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CONTENTS

CROWN RELEASE ACCELERATES DIAMETER GROWTH AND CROWN DEVELOPMENT OF YELLOW BIRCH SAPLINGS

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Yellow birch (*Betula alleghaniensis* Britton) is one of the most valuable northern hardwood species but is decreasing in both growing-stock volume and quality of trees. Recent surveys show the volume in sawtimber-size trees has declined by about one-third in the last 10 years and the proportion of trees 18 inches and larger is limited (Sternitzke 1974). Most Lake States stands are second-growth stands that are still too young to produce the saw log sizes now required by industry.

In 1968 we began a series of yellow birch crown release studies in seedling- to small sawtimber-sized stands in Upper Michigan and northeastern Wisconsin. Specific objectives of these studies are to improve bole quality and increase survival as well as growth rates in existing stands so that saw log rotations can be shortened. Results from the sapling-size phase of this study are reported here. Crown development data in this study were supplemented with branch elongation measurements covering 1 year before release and 4 years after release. All results presented, except for branch elongation, are for 3 years after release.

Study trees were selected from a 16-year-old even-aged stand that became established following salvage operations after a tornado in 1953 (fig. 1). The area is located about 11 miles south of Lake Superior on the Bergland District of the Ottawa National Forest in the western Upper Peninsula.

Judging by the number of dead understory birch stems present, competition had been severe. Undoubtedly more birch had seeded-in after salvage operations but their numbers had already been reduced by competing species and other causes. Stoeckeler and Arbogast (1948) reported a 21 percent reduction in the number of stems per acre (2,951 to 2,321) in an unmanaged 11-year-old northern hardwood stand after 8 years.

Although sugar maple was the most abundant species on the study area, it only accounted for 20 percent of the dominant stems. Most sugar maple stems were in codominant or lower

Figure 1.--*The 16-year-old stand before release.*

crown classes. The dominant saplings were primarily fast-growing-intolerant or moderately-tolerant species such as cherry, aspen, yellow birch, basswood, white ash, American elm, and paper birch. Scientific names and more details of original stand and soil conditions are included in Appendix I.

Five degrees of crown release were applied to 6 groups of both dominant and codominant 16-year-old yellow birch saplings, making a total of 60 study trees. Each group consisted of five saplings similar in stem and crown characteristics, diameters, and total heights. Initial diameters at breast height (d.b.h.) ranged from 3.04 to 3.99 inches for dominant groups and from 2.17 to 2.91 inches for codominant groups. Heavy, moderate, light, very light, or no crown release treatments were randomly assigned to individual trees within each group. All trees whose crown edges were within the following distances of the released tree's crown were cut as follows: (1) very light release, 2.5 feet; (2) light release, 5 feet; (3) moderate release, 10 feet; and (4) heavy release, 15 feet (fig. 2). Cuttings were applied before leaves appeared in the spring of 1970.

Figure 2.--*A moderately crown released 16- year-old sapling.*

Diameters at breast height were measured annually to the nearest hundredth of an inch. Tree height, height to live crown, clear bole length, and the number and length of epicormic branches were measured before release and again at the end of the third growing season. Average crown diameters were initially obtained from eight crown radii measurements made around each study tree and from branch growth measurements made later. Foliage density was rated in 1969, 1970, and 1972 after birches were in full leaf.

Lateral branch elongation was measured on each tree for crown width change 1 year before release and 4 years after release. Four branches per tree were used with one branch being measured in each cardinal direction at the widest portion of the crown. Annual increments were measured to the nearest ½ inch beginning from the branch tips toward the bole between terminal bud scars.

GROWTH RESPONSES

Diameter Growth

Crown release significantly (0.01 level) increased growth within each crown class (fig. 3, table 1); increases averaged about 36 percent the first year, 64 percent the second year, and 56 percent the third year for released over unreleased trees. Although actual diameter growth was greater for dominants, the percentage rate was higher for codominants. For the moderately and heavily released saplings, diameter growth averaged about 1.7 times more than the unreleased saplings during the 3-year period.

