

EARLY EVALUATION OF A SEED SOURCE STUDY IN EASTERN REDCEDAR
(JUNIPERUS VIRGINIANA L.) IN SOUTH CAROLINA 1/

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Eastern redcedar is an important and widespread coniferous species occurring throughout the eastern half of the United States (exclusive of south Florida) and in southern Canada. The climatic conditions that prevail over this large area are reflective of the great adaptability of this species and include a growing season variability ranging from 1.20 days in the northwest to 250 days or more in the southeast, and precipitation extremes from 16 to more than 60 inches annually. Nor are the soils on which it grows any less variable, since it does occur on dry rock outcrops, deep alluvial soils, limestone bluffs, heavy clays and swampy ground, with pH ranges of 4.7 to 7.8 (Williamson, 1957, U. S. Forest Service, 1965).

As in other wide-ranging species, eastern redcedar displays a great deal of variation, particularly in such characteristics as crown form, amount of scale foliage, and growth. Crown form was studied by Fernald and Griscom (1935) who were able to distinguish a northern race which they named Juniperus virginiana var. crebra. This variety, conspicuous with its slender, columnar, or narrowly-pyramidal crown form, was said to grow in the northeastern states south as far as Virginia, and westward to Illinois and Iowa. The broader-crown form, occurring mainly in the southern states, was considered more typical of the species as a whole. Fassett's (1943) study corroborated the work of Fernald and Griscom as far as the northeastern and southern states were concerned, but he was unable to apply varietal distinctions to the midwestern trees. Moreover, he was unable to confirm that the variety crebra could be distinguished by the shape of the scale leaves or the pitting of the seeds as reported by the New England observers. Since 1943 foresters in different parts of the South have noted that the columnar habit type of growth occurs commonly in redcedar in many areas, sometimes alone, but more often mixed with broad-crown trees. The validity of variety crebra as a taxonomic entity must, at this time, be questioned. It would seem to be better regarded as a habit type and given the designation forma. 3/

More common than broadly defined geographic races has been the variation observed among individual trees. In South Carolina at least six habit types can be found (personal observation). Horticulturists have long known of the

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3/ The designation forma is used in taxonomic literature for a more or less constant character that is not geographically defined.

species' variability and have taken advantage of numerous crown forms, foliage type, and foliage color variants to produce cultivars having ornamental value. A perusal of several taxonomic and horticultural tree manuals shows that Bailey (1933) lists 28 cultivars; Rehder (1940) describes 18; Krussman (1960) recognizes 31; Wyman (1965) lists 23 of which 13 were recommended for ornamental use; Dallimore and Jackson (1966) give 21; and Den Ouden and Boom (1966) recognize 61 of which 45 are still in cultivation. In a recent issue of the American Nurseryman (May 15, 1969) a Tennessee nurseryman claims to have 221 cultivars of Juniperus spp. under test, many of which are J. virginiana.

Winter foliage color in eastern redcedar was studied by McDermott and Fletcher (1955) in Missouri. These workers reported that the color variation found was due primarily to the amount of exposure to sunlight that the trees were subjected to, the red and purplish colors, in particular, being found on completely exposed trees, whereas green and blue colors were found mainly on shaded trees. They did not rule out the possibility that particular genotypes were more color-susceptible (as a result of anthocyanin production) than others, but believed that the amount of sunlight falling on the leaves was more important than either mineral nutrition or genetic factors in causing color variations **in** this species.

In an attempt to learn more of racial variation in eastern redcedar, the Central States Experiment Station in 1951 established on the Kaskaskia Experimental Forest near Carbondale, Illinois, a seed source study involving eight provenances. A report on this plantation, six years after planting, was made by Minckler and Ryker (1959). At eight years of age, crown form varied from bushy (broadly conical) to slender (almost cylindrical). Tree height-crown diameter ratios ranged from 3.1 (broad) to 4.1 (slender) among the eight sources. Pronounced differences were also noted for winter foliage color, leaf form, and susceptibility to cedar gall rust (Gymnosporangium sp.). The authors believed that the major variations were characteristics of the population from which the seed sources were obtained since within a seed source plot relative uniformity was exhibited.

