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development of objective criteria for measuring the direction and rate of migration. One would have to determine the physiological requirements of each species during all of its ontogenetic phases, from seed to mature plant. It would also be necessary to make an ecological study of habitats in which the species are established, comparing them to seemingly similar habitats beyond the limits of range of the species.

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Distribution Patterns of Eastern Red-Cedar *Juniperus virginiana* L. in Henry County, Iowa

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Abstract: The distribution patterns of Eastern red-cedar were studied in Henry County, Iowa, in a general survey and also in three intensive study areas in Marion, Jackson, and Wayne townships. It was found that the abundant seed sources of red-cedar and the predominantly rolling land in Henry County make extensive establishment of red-cedars possible. In the northern tier of townships red-cedars are restricted to fence lines and roadsides whereas in the hilly southern three tiers of townships they are much more abundant.

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Planted trees in occupied or abandoned homesteads and in cemeteries are invariably found within the area where naturally established red-cedars occur in pastures, roadsides, and fence-lines. Naturally established trees are seldom farther than $\frac{1}{2}$ mile away from the nearest planted tree. Age determinations show that naturally established trees are consistently and considerably younger than the planted seed-bearing trees; therefore, it was concluded that these planted sources are responsible for the present distribution pattern of red-cedar in Henry County. Historical evidence does not suggest otherwise.

What are the distribution patterns of Eastern red-cedar, *Juniperus virginiana* L. in Iowa? In some areas of the state large numbers of trees can be seen scattered in pastures, along road ditches and fences, whereas, in other areas the only trees appear to be those which have been planted for landscape effects or windbreaks. Most of the research was done for this study in Henry County, Iowa, where red-cedar is dense enough in southern townships to be a serious pasture management problem and of lesser occurrence in northern townships. This study is an attempt to rescribe the patterns and to obtain evidence to explain how these patterns of distribution of red-cedar originated.

METHODS

The presence of red-cedar was recorded along the total 794 miles of roads in Henry County (Figure 1). Three categories were used in recording sites with planted trees: 1) those sites where all trees were under 40 years of age, 2) over 40 years only, and 3) both age classes together. Approximate ages were determined from numerous increment borings. The presence of naturally established trees along the routes was recorded without regard to age classes.

Three intensive study areas were selected in Marion, Jackson, and Wayne Townships in an attempt to obtain a census of red-cedar trees. Selection of areas was made using the following criteria: 1) presence of scattered trees, 2) suitable habitat (uncultivated or disturbed areas), 3) the presence of a planted seed source, and 4) friendly residents. The Wayne Township study area with its level, extensively cultivated land is typical of the northern tier of townships in Henry County, whereas the rolling topography of the Jackson and Marion Townships is typical of the southern three tiers of townships.

The actual number and location of red-cedar trees within the three study areas were determined in the field and recorded on aerial photographs obtained from the United States Department of Agriculture (Figure 2).

Four age classes were used in recording the trees: 1) up to 10 years of age, 2) 11 to 30 years, 3) 31 to 60 years, and 4) over



Figure 1. Distribution map of Red-cedar Trees in Henry County, Iowa
Scale 1" = 3 miles

Planted trees under 40 years of age
Planted trees over 40 years of age
Planted trees of both age classes
Naturally established trees

60 years. Estimates of tree ages were based on numerous increment borings. The great variety of environmental conditions under which red-cedar trees were found growing made it difficult to relate precise age to height or diameter of trees or any other readily visible characteristic; however, it was possible to use these broad age classes effectively. The range of variation included annual growth increments of wood of one-fourth inch

for some trees in ditches and gullies to less than one-tenth on dry hillsides and yards.

Suitable habitat for red-cedar can be described as any un-



Figure 2. Aerial photo of Marion Township study area, located in section 34, Henry County, Iowa. The study area is divided into four quadrants by the string markers. The four circular belts are lettered A, B, C, and D, respectively, starting at the center. Scale $\frac{1}{2}$ " = $\frac{1}{4}$ mile

cultivated or waste area including pastures, fence rows between cultivated fields, and roadsides. The amount of suitable habitat was determined for each of the three areas by the use of a planimeter and aerial photographs.

Historical information on the presence of red-cedar was obtained from local residents and from the Iowa Land Survey Records, the latter consisting of the general field notes of the survey of Henry County in 1836-1838 (2). Witness trees were named in the notes, and the relative abundance of each species was recorded by the surveyor (1).