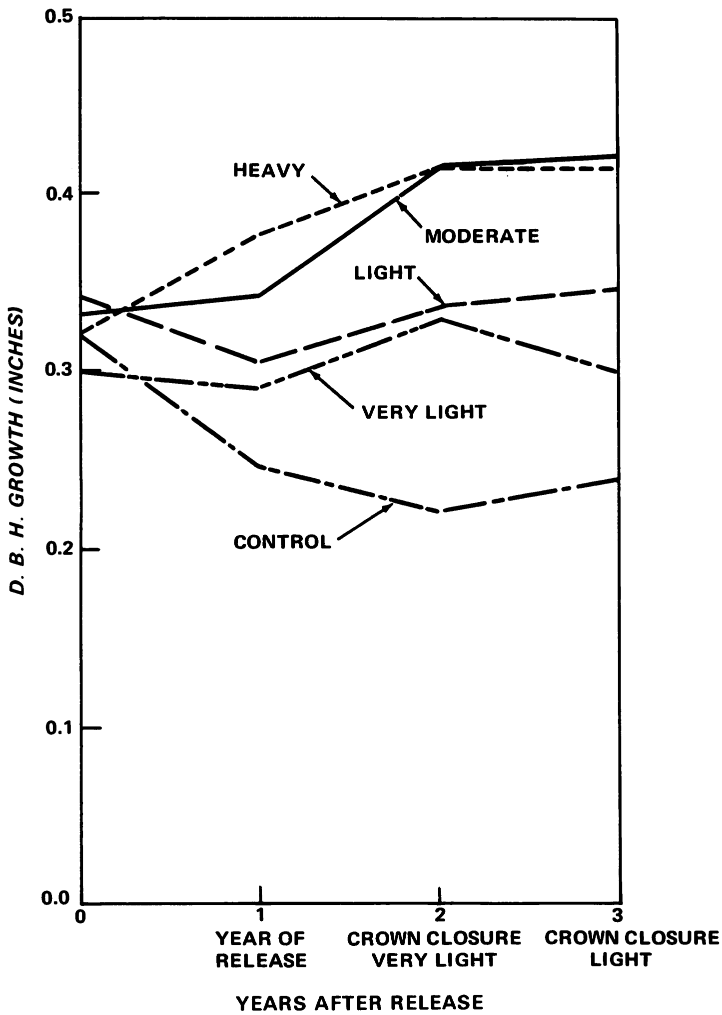

Figure 3.--*Effect of crown release on mean annual diameter growth of sapling-size trees.*

Diameter growth of dominants increased significantly with each successive degree of release through the moderate release treatment. The moderate and heavy treatments were equally effective in stimulating growth. In codominants, released trees responded better than unreleased trees, but differences in growth rates between various degrees of release were still not significant.

Height Response

Before release, dominant saplings averaged 28.4 feet tall; codominant saplings averaged 24.8 feet tall. During the 3-year period after release, height growth averaged 4.5 feet for both dominant and codominant saplings. Analyses of unadjusted 3-year height growth data indicated that there were no significant differences in growth among the release treatments. When the height growth data for dominants were either adjusted for total sapling height before release or height growth the season before release, however, there was a significant difference favoring the unreleased dominants.

CROWN DEVELOPMENT

Crown Class

All dominant stems, except one unreleased tree, were still dominant after 3 years regardless of whether they were released or not.

Table 1.--*Changes 3 years after crown release treatment in stem and crown characteristics of dominant and codominant yellow birch saplings*

