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# Influence of Light and Nutrition On Color and Growth of Redcedar Seedlings

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# Influence of Light and Nutrition on Color and Growth of Redcedar Seedlings

R. E. McDERMOTT and P. W. FLETCHER

It has been estimated that the cedar-hardwood forest type is the sixth largest timber type in Missouri (King, Roberts, and Winter, 1949). Many observers have noted that during the past 20 to 25 years, the invasion of eastern redcedar has been very rapid or accelerated on old fields and old pastures, grassy limestone glades and outcrops, and on ridges and post oak flats of the Ozark region. Beilmann and Brenner (1951) have called this rapid invasion "explosive" and have attributed it to the initiation of forest fire protection in the state.

Redcedar management has good promise in the Ozark and Ozark border region of Missouri. Markets for fence posts, pencil stock, paneling, flooring and Christmas trees appear to be well established. However, research is needed to define rotation age, adequate natural regeneration as related to fire, grazing and cutting, and growth rate as influenced by soil variables and microclimatic conditions.

On marginal agricultural lands such as old fields or unimproved pastures (Fig. 1), the invasion of redcedar permits two land-use alternatives—cedar management or cedar elimination—the choice of which must be tempered by the financial consequences of either action. The financial possibilities for redcedar management on such land are little more than speculative at present because of a lack of fundamental silvical and silvicultural knowledge of the species. This is in contrast to the relative wealth of information available for pasture improvement and management or row crop production. Thus, a preliminary silvical investigation of eastern redcedar appears warranted.

In central Missouri, summer color of the foliage of eastern redcedar has a wide range from blue-green through yellow-green. Fall introduces additional, varying, purple-red and yellow phases. Some of these summer and winter color differences appear to be due to a genetic variable within the species and to the degree of introgression of *Juniperus virginiana* L., eastern redcedar, and *J. ashei* Buchholz, Ashe juniper, as evidenced by branching patterns and gross and minute foliage characteristics (Hall, 1952).

The fall-initiated purple-red phase is more pronounced on awl foliage than scale foliage and is the result of the formation of the red pigment anthocyanin.<sup>1</sup> Trees that have sufficient crown diameters and leaf densities to

<sup>1</sup>For purposes of this investigation the red coloration is referred to as the pigment anthocyanin. This may or may not be the case. Onslow (1925) intimates that winter reddening of some of the Gymnosperms is due to the red products from chlorophyll in the chloroplastids. For a review of some of the more recent work concerning origin and function of accessory pigments the reader is referred to such sources as Blinks, 1954.

shade the interior of the crown are commonly red-purple and/or yellow on the exposed southern and western sides in contrast to the greener, shaded sides. Also, the undersides of unshaded branches are commonly a brighter green than the upper surfaces. These readily observable color differences in bright sunlight attest the influence of direct sunlight. However, there are differences in degree of red and yellow coloration of trees that have essentially the same relative proportion of awls and scales and the same degree of exposure to direct sunlight. This poses the question of whether these variations are due to genetic differences and/or to differences in microclimate and soil conditions. In this investigation no attempt was made to isolate genetic variables.

The production of anthocyanin in the autumnal coloration of leaves of many oaks, dogwood, maples, and gums is influenced by degree of exposure to direct light, relatively low nitrogen supply in the soil, and deficiency of soil moisture (Meyer and Anderson, 1952). The purpose of this investigation was to ascertain to what degree light, nitrogen, and microclimatic conditions are instrumental in the fall initiation of color changes in the foliage of eastern redcedar. In addition, it seemed desirable to test the further nutritional effects of varying calcium, phosphorus, and potassium levels as they influence eastern redcedar growth. Such growth responses, in turn, may have some correlation with the autumnal color changes. Accordingly, seedlings of redcedar were subjected to different light intensities and varying levels of nitrogen, phosphorus, potassium, and calcium during the growing season of 1953. Indirect physiological drouth effects were evaluated by recording temperature effects of direct sunlight and shade, and mulch was applied to some seedlings as night temperatures approached freezing at the close of the growing season.

## PROCEDURE

**Planting stock.** Dormant 1-0 nursery-grown eastern redcedar seedlings were planted singly in 8-inch pots in March, 1953. The seedlings had an average top length of about 5 inches and were pruned to an average root length of about 7 inches. The foliage was the juvenile awl form and had a marked purple-red color with no evidence of the cedar blight *Phomopsis juniperovora* Hahn. Minute anatomical characteristics of the awls indicated that these seedlings were of the species *virginiana*. Individual height measurements were recorded for each plant for comparison with subsequent growth during the growing season.