MATERIALS AND METHODS

In 1965 correspondence was initiated with 25 state, federal, and private forestry organizations and six privately-operated nurseries in an attempt to obtain known provenances of eastern redcedar seedling stock. As a result 21 seed source lots were obtained from 13 forestry agencies and nurseries in 13 eastern, southern, and midwestern states (Table 1). Of the 21 seed source lots, eighteen were grown in state nurseries and three were native wildlings dug from pastures and old fields. Eight seed source lots were obtained from one Illinois state nursery. Seedlings were shipped to the Clemson Department of Forestry over a period extending from January 1965 to January 1966. From six nurseries, two shipments were made, each at the end of two successive growing seasons. This was necessary to obtain the desired number of seedlings (approximately 200) from each seed source. The source of seed was traced from nursery records as far as possible. In some cases the state where

Table 1. Seed Source Data on Eastern Redcedar in Clemson, S. C. Plantation

<u>Name of Source</u>	<u>Nursery where raised</u>	<u>Source of seed</u>	<u>Age of Stock</u>	<u>Date received</u>
1. South Dakota	Mason State Tree Nursery, Topeka	South Dakota	a) 2-0 b) 2-0	a) May 1965 b) Nov. 1965
2. Minnesota	Mason State Tree Nursery, Topeka	Minnesota	2-0	May 1965
3. Wisconsin	Mason State Tree Nursery, Topeka	Wisconsin	2-0	May 1965
4. New York	None, wildlings collected	Vicinity of Canton	2-5 yrs.	May 1965
5. Connecticut	None, wildlings collected	Vicinity of North Windham	2-5 yrs.	April 1965
6. Mason, Illinois	Mason State Tree Nursery, Topeka	Mason, Illinois	2-0	May 1965
7. Union County, Ill.	Mason State Tree Nursery, Topeka	Union Co., Ill.	2-0	May 1965
8. Iowa	Iowa State Forest Nursery, Ames	Windbreak trees, Ames vicinity	1-0	Jan. 1966
9. West Virginia	None, wildlings collected	Vicinity of Lakin	2-5 yrs.	a) Jan. 1965 b) Jan. 1966
10. Virginia	Dept. of Conservation, Charlottesville	Virginia	1-0	Jan. 1965
11. Kentucky	Mason State Tree Nursery, Topeka	Kentucky	a) 2-0 b) 2-0	a) May 1965 b) Nov. 1965
12. Dixon Springs, Illinois	Mason State Tree Nursery, Topeka	Dixon Springs, Ill.	a) 2-0 b) 2-0	a) May 1965 b) Nov. 1965
13. Nebraska	Bessey Nursery (U.S.F.S.), Halsey	Vicinity of Anselmo	1-0	May 1965
14. Oklahoma	Oklahoma State Forest Nursery, Washington	Logan County, N. of Cimarron River	a) 2-0 b) 1-0	a) Jan. 1965 b) Jan. 1966
15. Missouri	George White Nursery, Licking	Not known	2-0	Jan. 1965
16. Tennessee	Mason State Tree Nursery, Topeka	Tennessee	a) 2-0 b) 2-0	a) May 1965 b) Nov. 1965
17. North Carolina (Piedmont)	Clayton State Forest Nursery, Clayton	Piedmont of N. C.	1-0	Jan. 1965
18. Mississippi	Waynesboro State Nursery, Waynesboro	Not known	1-0	Jan. 1965
19. Alabama	Olustee State Nursery, Olustee, Fla.	Dallas County	1-0	Jan. 1965
20. South Carolina (Piedmont)	Piedmont Nursery, Pickens	Spartanburg County	1-0	Jan. 1965
21. South Carolina (Coastal)	Piedmont Nursery, Pickens	Vicinity of Georgetown	1-0	Jan. 1965

collections were made was known. In other cases, the county or locality was given. In the case of one source (Mason, Illinois) the seed was obtained from an individual tree.

In summary, neither the method of collection nor the type of material was ideal. However, it was possible in this way to obtain a wide variety of sources more easily and cheaply than by any other method. Sources represented did sample the extremes of the range including Minnesota and New York in the North, South Dakota and Oklahoma in the West, and Mississippi and South Carolina in the South. Seed source information is summarized in Table 1.

