On the Occurrence of Redbud in Indiana[1]

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Distributional records for *Cercis canadensis* L. show that this tree occurs in nearly every county in Indiana. Aerial reconnaissance surveys during the flowering seasons of 1953 and 1954, and more than 5,000 miles of ground travel confirm the state-wide occurrence of the species and its associated form *C. canadensis* L. f. *glabrifolia* Fernald. The latter grows side by side with the typical, pubescent-leaved plant, which suggests that the variation of the leaves is a genetical rather than an ecological difference. A white-flowered form is reported in Henry and Harrison Counties (5) but none was found during our field studies. Redbud is probably as abundant in Indiana now as it ever was.

In Indiana, the abundance of redbud roughly increases from west to east and from north to south. It is most abundant in the southeastern part of the state. Coincident with this distribution is the increase in the abundance of calcareous soil-forming materials from west to east, and the increasing suitability of climate from north to south. Furthermore, the amount of woody vegetation increases southward coinciding with changing land-use patterns from cultivated soils to forested soils and soils being returned to woodland where the successional transgressiveness of redbud is enhanced. Other environmental factors are not necessarily less influential upon the distribution of redbud, but those factors mentioned appear to play the most important parts in governing its abundance.

Light Requirements

Light intensity is very important in determining site suitability, since mature redbud is very intolerant. Its requirement for strong light is not in itself an important factor in governing the general distribution because forested areas usually possess adequate seed sources on sites with suitable light intensities. Elsewhere there is sufficient edge with seed supplies and with adequate light to support vigorous growth, but the lack of redbud seems to be the result of arrested succession.

There is some evidence that the species becomes more shade tolerant in the southern states, but only one place has been found in this state where a large number of trees occupied a prominent position in the understory. This area is found in southeastern Gibson County, on the Bertram Farm, in a cut-over oak-hickory woods which has been a hog lot for many years. Elsewhere redbud grows in the understory more abundantly as saplings than as trees.

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1. This paper is a condensation of the Indiana portion of the section on occurrence in a Purdue University doctorate thesis (7) dealing with the entire range of the ecological life history of *Cercis canadensis*. That work was supported by a fellowship grant by the Purdue Research Foundation to the authors. Advice on soils from Profs. T. M. Bushnell and H. P. Ulrich is gratefully acknowledged.

Its heliophytic nature is vividly exemplified along the precipitous slopes around Leavenworth where it has almost equal chances of growing either in shade or in full sunlight. Another indication of intolerance to shade is the thin crown canopy of leaves resulting from lack of foliation on the inner branches. An extremely lopsided form is characteristic of redbud when growing in woods edges; frequently the exposed side of the crown touches the ground.

Experiments performed with young redbud growing in the Purdue controlled-climate laboratory showed terminal growth generally ceases when the intensity of incident light falls below 100 footcandles. Lesser intensities may or may not support growth depending upon the vigor of the plant, the air temperature, and the available soil water. Illumination higher than 500 f.c. is supraoptimum. More than 13 hours of light is necessary to maintain terminal growth.

Although the species ecises better in shaded areas, the requirement for high light intensity becomes greater with age. Well established root systems produce year-old sprouts 10 feet tall in full sunlight.

Association with Limy Materials

Redbud attains its most important ecological role in southeastern Indiana where calcareous bedrock outcrops are important soil forming materials. The association with limestone has been shown by Braun (3) in the Cincinnati area, by Read (9) in the Ozarks, by Hopkins (6) and by Anderson (1) in the Arbuckle Mountains, and by information received from botanists in the Great Valley of Virginia. Redbud also occurs with limestone in the area south of Bloomington and Paoli, Indiana; the soils there differ markedly from those of southeastern Indiana in the scarcity of calcareous and carbonaceous clays and shales.

Redbud seldom grows on acid shales. However, it is characteristically present on acid sandstone soils. There are three major sandstone soil regions in southern Indiana differing in their geological make-up. Woods states [Belcher, Gregg, and Woods (2)] that shale constitutes about 50 per cent of the exposed bedrock in Indiana. Some of this shale outcrops in the sandstone area on hillsides along with thin laminations of limestone and clay. Wherever limestone or calcareous shale occurs in the sandstone regions, it might be expected, in view of the effect of limy materials in southeastern Indiana, that redbud would be more conspicuous than on adjacent sandstone.

On soils derived from sandstone, stands are fewer and these are generally less dense than the stands on calcareous sites. As might be expected, the sandstone soils adjacent to the limestone areas bear more redbud than those farther removed. This is chiefly the result of the abundant seed source in the high lime areas.

