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ANNUAL REPORT

of the

RESEARCH PROJECT

THE ECOLOGY OF THE BOREAL FOREST-TYPE

of

ISLE ROYALE NATIONAL PARK

Submitted by

Robert A. Janke

to the

United States National Park Service

June 1978

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This report will describe our research efforts of the past year (June 1977-June 1978) on the study of the ecology of ground cover species of the boreal forest type of Isle Royale National Park and a study of two recent burns. Emphasis of the ground cover study was on relating vascular ground cover species to successional stages of the forest. Use was made of approximately 250 plots which had been previously set up for our study of succession and tree seedling establishment. This report will also summarize the results, to date, of these studies.

METHODS

Methods for the seedling and succession study are detailed in our annual report to the National Park Service of May 1976. We shall here describe the methods used for the ground cover study and the recent burns study of the past year.

Field work for the summer of 1977 was done on Isle Royale between June 7 and September 1. It was carried out by myself, a graduate student, William Gibson, and a field assistant. The 250 plots used on our previous study were easily relocated since they were permanently marked with stakes.

Percent cover of vascular ground cover plants was estimated in 20 quadrats each 20 x 50 cm placed within each of 250 plots. A metal quadrat frame was used for this purpose.

The recent burns that were studied were on card point and near McGinty's Cove. The card point fire occurred in the summer of 1976; the McGinty's Cove fire, in the summer of 1975. Both were natural fires which were permitted to burn under the new "let-burn" policy. Parallel sampling lines were laid out in these burns perpendicular to the parallel system of ridges and valleys within the park. Using the line-intercept method along the sampling lines, the percentage of the area having burned soil within the burn periphery was determined. Post-fire tree seedlings were sampled in a one meter wide strip

along one side of each sampling line on burned soil. Ground cover vegetation was sampled in permanent plots randomly located along the sampling lines. These were 2 x 2 meters on burned soil and 1 x 1 meter on unburned soil plots. At each of these sampling locations trees were sampled in a circular plot of 6 meter radius. All trees, whether living, standing and dead, or fallen, having their base within the plot, were tallied and their condition noted. Average litter and ash depths were also measured at each sampling location. In each of the two burn areas a few of the largest pioneer-type trees (mostly white birch) were aged with increment borers.

RESULTS AND CONCLUSIONS

Succession Studies

The stands represented by the 250 plots ranged in age from 40 years (corresponding to a catastrophic fire in 1936) to about 225 years. They were divided into five age groups each representing a cluster of more or less similar ages. Several parameters were then averaged for each age group and plotted against the average age of the group in order to detect successional trends.

Relative densities of balsam fir (Abies balsamea) and white spruce (Picea glauca) both tend to increase with increasing stand age (Figure 1 and 2). These tendencies reflect the shade-tolerant nature of these two species. The shade-intolerant white birch (Betula papyrifera), on the other hand, tends to decrease in relative density as stand age increases (Figure 3). The decreasing trend for the shade-intolerant quaking aspen (Populus tremuloides) is not as clear-cut (Figure 4). Since this species is less ubiquitous than the other three major species, it is possible that factors other than stand age may be important in explaining the relative density of this species.

A plot of the relative density of all shade-tolerant species is shown in Figure 5. In addition to balsam fir and white spruce, this includes black spruce

(Picea mariana) and northern white cedar (Thuja occidentalis). This quantity increases with stand age but the rate of increase tends to decrease with time. A similar graph for shade-intolerant species is shown in Figure 6. In addition to white birch and quaking aspen this includes jack pine (Pinus banksiana). These tend to decrease with age, but the rate of decrease becomes increasingly less with time. It appears that the older stands sampled in this study (200 - 225 years old) may be approaching a steady state.

One of the major factors in determining the inflammability of a forest is the basal area of coniferous tree species. Our data indicate that this quantity increases as the forest increases in maturity (Figure 7). Two quantities sampled in this study are measures of the amount of fuel on the forest floor. These are (1) the percentage of the ground covered by wood and (2) the depth of the A_0 soil litter layer. The total amount of wood cover is made up of decayed wood (D), moss on decayed wood (MD) and undecayed wood (W). The plots of $D + MD + W$ and A_0 versus stand age (Figure 8 and Figure 9) show that both of these quantities increase with time.

Another method of detecting successional trends in the abundance of various tree species is by examining the size structure of each species in stands of similar age. This was done for stands in the age group 85 - 112 years. This age group was chosen because it represents stands of intermediate maturity and because the number of plots in it are relatively large. For each species, each tree was placed in a 5 cm. diameter class. The logarithm of the density of trees in each age class was then plotted against the average diameter of that class (Figure 10). For white spruce the resulting curve was close to a straight line indicating a logarithmic relationship of density versus diameter. For balsam fir, densities also increase toward smaller diameter classes but in the smaller size classes there is a slight departure from the straight line type relationship found in white spruce.

This is probably the result of moose browsing on fir over the past 70 years. For comparison, a similar diagram is shown in Figure 11 for balsam fir on small offshore islands on which moose browsing has not occurred. Here, as in the case of white spruce, a straight-line relationship exists. For both the birch and aspen, densities fall off markedly in the lower age classes (Figure 10). These four diagrams suggest that birch and aspen will decline in importance in the future, while spruce and fir will increase. They also suggest that for unbrowsed shade-tolerant species, diameter-class densities increase logarithmically as diameters become smaller. Finally, they show that moose have noticeably decreased the density of fir trees in the smaller size classes.

Tree Reproduction Studies

In sampling tree reproduction, the microhabitat (leaf litter, decayed wood, moss, or moss on decayed wood) on which each specimen had been established was recorded. For each species the percentage of seedlings sampled, that were established on each soil microhabitat type, was calculated. This was then divided by the percentage availability of that microhabitat on the forest floor to give what we will call the preference ratio for that microhabitat. A preference ratio greater than one would indicate a preference of that site over others; less than one, less than average preference; and equal to 1, average preference. For both white birch and white spruce (Table 1), the low preference ratios for leaf litter indicates that this generally is a very unsuitable site for seedling establishment but that decayed wood and moss on decayed wood are highly suitable. In addition, moss is a highly suitable site for white spruce germination. Balsam fir fares much better on leaf litter, shows no preference for decayed wood and a high preference for moss.

Most of the quaking aspen reproduction observed was on leaf litter. Unlike other species, practically none was found on decayed wood - with or without moss. The preference ratio of one for leaf litter indicates that the presence of leaf litter neither inhibits nor promotes aspen reproduction.

One might expect that preference ratios for leaf litter would depend upon the thickness of the litter layer. Values given in Table 1 are averages for groups of plots having similar litter depths. Figure 12 shows how preference ratios for leaf litter vary with litter depth. For spruce and birch the ratios are close to one for zero litter depth (exposed mineral soil). As litter depth increases, the ratios decline, but beyond about 4 cm. further increases in litter depth have little effect. The decline in preference ratios with increased litter thickness is undoubtedly due to the tendency of litter to dry out rapidly since, compared to mineral soil, it is relatively unconsolidated and hence well-ventilated. Therefore, the thicker the litter layer the deeper seedling roots must penetrate to reach mineral soil where the moisture supply is more stable.