All material received was transplanted into nursery beds of the Piedmont Nursery, South Carolina State Commission of Forestry, and grown for one year before being removed to the planting site. The latter was located on the Clemson Forest (Mill Division, Compartment 4) five miles southeast of Clemson. The area was an old field covered with broom sedge (Andropogon spp.) and a variety of other grasses and herbs, and in which a few seedling shortleaf (Pinus echinata) and Virginia (Pinus virginiana) pines and cedars were becoming established. Redcedar occurs commonly in this area. The soil type is classed as a Cecil clay loam, and much of the topsoil had been removed by erosion as a result of past farming practices. Volunteer trees were removed from the area and it was disked three months prior to planting.

The planting design was a randomized block with four replications. Plot size was 25 trees arranged in a 5 x 5 square. Spacing was 5 x 5 feet. The first planting was made in December 1966. In October 1966 a survival count was made and the amount of stock required to replace the seedlings which died during 1965 was tallied. Except for two seed sources (South Carolina coastal and Connecticut) there was sufficient stock in the nursery to replace the dead and missing seedlings. In addition one new seed source lot (Iowa) was planted for the first time. The replacement seedlings were planted in December 1966. No additional seedlings have been planted since this date. The planting site was mowed in September 1967 and in September 1968. No other cultural treatments have been made.

MEASUREMENTS

The first measurements were made in March 1969, three growing seasons after the first trees were planted. Data taken included survival, total height, evidence of disease, winter foliage color, foliage density, and proportion of juvenile foliage. The seedlings were too small to show a trend toward a definite crown form, hence this characteristic was not evaluated.

Two types of disease symptoms were recorded, i.e., presence of cedar galls, and foliage dieback. The symptoms were taken as evidence of Cedar apple rust (Gymnosporangium iuniperi-virginianae) and Phomopsis blight (Phomopsis juniperovora) although other leaf diseases might also be involved. Winter foliage color varies considerably from tree to tree and source to source. Four colors were recognized, i.e., green, green-red, purple-red, and red-brown. Foliage density was simply tallied as light,

medium, and heavy, by ocular judgment. Juvenile foliage (awl-shaped, sharp-pointed leaves) was estimated by four, 25 percent classes, i.e., 0-25%, 26-50%, 51-75%, and 76-100%. The results of these measurements are summarized in Tables 2 and 3.

DISCUSSION

Survival. Survival was generally excellent, ranging from 81 to 97 percent except for the Connecticut and Iowa sources in which it was only 55 percent. The Iowa source in particular was heavily attacked by *Phomopsis* blight and many seedlings were lost. This measure is, however, not significant since first year deaths were largely replanted with nursery replacement stock as described above. It is concluded that initial survival of eastern redcedar is not a problem on suitable sites in the South Carolina Piedmont from whatever seed source the plants are derived as long as they are healthy and vigorous.

Total height. Age at the time of measurement was not constant but varied from four to six years for nursery grown seedlings and probably from four to nine years for wildling stock. Offsetting the age factor, however, are the effects of several transplantings, the shock being much greater for the larger plants. Hence, although a statistical comparison is not valid, a comparison of the average heights still shows several interesting and perhaps significant trends. There were three seed sources, i.e., South Carolina Piedmont, North Carolina, and Virginia, which averaged over four feet in height. These are most certainly the three whose natural habitat coincides most closely with the planting locality. Ten sources averaged between three and four feet in height. This included the remaining southern sources, several from the midwest, and the one from New York. The far west, several midwest, the northern-most and the northeastern-most sources averaged less than three feet in height. The Connecticut source was much the smallest after four years although the stock (wildlings) were among the oldest represented in the plantation.