In the recently glaciated portions of Indiana, redbud grows abundantly on river terraces which are predominantly gravelly and usually of calcareous materials. It does not grow on the sand dunes around Lake Michigan. Redbud was not found on acid wind-blown sands along the principal rivers in southern Indiana (Oaktown soil series), but it grows

very well on calcareous wind-blown sands in Knox County (Princeton series). Bushnell's classification (4) is used herein for soil types.

Observations indicate that a certain environmental complex best supports redbud in Indiana. Dark alkaline soils derived from limy parent materials occur on very steep slopes and have adequate moisture for seedling establishment. Sufficient light intensity for mature redbud is provided. However, the plant community as a whole is growing under relatively unfavorable edaphic conditions for the mature trees. One or both of two possible relations might apply between redbud and the edaphic complex on these situations: (1) it is tolerant to soil conditions so that it suffers no appreciable disadvantage, and (2) it is favored by this complex either directly or indirectly by competitive relations with its associates.

The woody vegetation on these alkaline soils is highly diversified. It includes a wide variety of such species as the oaks, hickories, ashes, cedars, walnuts, haws, beech, maple, and tulip-tree. Wilde (10, p. 26) points out that "all trees" on this kind of soil (rendzina) suffer from "malnutrition" because of the high carbonate content of the soil. He indicates that trees there have very low rates of growth, are frequently deformed and are subject to premature death. Furthermore, seedlings seem to be either handicapped by the absence of mycorrhizal organisms or their growth may be inhibited by attacks of damping-off fungi. His observations are probably based upon some well-known effects of soil alkalinity whereby nutrients, especially iron, manganese, boron, phosphate, etc., occur in such insoluble forms that the roots cannot bring enough of them into solution for the requirements of the tree.

Since redbud is most abundant on these highly alkaline soils, and no less vigorous, mineral deficiency does not appear to be a problem there for this tree. It is certainly tolerant to the existing edaphic conditions. In view of Wilde's observations it is suggested that redbud is more tolerant to nutritional shortages than other tree species associated with it, and it

TABLE 1

Chemical analysis of four soil series in Indiana where redbud is exceptionally abundant. These soils represent two extremes in relation to the amount of certain minerals present.

Series, Horizon, and sample number	pH	m.e. per 100 g.				Cation Ex. Cap.
		Mg	K	P (ppm)	Ex. Ca.	
Zanesville 119A	5.6	1.4	.17	5	4.3	12.5
B_1	4.8	3.3	.13	3	2.3	17.3
B_2	5.0	2.4	.11	3.5	6.0	17.0
Zanesville 131A	5.7	1.3	.16	6	5.3	12.5
B_1	4.9	2.5	.09	4	3.0	12.5
B_2	4.7	3.0	.11	5	2.3	14.2
Fairmount 115A	7.7	1.3	.29	76	28.0	28.4
C	7.7	1.1	.18	92	26.2	27.8
Corydon 110A	7.8	1.3	.36	2.5	39.6	36.8

is favored in competition by the high light intensities under their relatively thin canopy. Also, land use patterns involving partial cutting, grazing, and the return of many fields to woodland contribute to the importance of redbud.

Comparison of Some Edaphic Extremes Suitable to Redbud

Nutrient availability on four soil series. In contrast to redbud on the high-lime soils is its occurrence on the very low-lime sandstone sites, namely, the Zanesville soil series, in Martin and Gibson Counties. Most of the roots were found in the A horizon of the soil profile, some in the B_1 horizon, and fewer in the B_2 horizon which extended along with the tap root more than 40 inches into the sub-soil. Table I compares the chemical analyses of these soils with two high lime soil series (Fairmount in southeastern Indiana, Corydon in the area around Leavenworth, Indiana).

The horizons taken from the Fairmount and the Corydon series were only those from which soil was available; beneath these were bedrock. The Corydon series yielded a figure for exchangeable calcium higher than the cation exchange capacity. This is caused by the presence of limestone fragments in the sample used in the analysis. The acid leaching agent reacted with these particles. The analysis reported represents duplicated trials done for us by the Soil Testing Division of the North Carolina Department of Agriculture.

Table I shows that redbud grows in soils where the available calcium is as little as 1,320 pounds per acre of the A horizon (Zanesville from Martin County #119) and as much as 15,800 lbs./A. (Corydon). On the other hand this amounts to 29 per cent of the cation exchange capacity in the Zanesville 119 and should be slightly less than 100 per cent for the Corydon. Judging also from the pH values it is apparent that the Zanesville is very low and the Corydon is very high in calcium content as well as in its availability. There seems little doubt that low quantities of this mineral are not significantly influential in limiting the growth and occurrence of redbud.