For balsam fir and quaking aspen, litter depth seems to have little effect on reproduction. For fir, this may relate to its larger seed size as compared to spruce or birch. It thus has more stored food and hence can more quickly send roots down to mineral soil to establish the steady supply of moisture which is so critical in the seedling stage. This may also account for its relatively low preference for decayed wood as compared with spruce or birch.

The preference ratio for aspen remains steady at about one for the entire range of litter depths. Our past studies based on excavations of aspen reproduction indicate that this species reproduces largely by succor shoots. The lack of response to change in litter depth would tend to support this contention since succor shoots originate from a well-established

root system and hence would not be affected by drying out of the surface litter layer. This may also explain the lack of aspen reproduction on decayed wood.

The effect of the abundance of nearly mature trees acting as seed or sprout source on the density of tree reproduction is summarized in Table 2. The abundance of seed or sprout source within 60 meters was estimated using a five-point index system as explained above the table. The number of plots having a given index is also given in the table. According to our results, aspen is the most dependent upon the abundance of nearly mature trees. This would be expected of a species which reproduces primarily by sucker shoots. Next in order is balsam fir followed by white spruce and paper birch. The latter species seems to be reproducing quite well without the presence of any nearby seed source. The relative behavior of these three species is probably due to the size of their seeds which in turn affects the distance that they will travel in the wind. The order of decreasing seed size is fir, spruce, and birch.

In order to determine the effect of stand age (time since last fire) on tree reproduction, average values of seedling density were computed for the same stand age groups as were used in the succession study. Except for the 1936 burn, balsam fir reproduction (Table 3) is considerably greater than that of all other species. Reproduction of this species shows a definite increasing trend with increasing stand age. Fir reproduction is exceptionally low in the 1936 burn area. This is undoubtedly due to the lack of nearby seed source. This burn was very large and very intense. Very few trees within the burn boundaries survived to act as a seed source. Since fir seeds do not travel far, an adequate seed source is to be found only near the burn periphery. When fir eventually does invade an area after a burn and these trees mature the seed source would increase and become more diffuse. This may account for the dramatic increase in fir reproduction as stands mature.

White birch seedling density also increases with forest maturity (Table 3). This may seem surprising since this species has already been shown to be primarily a post-fire invader whose abundance decreases with stand maturity. The low seedling density in the 1936 burn may be due to the low amount of decayed wood (Figure 8) for which this species has a high preference ratio (Table 1). Also, leaf litter for the burn averages 1.3 cm. (Figure 9) at which depth the preference ratio for birch is only about 0.5 (Figure 12). As stands mature the availability of rotted wood on the forest floor increases (Figure 8) and thus provides more preferred germination sites for white birch.

Areas burned recently enough to still have mineral soil exposed (zero litter layer) were insufficient in extent to have been included in this study. Such areas very possibly would contain abundant birch reproduction. This must have been true just after the 1936 burn, for example, since the area burned at that time is now dominated by birch trees which date back to about 1936. Since the preference ratio for leaf litter rises abruptly (Figure 12) as the litter depth approaches zero it is quite plausible to expect high birch reproduction on exposed mineral soil. The results of the recent Card Point burn study will shed further light on this matter.

White spruce seedling densities (Table 3) do not show any significant trend as stand age increases. The relatively high reproduction in the 1936 burn is probably related to the relatively high preference ratio for leaf litter corresponding to the average litter depth of 1.3 cm for that area. As litter depth increases with increased stand age reproduction in leaf litter undoubtedly declines but total reproduction is sustained at a relatively steady level because of the increase in quantity of decayed wood for which white spruce has a very high preference ratio.

Quaking aspen reproduction also shows no distinct trend with increasing stand age. Since reproduction, in this case, is mostly by sucker shoots,

it would not be expected to respond to changes in litter depth and amount of decayed wood as do the other three major species whose reproduction is mostly by seed germination.

The high seedling density of white birch, normally considered a pioneer species following disturbance, made us curious about the survival of these seedlings. Since we had measured the height of all seedlings it was possible to construct a table showing the distribution of seedlings in various sized classes. Table 4 shows such a distribution using 10 cm height classes up to one meter (the maximum size that we considered a seedling). White birch is compared to white spruce which also reproduces abundantly on decayed wood in old stands but, unlike birch, increases in importance as the forest matures. In each species a comparison is made between the height distribution in old stands, where germination is mostly on decayed wood, and that of the 1936 burn stands where germination is mostly on a shallow leaf litter layer. The preponderance of white birch seedlings in old stands is in the 0 - 10 cm. class. Relatively few of these reach the 90 - 100 cm. class. For the 1936 burn stands the survival rate is remarkably greater. For spruce, on the other hand, the survival rate is very similar for old and 1936 burn stands and is vastly superior to that of birch on old stands. This certainly helps to explain the apparent paradox associated with white birch having a high seedling count in mature stands where, in tree form, it has very low density. Survival of seedlings beyond one meter height could not be determined from our data but will be investigated in future studies.

Ground Cover Study

In assessing the ecological importance of the vascular ground cover plants (non-arboreal species one meter high or less), the plots were divided into three major groups according to the stand age. The young group was

represented by plots in the 1936 burn, the mid-group, by stands from 90 - 130 years old (mostly burned over during the mining era) and the old group by stands greater than 130 years of age. Average relative cover values for each species was calculated for each of these age groups. Table 5 tabulates the most prevalent ground cover species, each of which has a relative cover value of at least 2% in at least one of the three age groups. They are listed in the order of their abundance in the old group which is close to the climax. The underlined values correspond to species which collectively make up about 80% of the relative density of each age group. Numerals in parentheses are the relative ranking of that species within the top 80% of each group.

Aster macrophyllum (big leaf aster) is indisputably the most abundant ground cover species in the upland boreal forest type of Isle Royale. This is followed by Rubus parviflorus (thimbleberry) and Aralia nudicaulis (wild ~~sax~~ sassafras). These three species make up most of the ground cover in this forest type. The top 80% of relative cover for both the old and the mid-group are each made up of seven species, whereas for the young group it is made up of only four species. Aralia nudicaulis, Cornus canadensis, Clintonia borealis, Linnaea borealis, and Lycopodium annotinum all make up an increased proportion of the ground cover as the forest matures. Diervilla lonicera and Pteridium aquilinum, on the other hand, show a distinct downward trend as the forest matures. Aster macrophyllum does not differ significantly among the tree age groups. Rubus parviflorus seems to reach its maximum in the middle age stands.

Table 6 presents a list of all species sampled in this study whose relative abundance distinctly increases with forest maturity as well as a list of those which decrease with forest maturity, together with the relative cover values of each in the three stand age groups.

Table 7 shows the number of species which are unique to only one of the age groups as well as the number in common to two or more groups. Most species

seem to occur to some extent in all three groups. The young group has the greatest number of species unique to it; the old group, the least number. The young group also has the greatest total number of species while the old group has the least. There was a total of 120 species found among all age groups.