**Soil.** The A<sub>2</sub> horizon of Putnam silt loam in a 50-50 mixture with coarse sand was used as a potting medium. This soil mixture was used because it provided good drainage conditions together with low fertility properties as evidenced by an exchange capacity of 5 m.e. per 100 grams of soil,

a pH of 4.9, quick organic matter content of 0.4 percent, and readily available  $P_2O_5$  content of 4 lbs. per acre. Base saturation for this potting medium was 22 percent calcium, 11 percent magnesium, 1 percent potassium, and 66 percent hydrogen. To the basic mixture of Putnam silt loam and sand, calcium was added by mixing in the potting medium. The several phosphorus and potassium amendments were applied at root depth at the time of transplanting the seedlings to each pot. Nitrogen was applied at the soil surface at the rate of 100 lbs. per acre.

**Light<sup>2</sup> and Water.** Three sunlight intensities were used; full, one-third and one-tenth. Cloth shades reduced the light and were suspended over the beds with 15 inches of clearance to allow air circulation. Seedlings in the reduced light beds were allowed to become established for one week in full sunlight before the shades were placed over them.

The pots were embedded in sand to facilitate drainage, and during the growing season the seedlings were watered daily. The surfaces of the pots and surrounding sand were covered with a 1-inch layer of granulated vermiculite. Thus, with daily watering, the vermiculite mulch, and good drainage conditions, optimum soil moisture conditions were maintained.

**Experimental Design.** Within light intensities of 10,000, 3,300, and 1,000 foot candles, 14 fertilizer treatments were randomly located and replicated six times (Tables 1, 2 and Fig. 2).

TABLE 1 -- EXPERIMENTAL LIGHT AND FERTILIZER FACTORS FOR EASTERN REDCEDAR SEEDLINGS.

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1. light - 3 levels; 10,000, 3,300, 1000 f.c.
  2. P - 3 levels;  $P_1 = 4$  lbs./acre,  $P_2 = 50$  lbs./acre,  $P_3 = 200$  lbs./acre.
  3. K - 2 levels;  $K_1 = 36$  lbs./acre,  $K_2 = 200$  lbs./acre.
  4. Ca - 2 levels;  $Ca_1 = 392$  lbs./acre,  $Ca_2 = 5000$  lbs./acre.
  5. N - 2 levels;  $N_1 = 80$  lbs./acre,  $N_2 = 180$  lbs./acre.
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TABLE 2 -- EXPERIMENTAL DESIGN OF LIGHT AND FERTILIZER TREATMENTS FOR EASTERN REDCEDAR SEEDLINGS.

Treatments Per Light Intensity - Replicated Six Times		
1. $Ca_2P_3K_2N_2$	6. $Ca_2P_2K_2N_1$	11. $Ca_2P_1K_1N_2$
2. $Ca_2P_3K_2N_1$	7. $Ca_2P_2K_1N_2$	12. $Ca_2P_1K_1N_1$
3. $Ca_2P_3K_1N_2$	8. $Ca_2P_2K_1N_1$	13. $Ca_1P_1K_1N_2$
4. $Ca_2P_3K_1N_1$	9. $Ca_2P_1K_2N_2$	14. $Ca_1P_1K_1N_1$
5. $Ca_2P_2K_2N_2$	10. $Ca_2P_1K_2N_1$	

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<sup>2</sup>Full recognition is given such important light considerations as qualitative and photoperiod effects. For purposes of this investigation, however, quantitative expressions of light seemed adequate.

**Fall Mulching and Air-Soil Temperatures.** In early October, three seedlings of each fertilizer treatment were heavily mulched with hardwood sawdust. Three seedlings per treatment remained as unmulched checks. In late October, soil thermometers were placed at 1-inch and 3-inch depths in mulched and unmulched pots of seedlings growing in full, one-third, and one-tenth sunlight. Air temperatures, soil temperatures at 1 and 3 inches, and relative humidity were recorded daily for a period of six weeks.

**Major Observations.** In mid-October, 1953, early color differences of seedlings grown under full, one-third, and one-tenth sunlight were compared and recorded by means of a portable Tristimulus Reflectometer. By December, however, foliage color difference per light intensity had become so readily distinguishable that minute analysis by blue, green, and amber filters was no longer necessary.

In February, 1954, final height growth in inches per seedling was determined. The oven-dried top and root weights in grams were subsequently determined for each seedling.