Characteristic	None (control)	Very light	Light	Moderate	Heavy
	Crown release treatment				
DOMINANT					
Diameter (d.b.h.) (in.)	[1]0.78d	0.90c	1.04b	1.26a	1.28a
Total height (ft)	5.1	4.2	3.3	4.4	4.0
Limb-free length[2] (ft)	2.6a	0.5b	-0.4b	-1.1b	-0.9b
Live epicormic sprouts on butt log (No.)	1.0	2.8	1.5	3.7	2.0
Trees in dominant crown class (percent)	100	100	100	83	100
Trees in codominant crown class (percent)	0	0	0	17	0
Live crown length (ft)	2.4	3.7	3.4	5.4	4.9
Crown ratio (crown length/total height)(ratio)	.04b	.02b	.03b	.08a	.07a
Crown diameter (ft)	4.4b	4.1b	4.0b	5.5a	5.1a
Crown area (ft^2)	79b	70b	64b	96a	97a
Crown volume (length X area) (ft^3)	1,923	1,941	1,790	2,723a	2,834a
Foliage density[3] (percent)	-2.1	4.2	10.4	16.7	14.6
CODOMINANT					
Diameter (d.b.h.) (in.)	0.62	0.90a	0.95a	1.08a	1.11a
Total height (ft)	4.6	5.4	4.3	5.6	3.9
Limb-free length[2] (ft)	2.2a	0.2b	0.1b	-2.0b	-0.8b
Live epicormic sprouts on butt log (No.)	4.0	2.5	2.3	5.3	4.8
Trees in dominant crown class (percent)	0	0	17	50	33
Trees in codominant crown class (percent)	83	100	83	50	67
Trees in suppressed crown class (percent)	17	0	0	0	0
Live crown length (ft)	1.6b	4.2a	4.3a	7.0a	4.7a
Crown ratio (crown length/total height) (ratio)	0.04b	0.06a	0.06a	0.11a	0.07a
Crown diameter (ft)	4.4	4.0	4.8	5.0	5.0
Crown area (ft^2)	67	63	67	75a	89a
Crown volume (length X area) (ft^3)	1,323	1,499	1,524	1,944a	2,214a
Foliage density[3] (percent)	-10.4	-4.2	2.1	10.4	-2.1

[1]Values followed by the same letter or without a letter in a row are not significantly different at least at the 0.05 level.

[2]Height from groundline to the first live limb on epicormic branch more than 24 inches long.

[3]Based on the percent of the main stem within the live crown obscured by foliage when viewed from two sides at one tree-length distance.

Release often improved the crown position of codominant saplings. After 3 years, 42 percent of those moderately or heavily released moved up to dominant positions. Half of this improvement was attributed to the elimination of competition from tall saplings; the remaining half to increased height growth after release. Crown positions of very lightly and lightly released codominants were not improved by release. One of the six unreleased codominants dropped to an intermediate crown position because it had been outgrown by a neighbor.

Crown Length

Initially, codominants had about 65 percent of their total heights in live crown; dominants had about 70 percent. Over the 3-year period, the proportion in live crown increased for released dominants and codominants but decreased for the unreleased trees. Crowded crowns of unreleased, very lightly released, and lightly released trees generally had less live crown length for their heights than moderately and heavily released trees.[1]

Changes in crown length for codominants tended to increase with degree of release through the moderate release treatment, where crown length increases averaged 7 feet in the 3 years. For codominants, the differences in early changes in crown length were significantly better in released than unreleased trees (table 1). For dominants, trends in these changes appeared to be similar, but the differences between released and unreleased trees were not significant. These changes in live crown length were primarily caused by three factors: (1) higher natural branch mortality on unreleased trees, (2) longer retention of branches, and (3) development of some epicormic sprouts into branches on the more open-grown moderately and heavily released trees.

Changes in height[2] to the live crown for both dominants and codominants were significantly greater for unreleased than for released saplings (table 1). Live crowns of very lightly released codominants also receded more than other released codominants; other very lightly released dominants as well as lightly released dominants and codominants were just beginning to recede after 3 years.

[1]*Crown length is the length in feet from the tree's tip to the lowest live leaf on a branch that is part of the functioning crown.*

[2]*Height from groundline to the first live limb or epicormic branch more than 24 inches long.*

Crown Diameter

Before release, crown diameters of dominant and codominant saplings averaged 8.8 feet and 7.2 feet, respectively. In just 3 years diameters on both increased between 4 to 5 feet (table 1). Crown expansion was significantly more rapid on moderately and heavily released dominants than on less intensively released dominants. Similar trends were also apparent in the codominant saplings.

During the four growing seasons after release, branch elongation at the widest part of the crown was stimulated most by the moderate and heavy crown release treatments (table 2). Average lateral branch elongation in these two treatments was significantly greater than in the other treatments (fig. 4). Major differences in annual branch elongation between release treatments first occurred in the second season and again in the fourth growing season after release. Lateral branch growth was poor during the third season. The differences in the fourth growing season were related to poor growth following crown closure in the very lightly and lightly released treatments.