Study of Recent Burns

Aging of the oldest trees in the surrounding forest indicated that the forest burned at Card Point was probably older than 230 years and that of McGinty's Cove, older than 160 years. For Isle Royale these are both relatively old stands. The Card Point fire burned about four hectares (10 acres); the McGinty's Cove fire, less than one hectare. Characteristics of the two burns are summarized in Table 8. For both fires most of the trees were killed and most of the soil was burned down to mineral soil. Where the soil was not burned, the pre-fire ground cover plants survived.

In the larger Card Point burn the tree seedlings established after the fire were all pioneer-type species; namely, white birch, quaking aspen, and pin cherry, while for the McGinty's Cove fire, the shade-tolerant balsam fir and white spruce were reproducing. The lack of spruce and fir reproduction at Card Point may be due to remoteness of the seed-source, since the burn was larger and since it occupied most of a point of land protruding into Lake Superior. Comparing the birch seedling densities with the values of Table 3, suggests that this species produces seedlings best in very recent burns and in old stands, and attains minimum seedlings production somewhere between.

Percent cover of the most abundant ground cover invaders are presented in Table 9, in order of their abundance. Only species whose cover is at least 1% are given. The grasses could not be identified since they lacked fruiting bodies at the time of sampling. These shall be collected and identified during the coming field season. Most of these ground cover species are well-known as invaders of disturbed areas except for Cornus canadensis, Aralia

nudicaulis, and Linnaea borealis. The latter species were all survivors on unburned soil. Species common to both lists are Rubus parviflorus (thimbleberry), Rubus idaeus (red raspberry), Epilobium augustifolium (fireweed), Impatiens biflora (jewelweed), and an unknown grass.

The study of recent burns is just beginning. In future years we intend to continue to sample these burns at periodic intervals. We are interested not only in what conditions are present immediately after the fire, but also in what changes which occur in subsequent years. Also, we shall employ similar routines in the event that other fires occur.

SUMMARY AND RECOMMENDATIONS

The upland boreal forest-type on Isle Royale is potentially a dynamic ecosystem. Our succession studies demonstrate that, following fire, continual changes take place in the tree layer, the soil and in the vascular ground cover layer. In the tree layer white birch and quaking aspen gradually give way to balsam fir and white spruce. Ground cover plants such as Epilobium augustifolium (fireweed), Rubus idaeus (red raspberry), and Impatiens biflora (jewelweed) found in the recent Card Point and McGinty's Cove fires eventually are replaced by plants such as Cornus canadensis (Canada dogwood), Clintonia borealis (blue-bead lily), and Linnaea borealis (twinflower) as the forest approaches maturity.

Near the soil surface the leaf litter layer deepens and the amount of wood in various stages of decay increases. This, in turn, affects the reproduction of tree species in different ways. White birch reproduces well on mineral soil which enhances its role as a post-fire pioneer. The build-up of only a few centimeters of leaf litter, however, greatly inhibits seedling germination. Although it germinates very well in decayed wood which accumulates as the forest matures, few of these seedlings survive beyond the first year. White spruce also reproduces successfully on mineral soil and hence

can act as a pioneer species if a nearby seed source is available. In the mature forest it germinates successfully and has a high survival rate on decayed wood.

The rate and course of post-fire succession may be greatly affected by the size and intensity of the fire. After large fires, the invasion of balsam fir is considerably delayed by the absence of a nearby seed source. Thus, 40 years after the great fire of 1936, fir reproduction was still almost negligible. The same is true to a lesser extent of white spruce. Quaking aspen reproduces primarily by sucker shoots from the roots of the parent trees. If a fire is severe enough to kill these roots, aspen reproduction may not occur after the fire.

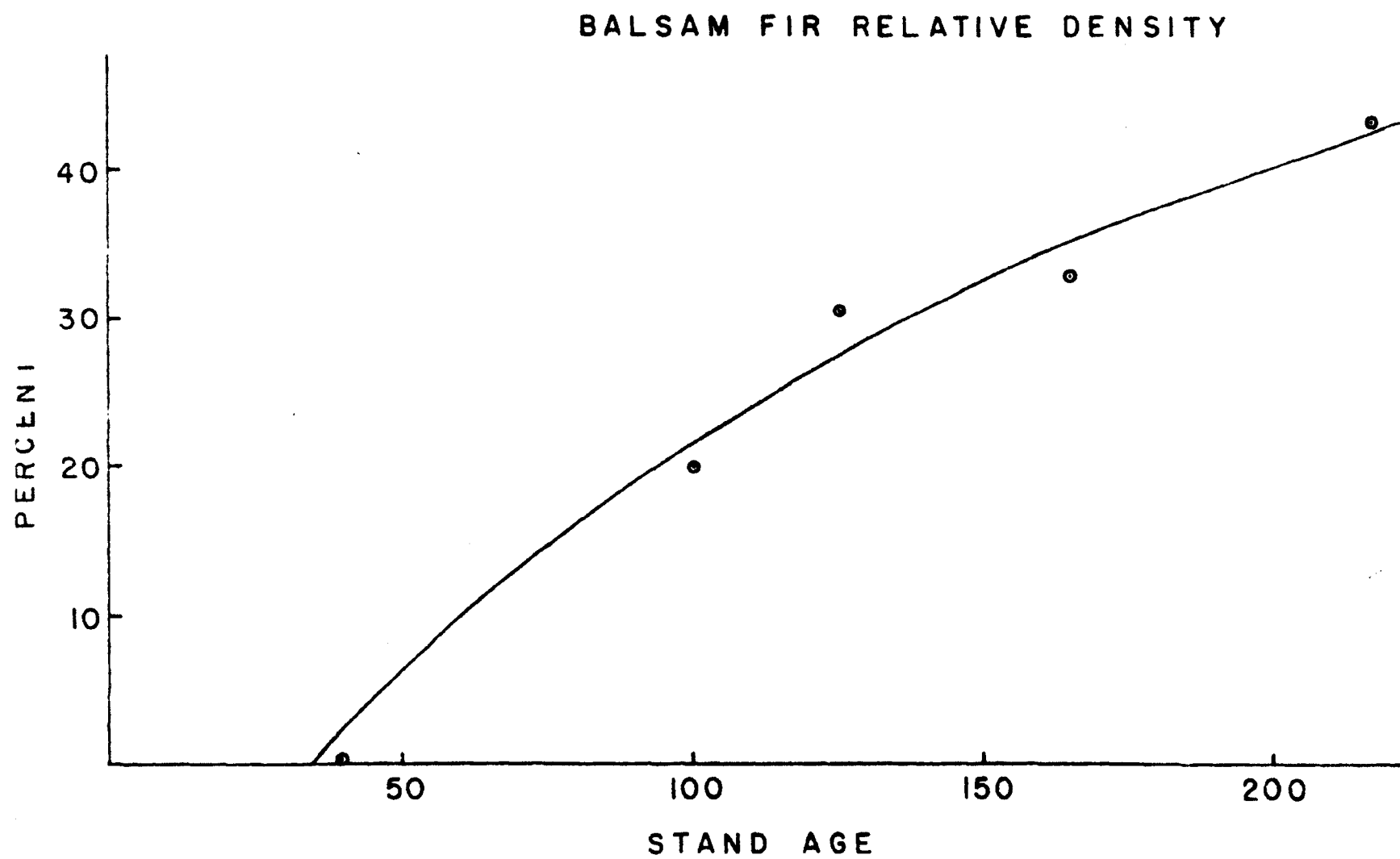
As succession proceeds the forest tends to increase in inflammability. This is due primarily to the increased percentage of the resinous conifers in the tree layer, the deepening of the soil litter layer and the increased amount of dead wood on the forest floor.