**Supplemental Observations.** Pin oak (*Q. Palustris* Muench.) seedlings were used to correlate the autumnal coloration of redcedar seedlings with color changes in a deciduous tree. Pin oak acorns were germinated in 8-inch pots containing fertile alluvial soil and allowed to become established for one week in April, 1953. At the end of a week, 12 of the young seedlings were placed with the cedar transplants in each of the light beds of 10,000, 3,300, and 1000 f.c. General growth and color developments were noted at the close of the 1953 growing season.



Fig. 1—An old field in Boone County, Mo., with characteristic invasion of redcedar, persimmon, and sassafras.



Fig. 2—Full, one-third, and one-tenth sunlight beds. December 1953. One-third sunlight (upper right) was obtained by shading with six layers of cheesecloth and one-tenth sunlight by one layer of drapery burlap.

It might be assumed that cedar seedlings grown in full sunlight and shaded just prior to the beginning of autumnal coloration of the hardwoods would exhibit different color characteristics than seedlings shaded through the entire growing season and autumnal coloration period. To test this hypothesis, 1-2 cedar seedlings that had grown two seasons in full sunlight were shaded at different areas of the stems just before the autumnal color changes in hardwood species in 1954. This shading was accomplished by enclosing different stem sections in aluminum foil. One seedling had sunlight excluded from the top one-third, another had light excluded from the center, and on a third seedling, light was excluded from the lower third. A fourth seedling was completely encased in foil and still another seedling served as a check with no shading. By December 12, 1954, all exposed foliage had turned the expected red-purple color, and comparisons were possible with the shaded portions of the stems.

There remained the question of whether the results obtained from potted seedlings would show upon larger trees growing under field conditions. Accordingly, in the late summer of 1954, pole and burlap tepees were erected over trees that were 4, 6, and 9 feet tall, and growing under uniform site conditions in an old field in Boone County, Mo. (Fig. 1).

## RESULTS

**Color.** By the middle of the 1953 growing season, color differences were pronounced in the awl foliage of seedlings grown in full, one-third, and one-tenth sunlight. The seedlings grown in full sunlight had a marked yellow-green color, those in one-third sunlight a pure green color, and those in the one-tenth sunlight a blue-green color that was influenced in part by a bloom on the twigs and foliage. These colors within light treatments were uniform and fertilizer treatments could not be identified visually.

In early October, 1953, as the autumnal coloration of hardwood trees was becoming defined, additional precise color changes were initiated in seedlings grown in full and one-third sunlight. Those in full sunlight developed a strong purple-red anthocyanin cast on the twigs and foliage. The seedlings in one-third light developed a yellow-green cast but with no readily apparent red or anthocyanin. The seedlings in one-tenth sunlight remained essentially unchanged—blue-green. These color differences were uniform by light intensities and no differences within a light intensity could be attributed to fertilizer treatments.

From November through December, 1953, daily air temperatures, soil temperatures, at 1- and 3-inch levels in mulched and unmulched pots, and relative humidities, indicated some pronounced microclimatic differences within light intensities and between light intensities. These microclimatic differences, however, did not influence to any degree the color uniformity within each light intensity.

**Height Growth.** By considering light intensities as blocks and testing to ascertain if fertilizer treatments had any effects on height growth, it was found by statistical analysis (F test) that fertilizer treatments did not influence height growth (Table 3). Block effects, however, were highly significant. And, by comparing mean height growth differences of blocks (Table

TABLE 3 -- ANALYSIS OF VARIANCE OF HEIGHT GROWTH OF EASTERN REDCEDAR SEEDLINGS GROWN IN THREE LIGHT INTENSITIES AND FERTILIZER COMBINATIONS AS A FUNCTION OF FINAL HEIGHT MINUS INITIAL HEIGHT.

Source	SS	DF	MS
Blocks	178.2227	2	89.1113*
Treatments	93.5094	13	7.1930
Interaction	52.0772	26	2.0029
Error	1106.3834	210	5.2685
Total	1430.1927	251	

\*Significant by F test at the 5 percent level.



4), it was found that seedling height growth in full sunlight did not differ significantly from height growth in one-third sunlight. Seedlings grown in one-tenth sunlight, however were significantly shorter than those grown in one-third sunlight.

TABLE 4 -- COMPARISON OF MEAN HEIGHT GROWTH DIFFERENCES OF SEEDLINGS GROWN IN FULL, ONE-THIRD, AND ONE-TENTH SUNLIGHT.

