 1946. At that time crown closure began to take place and heavy competition of young trees appeared to be in prospect.

The original spacing of 3 x 3½ feet was increased to an average of approximately 4½ x 7 feet by clear-cutting four alternate rows and reducing the number of trees in the intervening rows by 32 percent. In the latter case, the best trees were left to form the next crop, either of fence posts or larger and better Christmas trees.

The cut trees were graded on the basis of size, form, and the overall value as Christmas trees (Figure 2). Grade 1 was assigned to trees of symmetrical form and good color; the average height of trees of this grade was 59.2 inches. Grade 2

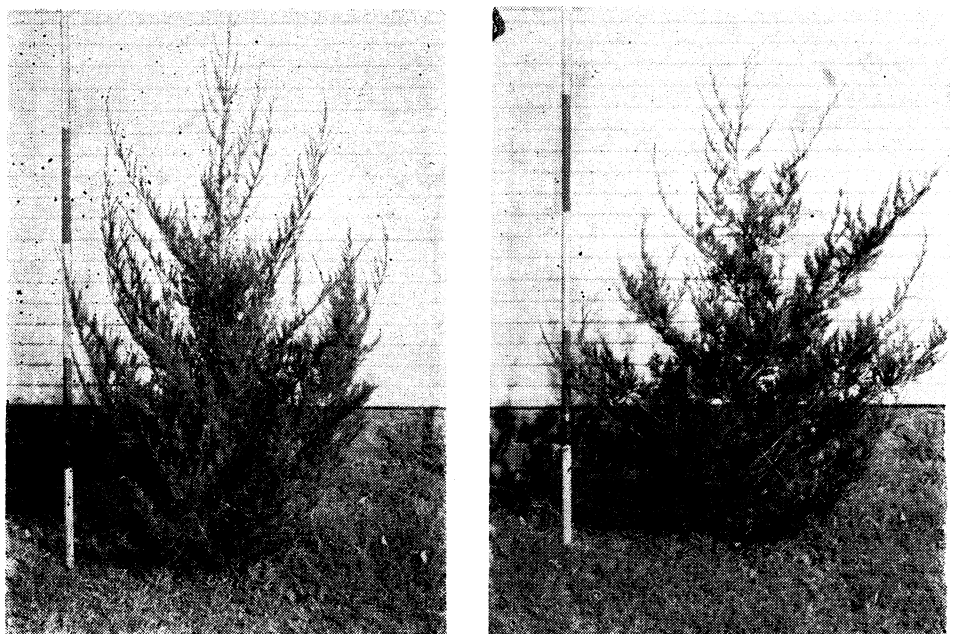

FIGURE 2.—Two grades of Christmas trees obtained from thinning red cedar plantations after four years in field; left, Grade 1, and right, Grade 2.

comprised trees of poorer form but still marketable; the average height was 51.8 inches. Trees too poor in form and quality or too small were considered as cull. Trees removed in December of 1946 were distributed among various grades as follows: grade 1, 43 percent; grade 2, 32 percent; and cull, 25 percent.

Assuming the wholesale price of trees of grade 1 at 25 cents apiece, and that of grade 2 at 15 cents, the total gross return from the thinning operation, involving removal of 66 percent of all stems, would have been approximately $425 per acre.

Removal of 66 percent of the stand left 1410 trees per acre, increasing the average space per tree from 10.5 sq. ft. to 30.9 sq. ft.

Trees given more space by removing alternate rows and thinning the remaining rows in the winter of 1946-47 have failed to respond to the treatment in regards to the rate of growth in height.

In examining the rates of height growth, trees which were given more space were compared with those in unthinned rows which at the time of thinning had approximately the same average height and vigor as the released trees.

From examination of Table II, it can be seen that during the first year unthinned rows added almost 60 percent more in height than trees which were given more space. Failure to respond to thinning in terms of increased height growth dur-

TABLE II.—Comparative Rates of Height Growth of Red Cedar in Thinned and Unthinned Plots.

Plot Treatments	Average Space per Tree (sq. ft.)	Average Height Before Treatment (Inches)	Average Increase in Height			
			First Year After Treatment		Second Year After Treatment	
			Inches	%	Inches	%
Thinned in '46-'47	30.9	57.3	8.4	14.6	14.4	21.9
Check	10.5	57.6	13.4	23.3	16.6	23.4
Thinned in '47-'48		62.5	11.9	19.0		

ing the first season was evident again the following season when another plot of red cedar was treated in similar manner. In that case, the average increase in tree height in the thinned plot was 11.9 percent as against 16.6 percent increase among the trees in the check plot. Lack of positive response of trees to thinning in terms of height growth was observed also by Stoeckeler and Arbogast (8).

During the second season after thinning, the rate of height growth in the thinned plot was practically the same as in the check plot.

DIRECT SEEDING

Two attempts to establish red cedar by direct seeding were made during this investigation. In both cases, seed were stratified in late fall and at the time of seeding were completely after-ripened.

The first seeding was done April 2, 1940. Three seeding plots were established. Two of these were located under partial shade in a post-oak-blackjack stand. The third was placed in the open.

Germination in all three plots was very poor; only a few seedlings in each case emerged from the ground. At no time did the seedlings appear vigorous and healthy. All were dead by the middle of the summer. Rapid fluctuation in moisture content of soil within the top 1 to 3 inches, together with frequent strong warm winds, was responsible for the complete loss of the seedlings. Moisture content of the soil was favorable for germination during and immediately following sowing. However this condition changed before all seed had a chance to germinate and before any of the seedlings became sufficiently large and strong to be able to withstand even an occasional brief dry spell.

The second attempt to establish red cedar by direct seeding was made on April 19, 1946. Again three lots of red cedar seed were sown in the open and under partial shade in post oak stand. Of the total of 3100 after-ripened seed, only one produced a seedling. As in the first attempt, germinative conditions were favorable on the day of seeding but did not last

long enough to permit full germination. Rodents might also have contributed to the destrucution of seed in the field.

In view of the exacting nature of red cedar seed in regard to germinative conditions (2) and because of invariable occasional drying of the top inch or two of soil occurring each spring, direct seeding of red cedar in Oklahoma appears entirely impracticable.

Summary

1. Two red cedar plantations have been established and maintained successfully on sites which would commonly be classed as "poor".

2. Although mortality was high in some instances of planting, survival of red cedar in general has been satisfactory, amounting in four years to approximately 80 percent.

3. Planting of 1-2 stock resulted in abnormally high mortality as compared with the mortality among 1-1 plants.

4. Most losses occurred during the first year after planting.

5. High clay content of the soil had detrimental effect on growth of red cedar in height.

6. The rate of height growth is correlated with the color of the soil: growth on red and reddish soils has been better than on soils of gray or grayish color.

7. Heavy thinning has failed to accelerate height growth of red cedar during the first two years after treatment.

8. Two attempts to establish red cedar by direct seeding resulted in complete failures.

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