Based on our findings we recommend continuation of the "let burn" policy for natural fires on Isle Royale National Park. Fire is, without question, a natural environmental factor of the boreal forest ecosystem. To preserve the ecosystem, we must preserve its environmental factors. By preserving natural fires we, at the same time, preserve the dynamic nature of this forest ecosystem as described above. We also preserve a greater diversity of plant life. As our study has shown, species diversity would become increasingly less if the entire forest of the park were to approach maturity. Greatest diversity would be found in the mosaic of stands in various stages of succession which would also result in greater diversity of habitat. With greater diversity of plant life and habitat, we could expect a greater diversity and balance of animal life. We would also minimize the possibility that species associated specifically with one stage of succession would become rare or extinct.

Another reason for our recommendation is based upon the inflammability factor. As we have shown, inflammability tends to increase as succession proceeds. If the entire forest of the park were to approach maturity it would really be a "tinder box" if a fire did get out of control. The resulting fire could indeed be catastrophic.

Finally, let us consider the park visitor. Certainly a greater variety of plants, animals, and habitat would make Isle Royale a more interesting park to visit. Also, the scenic beauty of the park would be enhanced by the opening up of vistas by fires in high prominences such as the Greenstone Ridge.

FIGURE 1.



W. SPRUCE RELATIVE DENSITY

FIGURE 2.

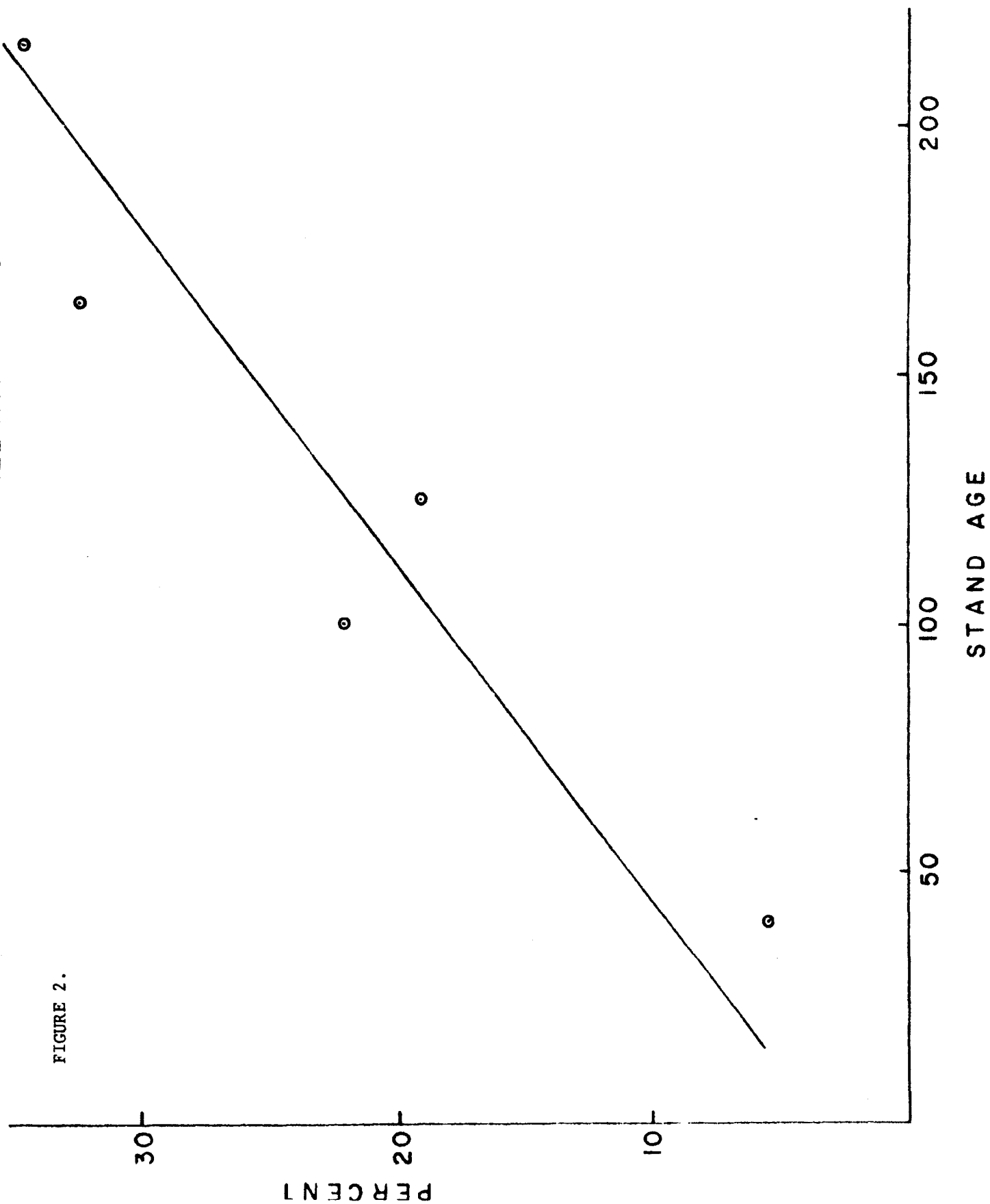


FIGURE 3.