$\bar{y}_3$ (Full Sunlight) = 5.603 inches		
$\bar{y}_2$ (1/3 Sunlight) = 5.452 inches		
$\bar{y}_1$ (1/10 Sunlight) = 3.749 inches		
SE ( $\bar{y}_1 - \bar{y}_2$ ) t = 0.8153 the significant difference		
$\bar{y}_3$ 5.603	$\bar{y}_3$ 5.603	$\bar{y}_2$ 5.452
$\bar{y}_2$ 5.452	$\bar{y}_1$ 3.749	$\bar{y}_1$ 3.749
0.151	1.854*	1.703*

\*Significant differences

**Top:Root Ratios.** A statistical analysis of top:root weight ratios to determine light, and fertilizer effects on seedlings growth, indicates the same relationships as height growth interpretations. Considering light intensities as blocks and employing the F test, block effects were highly significant while fertilizer treatments were not an influencing factor (Table 5).

TABLE 5 -- ANALYSIS OF VARIANCE OF TOP:ROOT RATIOS OF EASTERN REDCEDAR SEEDLINGS GROWN IN THREE LIGHT INTENSITIES AND FERTILIZER COMBINATIONS.

Source	SS	DF	MS
Blocks	4.4837	2	2.2418*
Treatments	1.1537	13	0.0887
Interaction	3.8701	26	0.1488
Error	18.9293	210	0.0901
Total	28.4368	251	

\*Significant by F test at the 5 percent level.

A comparison of block mean differences indicated that seedling growth in full sunlight did not differ significantly from growth in one-third sunlight. As with height growth, however, top:root ratios were significantly altered for seedlings grown in one-tenth sunlight in comparison with those ratios of seedlings grown in one-third and full sunlight (Table 6).

TABLE 6 -- COMPARISONS OF MEAN TOP:ROOT RATIO DIFFERENCES OF SEEDLINGS GROWN IN FULL, ONE-THIRD, AND ONE-TENTH SUNLIGHT.

$\bar{y}_3$ (Full Sunlight) = 1.4439		
$\bar{y}_2$ (1/3 Sunlight) = 1.4567		
$\bar{y}_1$ (1/10 Sunlight) = 1.7330		
SE ( $\bar{y}_1 - \bar{y}_2$ ) t = 0.0466 the significant difference		
$\bar{y}_2$ 1.4567	$\bar{y}_1$ 1.7330	$\bar{y}_1$ 1.7330
$\bar{y}_3$ 1.4439	$\bar{y}_3$ 1.4439	$\bar{y}_2$ 1.4567
0.0128	0.2891*	0.2763*
*Significant differences		

## CONCLUSIONS

Based on 1-0 seedlings of eastern redcedar grown under three light intensities and various fertilizer combinations, it is evident that the fall initiation of anthocyanin is primarily a reaction to high light intensity. High and low levels of potassium, phosphorus, nitrogen, and calcium did not influence to any observable degree the color limits that were imposed by light intensities.

Pin oak seedlings that were grown with the redcedar seedlings in the three light intensities revealed that the autumnal red and yellow phases of eastern redcedar are closely allied with the fall coloration of hardwood trees. By October, 1953, the pin oak seedlings growing in full sunlight averaged 6 inches in height and had a very pronounced red foliage color. By mid-November these red leaves turned the characteristic dull brown of dead, winter foliage, and soon dropped off. The pin oak seedlings grown in one-third sunlight averaged 7 inches in height and the leaves were predominantly yellow, with just a faint suggestion of anthocyanin. This pin oak color shift from green to yellow in one-third sunlight took place 10 days to two weeks after the seedlings in full sunlight had developed their strong red pigmentation. These yellow leaves turned slightly brown before falling off the seedlings, but they had essentially a cured, yellow appearance. The pin oak seedlings grown in one-tenth sunlight averaged about 5 inches tall and the leaves retained a strong green color with some yellow appearing shortly before they dropped off in November.

These comparative observations indicated that the strong development of anthocyanin in eastern redcedar seedlings in full sunlight was accompanied in developmental sequence by anthocyanin formation in the foliage of the pin oak seedlings. Furthermore, the yellow phase developed by redcedar

seedlings in one-third sunlight was accompanied by the yellowing of pin oak seedling leaves, and no anthocyanin was observed in the cedar foliage and very little in the oak. Likewise, the unchanged blue-green color of cedar seedlings grown in one-tenth sunlight was accompanied by a semi-stable green color of the oak leaves.