Branch elongation was similar on all sides (N, S, E, W) of both released and unreleased trees. Branches growing in openings elongated more rapidly than those closed with adjacent crowns. Annual branch elongation usually declined drastically

Table 2.--*Mean lateral branch elongation of yellow birch saplings in relation to crown release treatment and growing positions in 1972 and 1973*[1]

(In inches/branch)

Crown release treatment	1972		1973	
	In openings	After crown closure	In openings	After crown closure
None (control)	7.38(4)[2]	5.81(36)	2.50(4)	2.06(36)
Very light	7.00(2)	6.11(46)	10.00(2)	1.31(45)
Light	8.40(5)	5.70(43)	5.70(5)	2.70(43)
Moderate	6.75(45)	None	7.85(31)	7.80(15)[3]
Heavy	6.67(48)	None	8.27(46)	6.75(2)[3]

[1]Annual lateral branch elongation at the widest part of the crown at lower canopy level.

[2]Figures in parentheses show number of branches on which average is based.

[3]Crowns just closing.

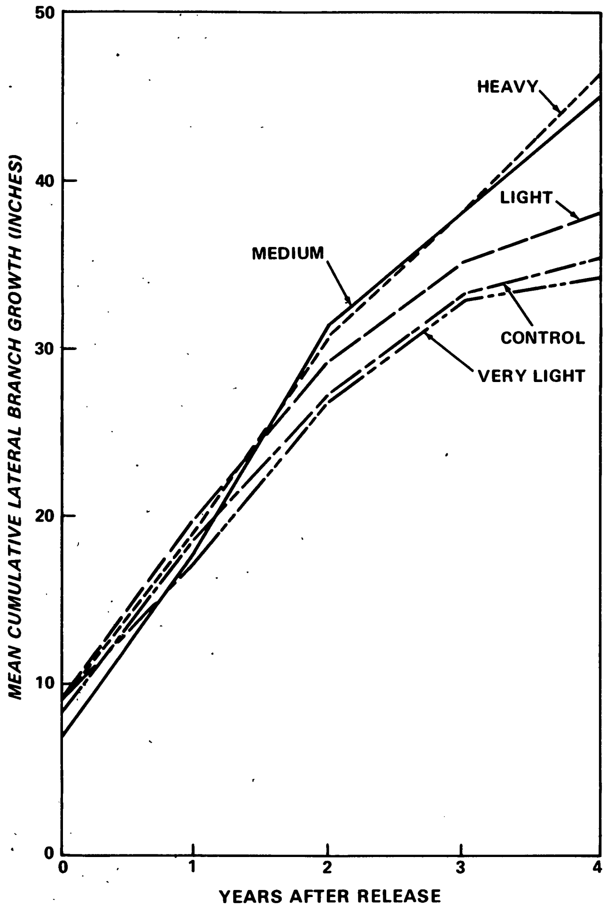

Figure 4.--*Mean cumulative lateral branch elongation by years and crown release treatments for dominant and codominant birch saplings.*

after crown closure. Lateral branch tips elongated less each season in unreleased and lightly released crowns and after the second season in the very lightly, moderately, and heavily released crowns. The very lightly released crowns closed almost immediately; most lightly released crowns closed within 3 years.

After 3 years, 33 percent of all moderately released saplings and 92 percent of all heavily released saplings were still completely free of crowding at the sides. Fifty-eight percent of the moderately released saplings still had at least two sides free of competition. At the present rate of growth six growing seasons would be required for all the crowns of moderately released saplings to close.

Crown Areas and Volumes

Crown areas (πr^2) and crown volumes (crown area x length) increased during the 3-year period. Changes in crown area were significantly (0.05 level) better for only moderately and heavily released dominants, but changes in crown volume were significantly better for both moderately and heavily released dominants and codominants (table 1). Buildups in crown volume were associated with the amount of additional growing space provided by the treatments. The greatest improvement in crown development occurred among moderately and heavily released trees.

Foliage Density

Almost every study tree had a crown with medium foliage density before release.[3] After 3 years, crown foliage density ratings had improved on 46 percent of the released trees but no improvement was observed in crowns of unreleased trees. The ratings improved most among moderately released crowns; 75 percent of them increased in density, only 8 percent regressed (table 3). Most of the increases were attributed to the formation of new leaves on the newly elongating tips of existing branches and vigorous new terminal growth.