WHITE BIRCH RELATIVE DENSITY

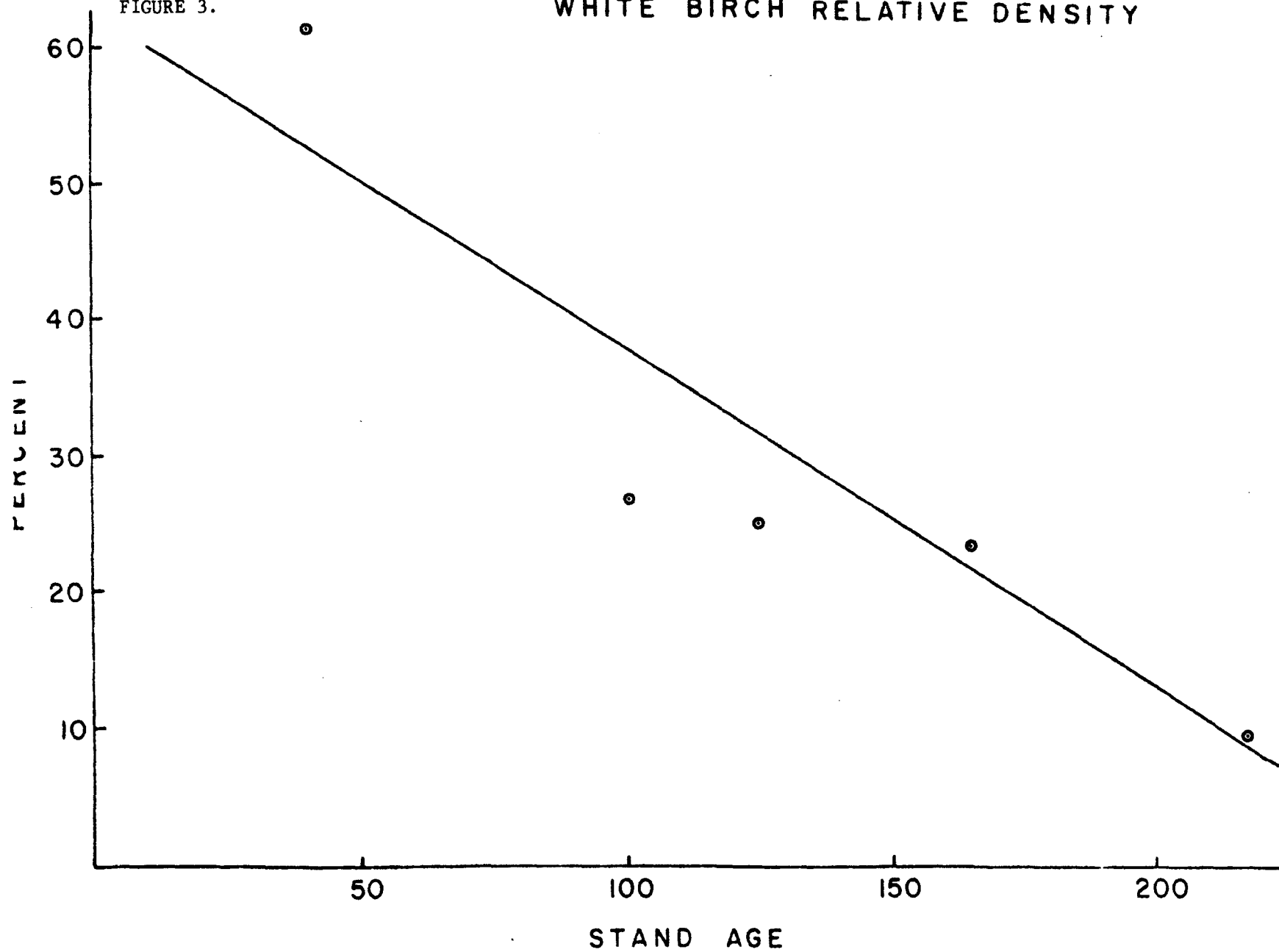


FIGURE 4.

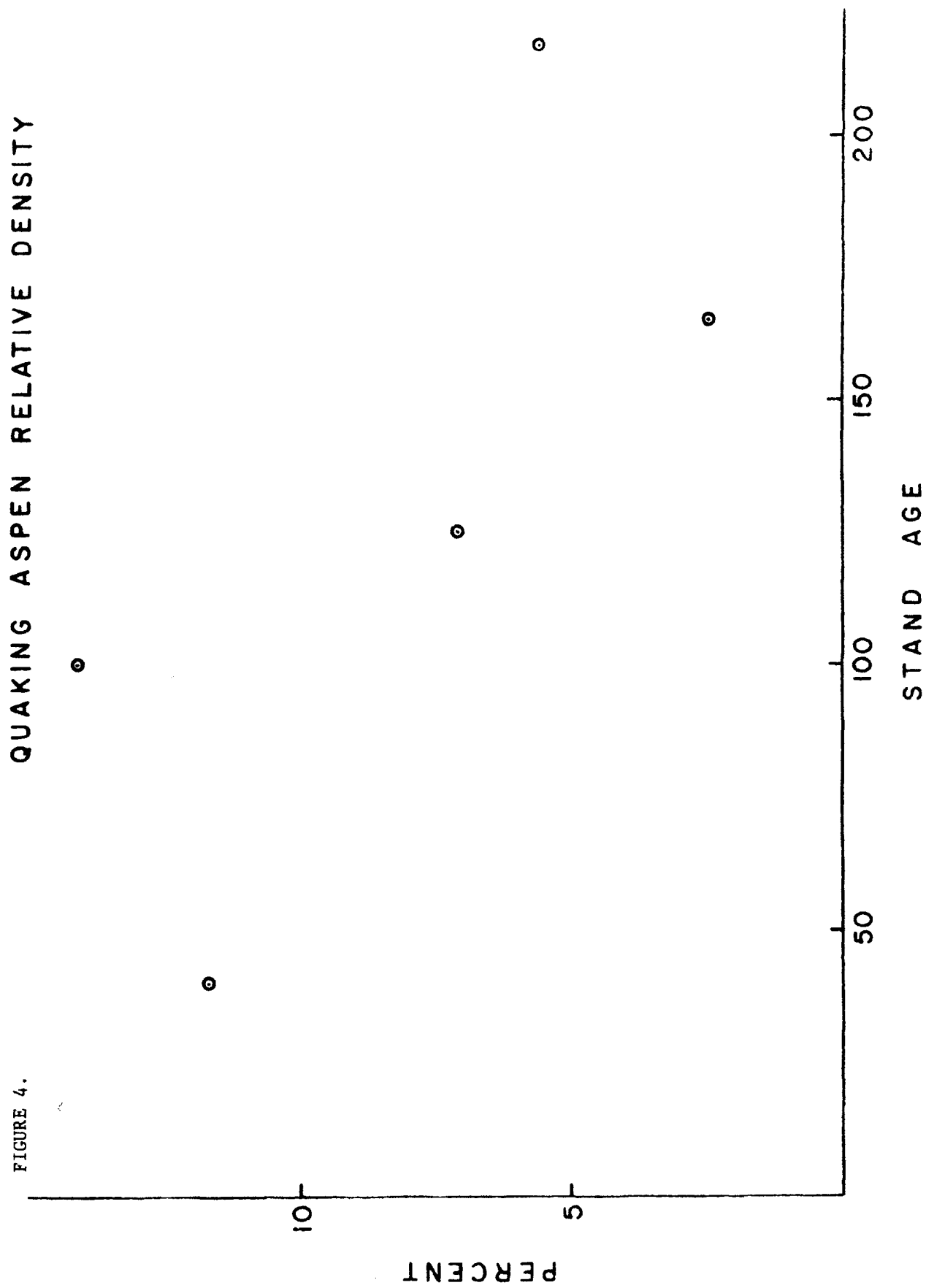


FIGURE 5.