The lowest base exchange capacity on which redbud was found was 2.2 milliequivalents per 100 grams of soil in the C horizon of the gravelly Rodman series along Pigeon River in northern Indiana. This is also illustrative of poor site qualities supporting this species. Its tolerance to certain other nutrient factors can be judged from the data presented in Table 1.

Soil water relationships and the occurrence of redbud. The presence of redbud on the gravelly Rodman series as well as in the clayey sub-soils of the Fairmount series sharply illustrates the tolerance to a wide range of textural classes and the water holding capacity of the soil. The tap root descends to indeterminate depths in the gravels and between the layers of bedrock. It probably plays the vital role in survival during the droughty seasons.

Redbud roots will withstand only temporary inundation. These trees have been found on 40 different soil series in Indiana and all the soil profiles showed good internal drainage. Occasionally redbud grows in wayside ditches and in stream embankments, but examination of the root

system usually shows that the roots grow away from the saturated soils. Zanesville soil in Martin County has an expansive clayey B_2 horizon which is nearly impervious in the spring. This creates a perched water table which temporarily saturates the upper levels. Tap roots on young redbud in the spring curve upward until the soil water moves away from this impervious layer. Later the soil aggregates shrink, the soil becomes well areated and the tap root descends. A J-shaped root results at the level of soil saturation.

It is not unusual to find redbud growing on limestone ledges with the tap root extending into a soil-barren crevice. On these exceedingly dry sites late in the growing season, probably some moisture from dew on the rocks becomes available to the root hairs. Probably the presence of thick-walled root hairs confers an advantage in such xeric habitats.

The Topographic Ecology of Redbud

Throughout Indiana the land-use pattern largely restricts redbud to the most rugged terrain in any locality. These areas include hillsides, river terraces and slopes, drainage ways, and highway and railroad embankments. This, in part, accounts for its abundance in the unglaciated portion of south central Indiana. On the other hand, the suitability of the habitats on the till plains, drained swamp land, valley fills, and other flat land is readily seen in fields abandoned for 3 or more years.

In southeastern Indiana, because of the steep gradient of the slopes and the short distance from the upland to the Ohio River, the relation of redbud to its associates, to the soils, and to the topography is fully expressed along most transects perpendicular to the river.

Uplands. Redbud is not found on the upland undrained flats, e.g., on the Blanchester soil series, among the mixed hydrophytic trees. Surrounding this woodland is usually cultivated ground on any or on a combination of Clermont, Avonburg, Rossmoyne, Cincinnati, Wynn, Edenton, and sometimes Hennepin soil series from Illinoian till. As the land becomes rolling, especially along drainage ways, Avonburg, Rossmoyne, and Cincinnati series predominate and redbud may or may not be present depending upon the employment of woody vegetation in conservation practices. As slopes become prominent, Wynn, Edenton, and Hennepin usually support woodlands in which redbud is nearly always a component. Both in the understory and along edges this tree is associated with other xero-mesophytic saplings as sassafras, buckeye, black locust, hackberry, black walnut, several haws and oaks.

High slopes and bluffs. After the till has eroded away, the soils of the dissected upland, e.g., Switzerland, are residual from the limy bedrock materials. With increasing steepness of slope (20-55%) the Fairmount series is found. Both soil series are occasionally cultivated, frequently grazed, and generally wooded. Grazing on these hillsides has long permitted the establishment of *Crataegus mollis*, other haws, and both locust trees. Their thorny branches and their ability to withstand strong sunlight and droughty conditions, coupled with transportation of the seed through animal feces, are chiefly responsible for their establishment and abundance.

The upper slopes expose Silurian limestones and shales (occasionally the Richmond formation of the upper Ordovician), and it is upon these limy materials in open areas that redbud abounds. These rocks also form the bluffs along the Ohio River in the vicinity of Madison. Red cedar and redbud commonly occupy these bluffs, cedar being the most xerophytic and occupying the more open places. These enter into new sites early and together with the xeromesophytes mentioned above compose the major successional transgressives on the high slopes where sites are being returned to woodland.