Table 3.--*Change in foliage density by crown release treatment*

(In percent of trees)

Foliage Density	Crown release				
	None (control)	Very light	Light	Moderate	Heavy
Remained the same	75	58	25	17	25
Improved[1]	0	17	50	75	42
Regressed[1]	25	25	25	8	33

[1]Improved or regressed at least one-half foliage density class (12.5 percent).

BOLE QUALITY

Before release, study saplings averaged 16.7 live branches, 0.3 epicormic branches, and 21.9 dormant buds per lower 17-foot bole section. Heights to their first live branch averaged 8.8 feet above groundline.

Crown release delayed natural branch mortality and the normal progression of the

[3]*See Appendix II for explanation of foliage density ratings.*

base of the live crown up the tree. During the 3 years, significantly (0.01 level) more live limb-free length[2] was added to the boles of unreleased saplings than to released sapling boles. On unreleased saplings, branch mortality increased live limb-free bole lengths an average of 2.4 feet (to 11.0 feet); on released saplings, the development of epicormic branches decreased these lengths about 0.6 feet.

Bole sprouting was highly variable among individual trees; it ranged from 0 up to 24 new sprouts on 1 unreleased sapling during the 3-year period. Sprout numbers on the lower 17-foot bole sections of saplings increased from 0.3 to 3.2, but these increases did not differ by release treatment, crown class, or number of visible dormant buds present before release. Unreleased saplings had equally as many new sprouts as released saplings; codominants averaged one more new sprout per bole (four) than dominants. Bole face also had little effect on the numbers of new sprouts produced. Saplings averaged about 0.8 sprout per north, south, east, and west face.

Of the 194 new epicormic sprouts formed, 72 percent were short shoots (about 1 inch) with 1 or 2 leaves, 12 percent ranged between 3 and 21 inches long, and 12 percent were at least 24 inches long.

During the 3 years, 4 percent of the new and 74 percent of the old sprouts died. Nearly twice as many sprouts died on the north side (E-NE-N-NW) as on the south side (SE-S-SW-W) of the stems.

During the 3 years, sprout growth was affected by bole aspect. Sprouts on the south face of both released and unreleased saplings grew more than those on the more shaded north faces of sapling boles. Three-year sprout growth also increased significantly with each successive degree of release; the maximum was 7.45 inches for the heavily released saplings.

DISCUSSION AND CONCLUSION

Where the objective of management is to increase the number, size, and grade of yellow birch in developing second-growth hardwood stands, it will be necessary to release birches at an early age. Yellow birch is a moderately tolerant species that can survive for long periods under high overhead cover but at greatly reduced growth rates and at considerable risk to mortality due to loss of vigor and increased susceptibility to infection from decay fungi. Previous experience in large openings on the Upper Peninsula Experimental Forest has shown that yellow birch can maintain an advantage in height over other species of the same age, but will fall behind sugar maple in height after 23 years (Eyre and Zillgitt 1953). This suggests that yellow birch should be released earlier for best responses.

Three-year results in our sapling stand suggest that birch trees will respond and benefit from release before 16 years of age. Better diameter growth responses would probably occur even earlier and should increase the number in the stand, particularly because dominant as well as codominant saplings have more ability to rapidly respond to increased growing space at these younger ages.

Growth responses in our sapling- , pole- , and small-saw log-sized crown release studies show that birches from 16 to 60 years old all respond to release. However, the best response is in the sapling stage. Sapling growth rates can be increased up to 4 inches per decade by cutting all stems whose crowns were within 10 to 15 feet of the released tree's crown. Growth rate on pole size trees can be doubled to a rate of over 2.5 inches in 10 years by release (Erdmann and Peterson 1972). Results in the pole and saw log studies also indicate that the present growth rates of 4 inches in 10 years in released saplings and over 2.5 inches in 10 years in poles will gradually fall off as tree diameter increases.

The question as to whether height growth of dominant saplings has been permanently or temporarily depressed by release remains to be answered. We believe that it will not be depressed at least up through the moderate release intensity.

Straight-stemmed trees with the fewest defects in their butt logs generally yield the largest volume of high grade material. The future quality of young trees can be improved most by reducing the number of surface defects caused by branches in the butt log section (Boyce and Schroeder 1963), because it usually contains the highest grade log in a tree and represents about 45 percent of the whole tree volume in northern hardwoods (Chase *et al.* 1970).