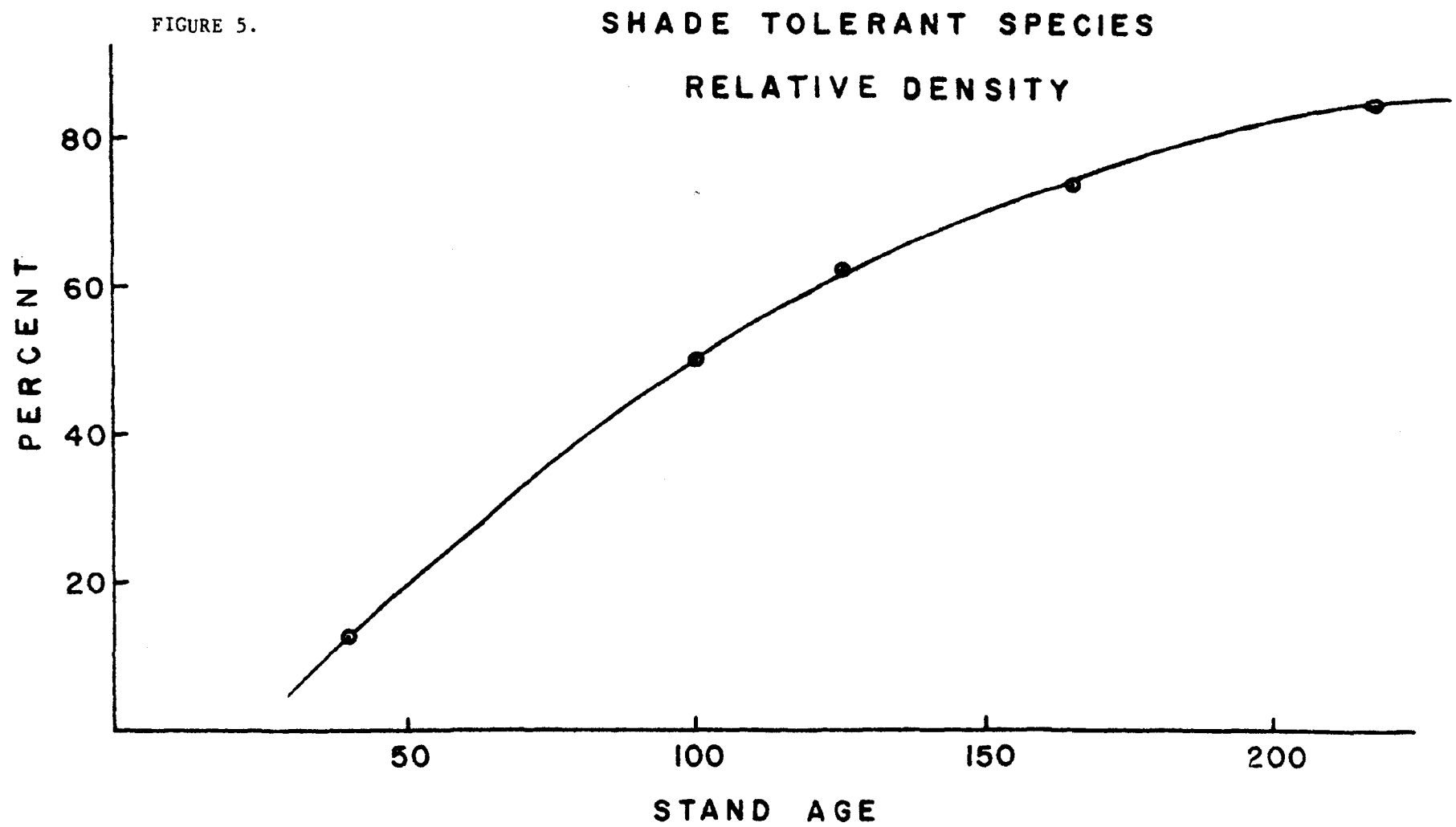
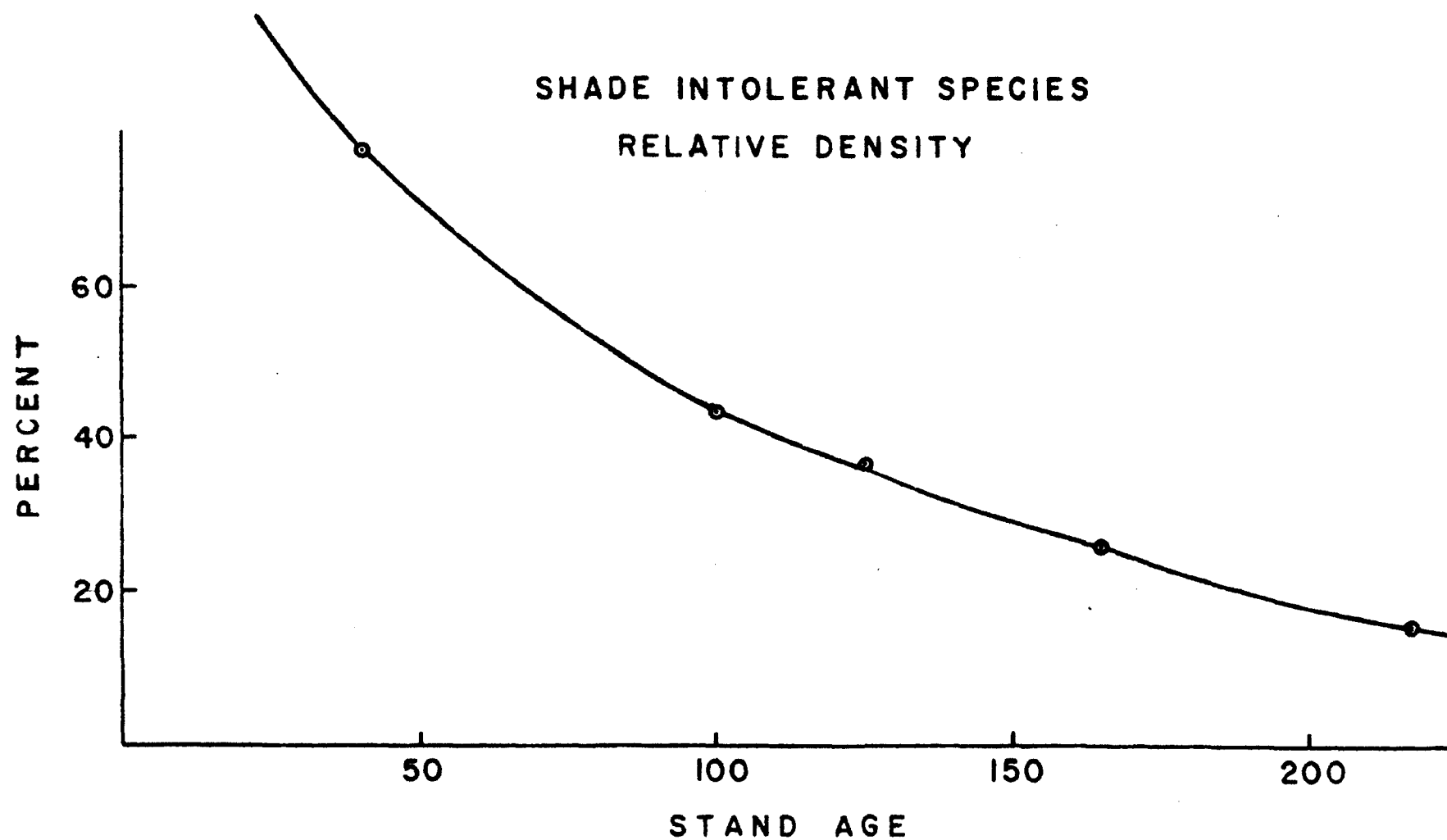


FIGURE 6.