RESULTS AND DISCUSSION

County Survey

The county survey strengthened the belief that the occurrence of naturally established red-cedar trees is closely related to the presence of planted trees in nearby windbreaks and landscape plantings in homesteads and cemeteries. Naturally established trees were consistently not more than one-half mile from the nearest planted tree. The age of planted trees was considerably greater than the oldest naturally established trees in surrounding areas. For example, a span of 62 years separated the planted and naturally established trees in the Jackson Township study area, 45 years in the Wayne Township study area.

The number of sites where red-cedar trees were planted was compared with the total number of potential sites for plantings (Table 1). Approximately one-third of the potential sites in Henry County have planted trees with some of the southern townships tending to be higher. Despite this extensive distribution of potential seed trees for natural establishment there are many areas where there is no establishment in the vicinity of planted sources. This can be explained by one or more reasons: 1) a lack of suitable habitat because of close mowing of ditches and fence lines or extensive cultivation of all available land, 2) lack of seed or lack of dispersal to a suitable site, 3) removal of newly established plants by residents, and 4) a failure to detect established individuals because of difficulty in distinguishing the red-cedar from surrounding vegetation during the summer when observations were made.

Abrupt boundaries were observed where mowing annually removed young trees on only one side of a fence. Cutting, close

Table 1. Comparison of sites with and without planted red-cedars

TOWNSHIPS	No. of sites without planted trees	No. of plantings over 40 years	No. of plantings under 40 years	No. of plantings with both age classes	Total No. of plantings	% of potential sites occupied by plantings	Total sites
Jefferson	147	47	14		61	29%	208
Wayne	141	34	14	4	52	27%	193
Scott	111	31	15	3	49	31%	160
Trenton	112	40	6	1	47	30%	159
Marion	74	56	8	2	66	47%	140
Canaan	111	34	23	2	59	35%	170
Tippecanoe	125	44	6	3	53	30%	178
Center	100	40	10	2	52	34%	152
New London	118	44	14	4	62	34%	180
Salem	95	55	9	1	65	41%	160
Jackson	90	42	10	6	58	39%	148
Baltimore	111	31	9	1	41	27%	152
Henry County Totals	1335	498	138	29	665	33%	2000

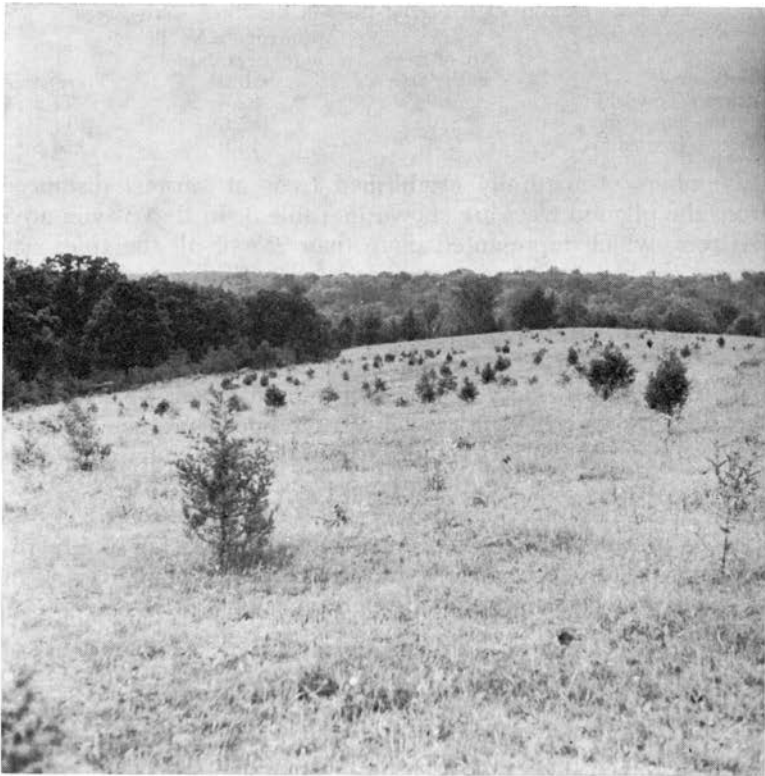


Figure 3. Establishment of red-cedars in an old meadow, Jackson Township study area. The oldest trees in this site were in the Class II (11 to 30 years of age) group. Local seed sources are shown in the left background.

mowing, or burning are effective management practices because red-cedar does not sprout from the stump. Where mowing is no longer practiced, there may be rapid establishment of seedlings. Thirty-six seedlings were recorded in one sample plot eight feet square in a pasture which had not been mowed for four years. Similar establishment occurs in unmowed ditches, roadsides, and creek banks. The rapid invasion of a pasture is clearly shown in Figure 3.