Counts of the total number of surface defects in the butt log section of 9 unreleased 65-year-old small saw log-sized yellow birches, showed that over 86 percent of the 4.2 surface defects found were branch related overgrown knots.[4] Marquis (1967) reported that 25-year-old yellow birch, having potential crop tree quality, in New Hampshire already had an average live, limb-free bole length of 15 feet with only 2.0 live branches and 2.5 epicormic branches in their lower section.

Younger sapling-size trees with their lower crowns obviously have more branch-caused defects in their lower bole sections than older and larger sawtimber- and pole-size trees. Crown release in sapling-size trees delayed natural branch mortality but did not significantly increase bole sprouting, a potentially important cause of new defects in hardwood trees. Whether any of the 23 new or 2 old epicormic branches will persist and cause any reduction in final tree grades or lumber grades remains to be proven. Marquis (1969) does not consider short epicormic shoots with one or two leaves as important defects and most epicormic sprouts probably will disappear within 8 years as Stoeckeler and Arbogast (1948) found after thinning to a 5-foot radius in an 11-year-old northern hardwood stand.

In the sapling stage of stand development, characteristics such as diameter growth rate, length of clear bole, number and size of branches, and crown width, length, and density are also important and related to a tree's future bole quality potential. The main idea at this stage is to increase or at least maintain the number of better quality birch stems in the upper canopy. Although the greatest improvement in final hardwood log quality can be made by reducing the number of branch-caused defects outside the heart center of the butt log (Boyce and Schroeder 1963), some additional increase in future valuable birch volumes should be possible by eliminating low forks at the time of release in saplings. This is especially true on the more widely released trees because forks tend to persist on more open-grown trees and merchantable heights in saw log-sized birches are often terminated by forks. By removing forks early, more merchantable length and resulting volume can be obtained without any reduction in upper log diameters.

It is still too early to determine whether a single release treatment will increase the numbers of birch or affect the quality of the final stand. However, results are promising. The 10-foot crown release treatment increased the stem and crown vigor of birch saplings and improved the crown positions of half of the codominant saplings in less than 3 years. Now these released saplings have a much better chance of surviving sugar maple competition than the unreleased saplings. Their crown edges still were free to grow at the end of 3 years and should be free of side competition for at least 2 years longer. The narrower crown release treatments were too short-lived, and growth rate in the 2.5 foot crown-released saplings dropped off the year after crown closure. Expected differences in diameter growth rate between 5-foot, 10-foot, and 15-foot release treatments should favor the wider release treatments following earlier crown closure on the 5-foot treatment. Growth responses are expected to last at least 10 years in the wider 10- and 15-foot crown release treatments.

If these trends continue, birch saw- and veneer-log rotations in the Lake States can be cut in half by doubling diameter growth rates of saplings and poles in existing stands through crown release.

[4]*Unpublished small saw log crown release data on file at the Northern Hardwoods Laboratory, Marquette, Michigan.*

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APPENDIX I

Before release the densely stocked uniform-sized stand contained 3,480 trees (0.6 inches d.b.h. and larger) with 49 square feet of basal area per acre. Species composition averaged 81 percent sugar maple (*Acer saccharum* Marsh.), 10 percent yellow birch, 6 percent ironwood (*Ostrya virginiana*) and 3 percent other northern hardwood species consisting primarily of white ash (*Fraxinus americana* L.), basswood (*Tilia americana* L.), and aspen (*Populus* spp.), with an occasional cherry (*Prunus serotina* Ehrh. and *Prunus pensylvanica* L. f.), American elm (*Ulmus americana* L.) and paper birch (*Betula papyrifera* Marsh.).

The stand occupies a broad ridgetop, elevation 1,580 feet, that slopes gently (0 to 6 percent) to the northeast. The soil is well-drained Iron River silt loam, which is acid in reaction to a depth of several feet and underlain by a weak fragipan. Site index for yellow birch was estimated to be about 60 feet at age 50.

APPENDIX II

Foliage density ratings were based on the average percent of the main stem within the tree's live crown that was obscured by foliage when viewed from two sides at one tree-length distance as follows: dense (87.5 or more), medium-dense (75 to 87.5), medium (62.5 to 75), fair-medium (50 to 62.5), fair (37.5 to 50), and poor (37.5 or less).

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