Lower slopes, deep ravines, and narrow valleys. The argillaceous Eden shales generally form the lower sides of ravines and valleys near the Ohio River. Farther north the upper Ordovician and lower Silurian formations are found. Fairmount soils still prevail on the hillsides. The vegetation going upslope from the most mesic places consists of willows, sycamore, cottonwood, buckeye, pawpaw, redbud, the elms, hackberry, dogwood, tulip-tree, blue ash, *Ostrya*, sugar maple, the locusts, haws, and oaks. Redbud is common generally, but is most abundant where it receives intense light. Since the flood plains and the high river terraces are generally cultivated where possible, redbud is of necessity confined to woods, fence rows, and the edges of roads and streams. Even in lowland habitats, redbud occupies soils with well drained profiles, usually the Huntington series.

Redbud in relation to exposure of slopes. Potzger and Friesner (8) assembled extensive data in their evaluation of the climax species in southern Indiana. They counted 28,842 woody stems of 73 species on 48 slopes, exposures, and ridges in Franklin, Bartholomew, Monroe, Brown, and Morgan counties. Calculations based upon their data show redbud, on the basis of total stems on all exposures, had a relative density of 0.71 per cent when compared with all tree species. If only the situations on north and south slopes are compared redbud is more abundant on southern exposures; the relative density is 1.42 per cent, that on the north slopes is 0.32 per cent.

In order to get the over-all relation between this species and its associates both the relative density and the relative frequency for each of the 73 species were calculated from the data presented by those authors. The sum of these values for each species provides an index (RD-RF index) having a maximum value of 200 per cent. I.e., a pure stand of only one species constituting the entire aggregate sample would have a RD-RF index of 200. The index expresses both number of stems and their uniformity of dispersal. One index was calculated for the occurrence of each species on the north slope and another index for the south slope. The species were listed for each slope-type in the order of decreasing values of the indices.

Redbud on north slopes occupied 32nd position with an index of 0.89, while on south slopes it stood 21st with an index of 2.24. This clearly shows redbud is here a species characteristic of southern exposures, and apparently has fewer serious competitors there. Sugar maple occupied first position on both exposures with 43.70 on the north and 19.99 on the

south. This treatment of Potzger's and Friesner's data also supports their conclusions about the climax species in southern Indiana.

Redbud on the south slopes is, roughly, three times as prominent (in terms of this index) as it is on the north slopes. It was found that redbud on the south slopes (2.24) is almost as prominent as such north slope species as *Benzoin aestivale* (2.28), *Hamamelis virginiana* (2.31), *Quercus velutina* (2.39), and *Liriodendron tulipifera* (2.66). Conversely, redbud on the north slopes (0.89) compares with those species on the south slopes as follows: *Liriodendron* (0.58), *Carpinus* (0.63), *Benzoin* (0.69), *Dirca palustris* (0.92), and *Carya cordiformis* (0.94). An interesting result of this arrangement is that redbud on the south slope has about the same index as tulip-tree has on the north. Since their data incorporated size classes down to 1 meter height, and redbud is most numerous as immature individuals of which few will survive, the importance of mature redbud is not nearly so great.

Flowering

Redbud generally flowers sometime between April 1 and May 15 throughout the state. However, a statistical evaluation of known blooming dates in comparison with actual temperatures suggests flowering is normally expected (with 95 per cent confidence) when the average daily mean temperature reaches 52-58 degrees F. Statistical analysis of 18 years of blooming dates recorded by Dr. C. C. Deam in his arboretum at Bluffton, in comparison with temperature means calculated from meteorological records of the adjacent Bluffton Water Works for the same years, shows that redbud comes into flower following a 30 day period for which the daily mean temperature averages 47-53 degrees (95 per cent confidence). Abnormally high temperatures (i.e. higher than the normal temperatures for the calendar period) usually precede flowering for about two weeks.

Outstanding Individual Specimens

The largest redbud found in Indiana is the Fairfield Redbud, along state road 101 near the Union-Franklin county line. It measured 25.3 inches in diameter at 30 inches from the ground in 1953. In its senescent status it is broken, weather-beaten, and laden with poison ivy, wild grapes, and Virginia creeper. In the spring of 1954 it was nearly dead. One tree with exceptionally well balanced form and vigor occurs at 1505 N. Main Street, Petersburg. The trunk measured 17 inches in diameter below the lowest branch at 28 inches above ground. A large tree in Allen County is shown in Figure 1; this photo was taken in 1937 by Mr. Frank Wallace, and is used here through the courtesy of Prof. Daniel DenUyl. The tree was still alive in 1947. Calculations based on the diameter of the hat crown in the picture show this redbud was approximately 30 in. d.b.h. The largest known redbud occurs near North Kingsfield, Ohio, with a diameter of more than 30 inches and a crown spread of more than 40 feet.