Township Study Areas

The density of naturally established red-cedar trees in the three census areas is shown in Table 2. The Jackson Township study area has more than six times as many red-cedar per acre of suitable habitat as the Marion area, and the Wayne Township has the lowest number. Density has been figured on the basis of the number of trees per acre of suitable habitat to obtain comparable values for the three areas.

Table 2. Density of red-cedar trees in the three study areas

Study area	No. of trees in the area	Approximate No. of acres of suitable		Trees/acre
		habitat		
Jackson Township	5865	82.4		71.2
Marion Township	2165	185.6		11.7
Wayne Township	67	13.9		4.8

Numbers of naturally established trees at various distances from the planted trees are shown in Table 3. In the Wayne area 64 trees, which represented more than 95% of all the trees observed in this study area, were counted within one-eighth mile of the 85 year old planted trees. The large percentage of trees less than 10 years old indicates that establishment has been recent or that trees were more effectively controlled in the past. However, in Jackson Township establishment by red-cedar has occurred over a long period of time and a problem of control is quite evident. Here the lack of trees within one-eighth mile radius of the planted trees is associated with extensive cultivation. The large number of naturally established trees at greater distances from the center of this plot is probably related to the presence of three additional sites of planted trees in the area which complicates the pattern.

Table 3. Census of red-cedar trees in study areas of Jackson, Marion and Wayne Townships

Study area	Distance from planted trees, fraction of mile				
	0- $\frac{1}{8}$	$\frac{1}{8}$ - $\frac{1}{4}$	$\frac{1}{4}$ - $\frac{1}{2}$	$\frac{1}{2}$ - $\frac{3}{4}$	Total
<i>Jackson</i>					
Number of trees in					
all age classes	0	706	2071	3088	5865
Percent over 30 years	0	13	4	3	4
Percent under 10 years	0	29	25	38	32
<i>Marion</i>					
Number of trees in					
all age classes	180	1684	213	88	2165
Percent over 30 years	0	0	0	0	0
Percent under 10 years	34	92	46	30	80
<i>Wayne</i>					
Number of trees in					
all age classes	64	2	1	0	67
Percent over 30 years	0	0	0	0	0
Percent under 10 years	89	50	100	0	88

The Marion area shows a typical pattern of distribution except for the extremely large number of small trees about one-eighth mile from the central seed source. Nine hundred and ninety-three trees were counted in six-tenths acre with a high percentage of these less than 10 years old. The fewest trees appeared in the area farthest from the planted source, a situation similar to that occurring in the Wayne area.

Historical Information

No bearing or witness trees of red-cedar were recorded in the original land survey. The only mention of red-cedar at all in the

county was made in relation to Salem Township, Section 18, where red-cedar was included at the bottom of the list of forest tree species. There was no indication of size or age, but the position at the bottom of the list indicated that the species was not abundant. At the time of the survey in 1836-1838 there was a mill-site already operating in this area, and the nearby town of Salem had 50 occupants.

SUMMARY AND CONCLUSIONS

It was observed in this study that 1) there are abundant seed sources of red-cedar in Henry County, Iowa, and 2) the predominantly rolling land provides large areas of suitable habitat. The planted trees in homesteads are assumed to be the original seed sources for most of the naturally established trees; however, it is obvious that there is much seed production by the latter which provides local centers of distribution to further complicate the patterns.

The abundance of red-cedar in Henry County is increasing as shown by the greater number of young trees in most of the samples. Grass production is reduced where these trees are established in pastures, and operation of machinery is hampered by their presence in various other sites. This rapid increase in the density of red-cedar, especially where naturally established trees are bearing seeds in large quantities, can be expected to continue unless effective management practices of cutting, close mowing, or burning are adopted.

The distribution patterns of eastern red-cedar in Henry County are explained by the location of planted trees which have acted as centers of distribution. The county survey, the census of red-cedar in special study areas, and historical information have lead us to this conclusion.

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