Disease. Cedar-gall rust infection was generally low and without a pattern among the various seed sources. Most infection occurred on stock originating in Mississippi (13%), Minnesota (10%), and Oklahoma (12%). South Carolina sources were intermediate (8% and 5%). The two northeastern sources had virtually no infection although seven other sources also showed less than three percent infection. Cedar galls are hard to detect when very small, and it will be several years before data taken on this disease will become meaningful for the plantation. Foliage diseases ^{4/}, of which *Phomopsis* is the most important, are serious on eastern redcedar and were responsible for most mortality in the first two years and even now account for the poor vigor of many plants and sources. Oklahoma, Alabama, Iowa, and Kentucky

^{4/} Other leaf diseases including *Monochaetia* and *Cercospora* have been reported on junipers. These are not distinguished here from *Phomopsis* and all are considered simply as leaf diseases.

Table 2. Survival, growth, and disease characteristics of progeny from 21 redcedar seed sources two and three years after planting.

Seed Source	<u>Trees Planted and Survival</u>			Age of Stock Years	<u>Average Height</u> Feet	Disease Symptoms		
	Blocks	Trees	Survival Percentage			Cedar Gall	Foliage Disease	Disease- free Percentage
1. South Dakota	4	100	96	5-6	2.84	1	44	55
2. Minnesota	4	100	87	6	2.95	10	62	33
3. Wisconsin	4	100	95	6	3.68	2	59	39
4. New York	4	100	97	6-9	3.17	1	28	72
5. Connecticut	2	50	54	6-9	2.14	0	7	93
6. Mason-Illinois	3	75	89	6	2.61	3	62	37
7. Union Co.-Ill.	4	100	92	6	3.15	1	34	66
8. Iowa	4	100	55	4	2.56	2	60	40
9. West Virginia	4	100	96	5-9	3.85	4	62	37
10. Virginia	4	100	96	5	4.42	4	21	75
11. Kentucky	4	100	97	5-6	2.84	2	75	23
12. Dixon Springs- Illinois	4	100	93	5-6	3.23	0	45	55
13. Nebraska	4	100	93	5	2.81	7	62	41
14. Oklahoma	4	100	89	4-6	2.96	12	77	19
15. Missouri	4	100	90	6	3.66	6	50	47
16. Tennessee	4	100	96	5-6	3.38	2	40	60
17. North Carolina (Piedmont)	4	100	94	5	4.72	1	31	69
18. Mississippi	4	100	94	5	3.93	13	53	37
19. Alabama	4	100	94	5	3.85	6	68	31
20. South Carolina (Piedmont)	4	100	94	5	4.11	5	27	69
21. South Carolina (Coastal)	3	75	81	5	3.24	8	44	53

Table 3. Evaluation of progeny from 21 redcedar seed sources for winter foliage color, foliage density, and amount of juvenile foliage, two and three years after planting.

Seed Source	Winter Foliage Color				Foliage Density			Juvenile Foliage			
	Green	Green-Red	Red-Purple Percentage	Red-Brown	Light	Medium	Heavy	0-25	26-50	51-75	76-100 Percentage
1. South Dakota	1	85	7	7	9	76	15	23	39	22	16
2. Minnesota	0	47	39	14	2	75	23	24	32	30	14
3. Wisconsin	2	80	10	2	5	79	16	47	34	13	6
4. New York	0	38	29	33	1	77	22	27	25	28	20
5. Connecticut	0	11	56	33	0	74	26	19	26	18	37
6. Mason, Illinois	0	13	34	53	4	72	24	0	12	30	58
7. Union County, Illinois	1	65	15	19	5	74	21	35	30	21	14
8. Iowa	0	55	25	20	2	84	14	9	29	25	37
9. West Virginia	0	64	5	31	3	73	24	43	30	17	10
10. Virginia	2	71	18	9	11	81	8	15	41	30	14
11. Kentucky	0	68	11	21	14	62	24	9	36	34	21
12. Dixon Springs, Illinois	4	82	8	6	3	84	13	16	30	37	17
13. Nebraska	5	66	19	10	10	70	20	10	13	29	48
14. Oklahoma	12	80	7	1	1	66	33	24	21	25	30
15. Missouri	0	71	17	12	2	78	20	29	30	26	15
16. Tennessee	0	76	14	10	10	74	16	28	33	21	18
17. North Carolina Piedmont	8	80	7	5	17	77	6	26	39	28	7
18. Mississippi	4	63	19	14	7	78	15	14	22	37	27
19. Alabama	9	78	11	2	5	64	31	34	27	20	19
20. South Carolina Piedmont	7	77	6	10	6	78	16	66	24	7	3
21. South Carolina Coastal	3	62	25	10	21	69	10	8	26	28	38