One season's growth of cedar seedlings under full, one-third, and one-tenth sunlight intensities illustrates that they grow equally well in height, and growth expressed in top:root ratios, in full and one-third sunlight. One-tenth sunlight markedly reduces both height and vigorous top:root relationships. It appears, therefore, that sunlight intensities between 3300 and 10,000 f.c. do not materially alter vigor, but formation of anthocyanin in the fall is somehow a critical combination of light intensities approaching full sunlight and the more obvious climatic alterations of photoperiod and day-night temperature relationships.

Removal of the aluminum foil from different areas of seedlings on December 12, 1954, revealed a striking red-purple contrast of exposed foliage to the relatively brilliant green of the shaded foliage. This illustrates that despite high vigor as a result of a full season's growth in 10,000 f.c., and presumably high levels of carbohydrates and glucosides that are generally considered prerequisite for anthocyanin formation (Onslow, 1925, Robinson and Robinson, 1931, Arthur, 1936, and Stiles, 1950), the full anthocyanin potential is realized only by high sunlight. Microscopic sections of completely exposed awls and twigs reveal that in a majority of cases the red coloration is concentrated in the three outermost cell layers of mesophyll. The mesophyll cells in close proximity to the vascular bundle contain an abundance of chlorophyll. Sections of awls and stems that were heavily shaded revealed a uniformity of chlorophyllose mesophyll.

The anthocyanin winter color phase of redcedar seedlings is a semi-stable dormancy condition. Presumably, in high sunlight chlorophyll synthesis is curtailed and anthocyanin is formed. If the light intensity is reduced to one-third full sunlight a yellow cast becomes evident. This yellow color may be a result of chlorophyll destruction, which reveals the yellow chloroplastid components or the initiation of chromogen activity. Ordinarily, spring inaugurates a color transition back to some stage of green with just minute quantities of the winter anthocyanin remaining. In December and January, strongly red-pigmented seedlings, when brought inside to room temperature and 200 f.c. of mazda light, started turning green within a week. Cross sections of stems and awls indicated that the anthocyanin was absorbed in the outermost mesophyll cells, with chlorophyll uniformly distributed throughout the tissue. Shortly after the redistribution of chlorophyll and disappearance of anthocyanin, apical meristem activity began. However, seedlings that were grown in full sunlight and shaded prior to autumnal coloration, and then uncovered in early December in full sunlight, outdoor

temperatures, and photoperiod conditions, reverted only slightly and slowly to the anthocyanin phase. Thus, it appears that the time of greatest potentiality for formation of anthocyanin in cedar seedlings is in the fall.

It seems possible that high sunlight intensities are responsible for the breakdown of chlorophyll in foliage of eastern redcedar seedlings much as is the case with autumnal coloration of leaves of deciduous trees. The fall initiation of red or yellow coloration in cedar seedlings, however, is unlike coloration in deciduous trees in that it does not go to completion (i.e., the obvious formation of abscission layers and ultimate curtailment of all physiological processes within the leaves). Rather, it appears that the autumnal coloration of cedar is a temporary winter-dormancy phase in high sunlight that is a reversible phenomenon with the advent of spring.

Nutrition of cedar seedlings does not appear to affect growth or foliage coloration within light treatments in the brief span of one growing season. The most critical nutrient condition pertaining to anthocyanin formation is low nitrogen (Meyer and Anderson, 1952). But, despite a high surface application of nitrogen to cedar seedlings of some treatments, light effects were paramount. Thus, it appears evident that although soil fertility and possibly water availability may have a cumulative influence on the color of redcedar foliage, these effects only accentuate the fundamental light reaction.

On large cedar trees, winter color of the foliage (awls and scales) is greatly influenced by high light intensities. By mid-December, 1954, large trees that had been shaded by burlap since late summer were a uniform, striking green in contrast to prevailing red-purples and yellow-greens of other large trees on the area. This further indicates that red or yellow winter coloration of cedar is a high sunlight manifestation, and is not restricted to juvenile (seedling) foliage.

From the latter part of October, 1953, through November, recorded air temperatures and soil temperatures at 1 and 3 inches in mulched and unmulched pots, and relative humidities indicated that microclimatic conditions in one-tenth and one-third sunlight did not differ significantly. Air temperatures in full sunlight, however, were as much as 5° to 7° F. warmer than shaded beds in the daytime. Within light intensities, no significant differences were recorded for soil temperatures at 1- or 3-inch depths. The application of a heavy hardwood sawdust mulch resulted in a leveling of temperature differences. Under the light shades, the average daytime soil temperatures were 5° to 6° warmer under the mulch. In full sunlight, mulching resulted in soil temperatures that were 2° to 4° higher than in unmulched pots. As has been noted previously, no foliage color differences were distinguishable within light intensities. Thus, microclimatic temperature relationships had no bearing on the foliage color differences between light intensities. That fall initiation of color changes in the juvenile foliage of eastern redcedar does not appear to be an early manifestation of winter injury,

is further substantiated by Stoeckler and Rudolf (1949) who reported very little winter injury to eastern redcedar in Minnesota.