Crown Cover

Redbud when in flower is conspicuous from the air and well suited for determination of its crown cover by vertical 35 mm. kodachrome transparencies taken from airplanes at 1500 ft. above ground by a hand-held

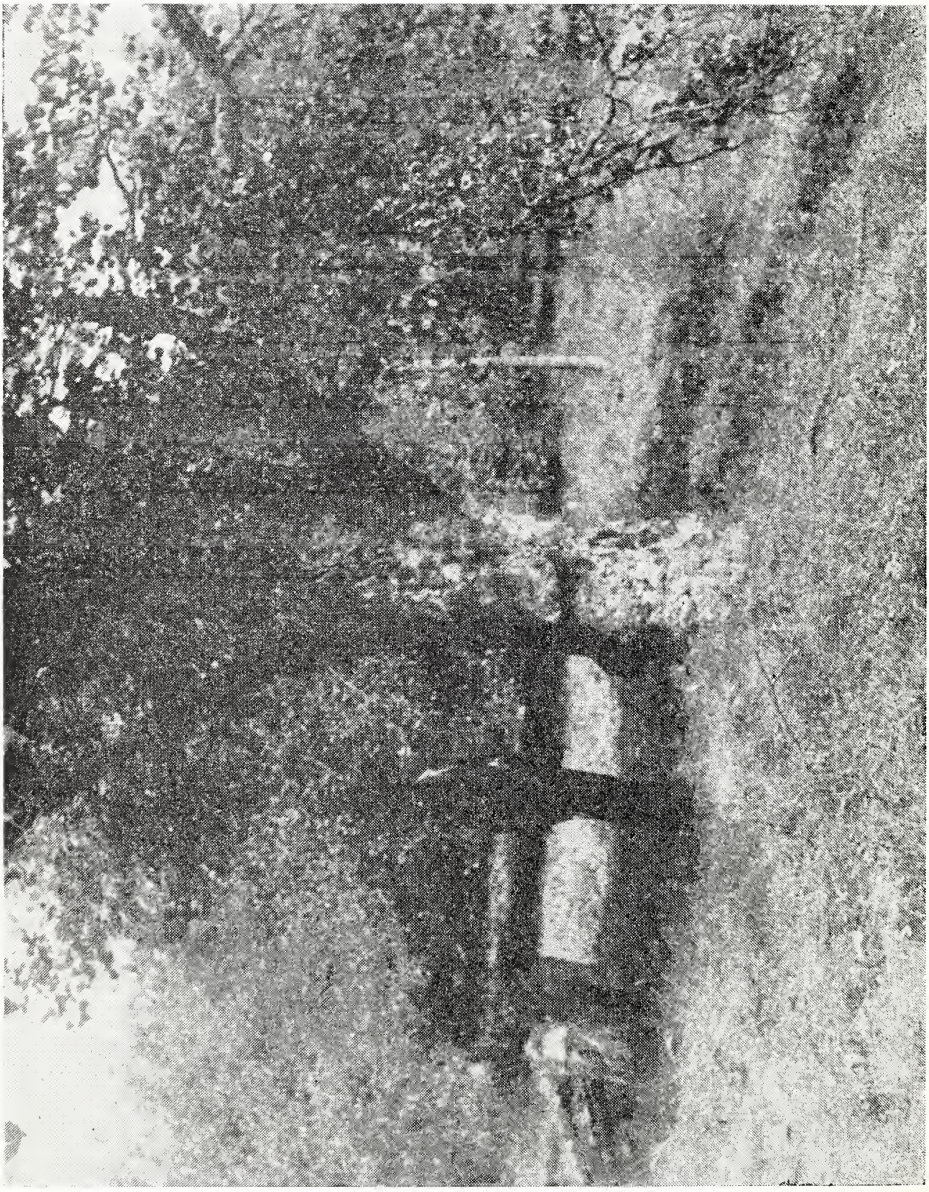

Fig. 1. Large redbud near Huntertown, Allen County, photographed in 1937.

camera. Such photographs were projected in a darkened room upon smooth white tag paper previously ruled into one-inch squares. The image was about 48 x 36 inches. The pink redbud crowns were measured where they intercepted the vertical and horizontal lines; the total line cover for redbud divided by the total length of the lines yields the proportion of coverage. Expressed as per cent, this represents ground coverage. Seven representative sites where redbud is prominent in southeastern Indiana were thus studied. The maximum redbud coverage found for tracts as large as 10 acres was 22 ± 1 per cent of the area. In areas of 1 acre, selected for maximum coverage, the redbud crowns occupy as much as 90 per cent of the ground.

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