stock show serious leaf disease on 68 to 77 percent of the plants. Virginia, North Carolina and South Carolina stock rated among the least infected. The lowest rate of infection, by far, was shown by the Connecticut source, on which 93 percent of the plants were rated as disease-free. Other sources were intermediate. Since this disease is primarily a nursery disease, the pattern shown may be more indicative of stock infection before planting; however, the health and vigor of the three South Atlantic sources seem to result largely from good general adaptability.

Winter foliage color. Green winter color was most pronounced in the Oklahoma source but even here only 12 percent of the trees were rated green. Green-red or rusty-green accounted for the largest proportion of seedlings in all but two sources. In one of these--the Connecticut source, red-purple foliage color predominated, and in the Mason, Illinois (single tree) source, most of the seedlings were red-brown. Other sources showing a high degree of purplish or red-brown winter foliage included those from Minnesota, New York, and Iowa. Although northern sources generally had more trees showing these colors than did southern sources, there were a number of exceptions. For example, the Wisconsin source had only 12 percent of its trees in these two color classes whereas the South Carolina coastal (southernmost source) had 35 percent.

Foliage Density. The medium foliage density class predominated in all sources, the lowest value being 62 percent (Kentucky source) and the highest, 84 percent (Iowa and Dixon Springs, Illinois sources). Sources with relatively high proportion of trees in the light foliage density class included South Carolina Coastal and North Carolina. Those with low proportion of such trees included the Connecticut and New York sources. Seedlings in the heavy foliage density class were most common in the Oklahoma and Alabama sources.

Juvenile Foliage. The prickly, awl-shaped juvenile leaves persist longer on some trees and sources than on others. This character varied tremendously among the sources. The proportion of trees having juvenile foliage in the 0-25% class ranged from zero to 66 percent. No pattern among the seed sources was apparent and it is quite probable that this is a character more of individual progenies (as the Mason source would indicate) than a reflection of the source. Sources with a high proportion of juvenile foliage included the Mason, Illinois, Nebraska, and South Carolina Coastal sources. Low proportions of juvenile foliage were found in the South Carolina Piedmont, North Carolina, and Wisconsin sources.

CONCLUSIONS

These data are very preliminary since they represent trees that are only four to nine years of age. Therefore, all conclusions must be considered as tentative. Nevertheless, some of these are quite interesting and are set forth here.

1. The three sources representing South Carolina Piedmont, North Carolina Piedmont, and Virginia rate high in survival, total

height, and freedom from disease. They seem to have the best general adaptability to South Carolina Piedmont conditions.

2. Initial survival of all sources is satisfactory. This will be of importance to Christmas tree growers and horticulturists, although it would probably be of somewhat less significance to foresters.
3. Several striking characteristics shown by the Mason, Illinois, single tree source suggests that many characters are under strong genetic control and can be transmitted to their progeny. These include winter foliage color, and proportion of juvenile foliage. The lack of pattern that these characters show with respect to seed source suggests that these are not general population characteristics.
4. Western and northern sources grow more slowly than southern and eastern sources. This conclusion would follow that of many other species. However, there is probably a strong interaction with site as the first conclusion suggests, and it may not be valid in all cases.
5. Sources that show distinctly different characteristics from most include the Connecticut and South Carolina Coastal sources. It is not impossible that introgression with closely allied species (Juniperus horizontalis and Juniperus silicicola) is involved. Western sources which appear very similar may also show introgression with the related Juniperus scopulorum and Juniperus ashei. Such introgression has been reported in the literature (USFS, 1966).
6. The growing of seedlings in one local nursery as transplants for a year or more tends to reduce although it does not eliminate variation in stock grown under a wide diversity of conditions. This method could be used, then, as a means to obtain a wide variety of seed source material for experimental purposes in those cases where the growing of stock from seed is not practicable.

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