Redcedar trees that are growing on the same site and are approximately the same age and size may vary considerably in overall color. Indeed, two trees that are of equal size and are growing side by side on the same site can differ markedly in degree of winter red and yellow coloration. Hall (1952) suggests that for central Missouri this may be the result of genetic limitations that result from the degree of hybridization and introgression between *Juniperus virginiana* and *J. ashei*. Among larger trees, empirical field observations indicate that in winter the females are consistently greener than males of comparable size and growing under comparable site conditions. To be sure, the color of the fruit lends an overall darker appearance to the females but female foliage, regardless of fruit, appears to be greener in the winter than male foliage. This may, in part, be related to the higher content of magnesium in winter female foliage reported by Fletcher and Ochrymowych (1955). Stone (1953) reported a winter chlorotic condition in some of the northeastern Gymnosperms that may be related in part to magnesium deficiency in the soil.

Bailey (1933) and Rehder (1940) list several varieties of eastern redcedar that are recognizable by pronounced differences in color and form (pyramidal-columnar), percent awls and scales of the mature foliage, and degree of rigidity and pendulousness in the branches. The genetic, anthocyanin variance has been selected particularly in the Hill and Dundee junipers. Hill juniper, *J. virginiana* var. *pyramidiformis Hillii* D. Hill, has ascending branches with acicular leaves that are conspicuous for becoming plum-colored in autumn. It is quite apparent that percentages of leaf types and degree of autumnal coloration of redcedar are governed a great deal by degree of segregation of genetic potentials for these characteristics.

## SUMMARY

During the growing season of 1953, 1-0 seedlings of eastern redcedar were grown under three light intensities and varying fertilizer levels of nitrogen, calcium, phosphorus, and potassium. At the close of the 1953 growing season, growth responses of seedlings indicated that fertilizers did not affect growth in any of the three light intensities. Moreover, growth responses in full sunlight and one-third sunlight were the same while one-tenth sunlight resulted in seedlings that were significantly stunted both in height and top:root weight ratios.

Fertilizer applications did not influence summer foliage color differences or fall initiated and winter semi-stabilized color differences. During the summer of 1953, foliage of seedlings grown in full sunlight was relatively yellow-green, foliage in one-third sunlight was a pure green, while seedlings growing in one-tenth sunlight had blue-green foliage. In the fall, the seedlings in full sunlight developed a strong anthocyanin pigmentation and the seedlings in one-third sunlight developed a pronounced yellow-green cast. Seedlings grown under one-tenth sunlight showed no discernible change from summer color to fall and winter color, remaining blue-green.

By a comparison of fall initiated foliage color changes of pin oak seedlings and redcedar seedlings in full, one-third and one-tenth sunlight, it was found that anthocyanin formation in both pin oak and redcedar foliage was essentially a high sunlight phenomenon, while yellow formation occurred in one-third sunlight. These color changes in pin oak and redcedar occurred almost concurrently, indicating that the fall color changes in cedar are closely allied to the general autumnal coloration processes of the deciduous trees. That the red and yellow color phases of redcedar are not restricted to juvenile foliage was demonstrated by shading large trees prior to the advent of autumnal coloration of hardwood species and observing that these shaded trees remained green through December while exposed trees turned to varying degrees of red and yellow.

The anthocyanin phase in redcedar is a semi-stable, winter dormancy condition. When parts of seedlings were heavily shaded prior to autumnal coloration and then exposed to full sunlight in December, anthocyanin development was very slow on these shaded areas, whereas the continually exposed foliage had previously developed and maintained a strong purple-red cast. An indication of breaking dormancy for anthocyanized seedlings is the replacement of the red color with a strong green color.

It seems evident that the autumnal coloration of redcedar is essentially a light phenomenon that may or may not be influenced by cumulative effects of soil nutrition and microclimatic conditions pertaining to moisture stresses in the foliage and soil. It is suggested further that the degree to which red or yellow color is developed in the fall in eastern redcedar foliage is primarily governed by genetic tendencies.

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