CONIFER BASAL AREA

FIGURE 7.

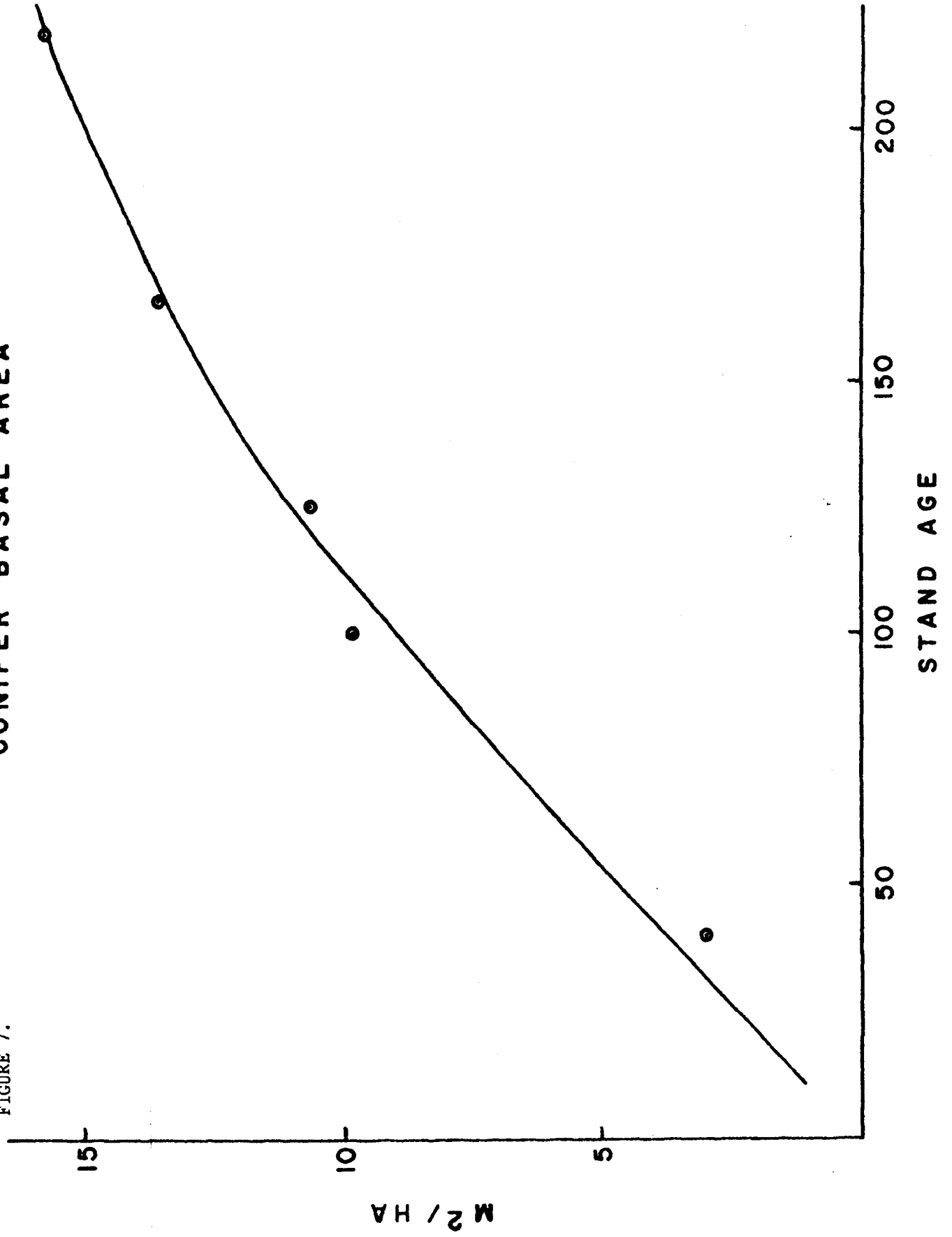


FIGURE 8

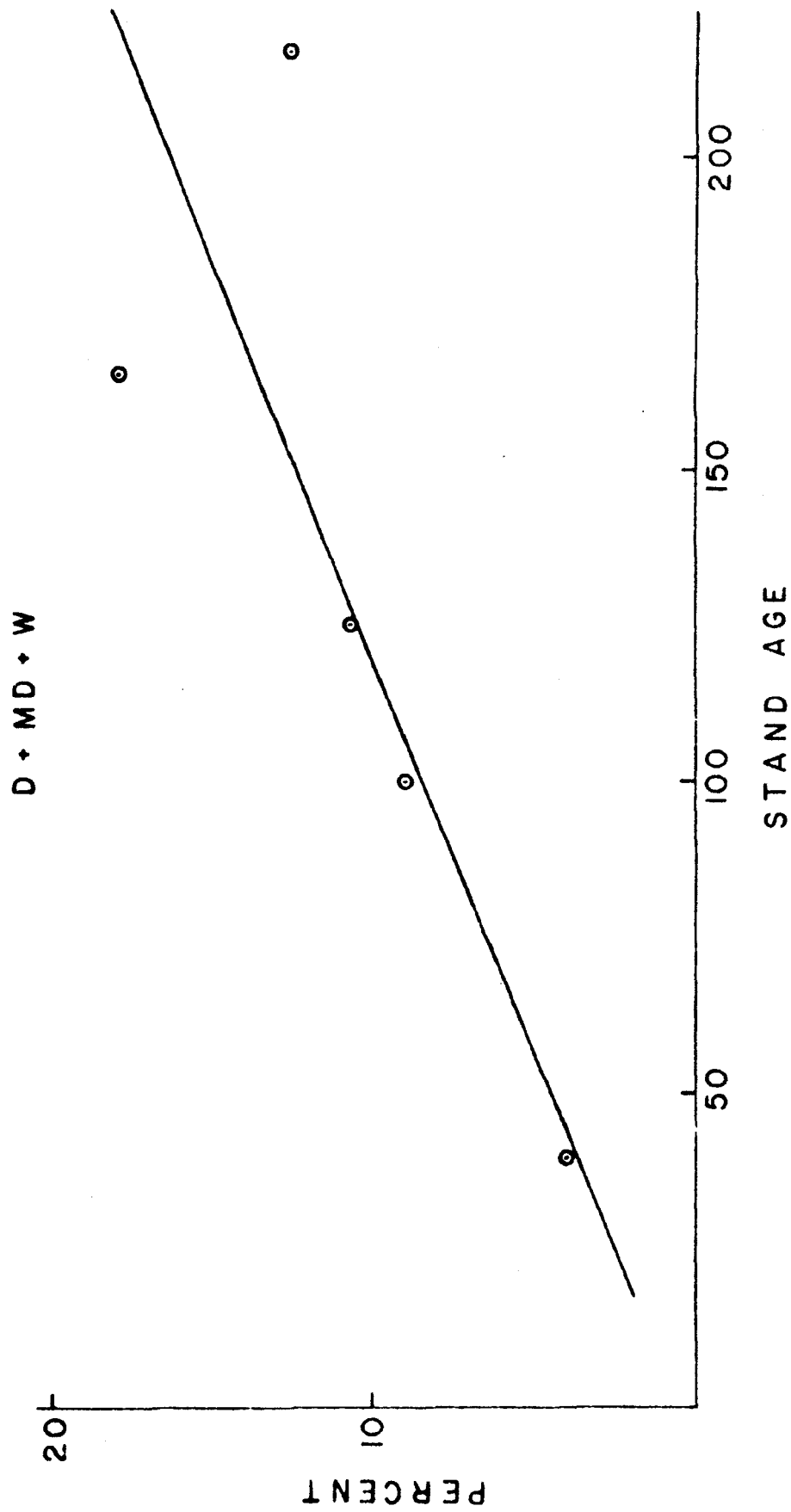


FIGURE 9.

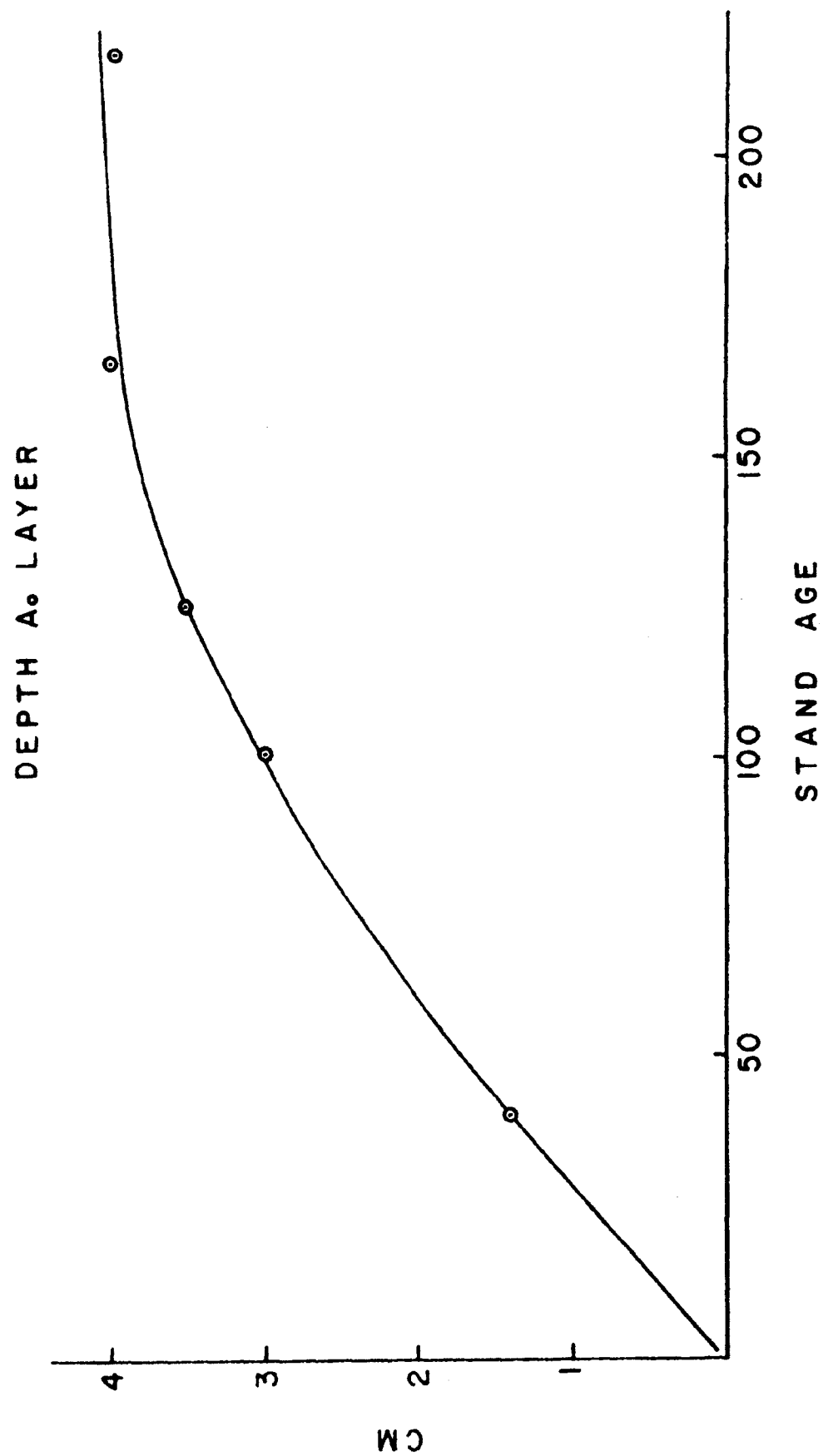


TABLE 1. Seedling establishment preference ratios for major tree species on various soil microhabitats. L, D, M, and MD represent leaf litter, decayed wood, moss, and moss on decayed wood, respectively.

	L	D	M	MD
balsam fir	0.8	0.8	7.8	2.5
white birch	0.3	5.2	1.0	10.2
white spruce	0.5	4.9	5.0	9.1
quaking aspen	1.0	*	*	*

*Preference ratio very inaccurate because of low occurrence on these sites.

TABLE 2. Tree seedling density versus abundance of mature trees within 60 meters. Key to abundance index: 0 = no trees; 1 = 1 tree; 2 = 2 trees; 3 = 3 - 6 trees; 4 = 7 or more trees.

		Mature tree abundance index				
		0	1	2	3	4
balsam fir						
seedl. dens.		193	1,710	1,730	6,370	14,420
no. plots		100	1	3	19	125
white birch						
seedl. dens.		11,900	2,980	100	4,890	2,550
no. plots		1	1	2	7	241
white spruce						
seedl. dens.		32	225	420	598	1,600
no. plots		25	8	9	30	180
quaking aspen						
seedl. dens.		0	-	0	400	1,980
no. plots		22	0	3	5	222

TABLE 3. Average seedling density (stems/hectare) of the four major tree species for various stand age groups.

age range years	balsam fir	white birch	white spruce	quaking aspen
40 ('36 burn)	125	204	1,279	558
91 - 105	7,742	1,282	1,402	3,913
106 - 130	9,349	1,923	1,292	1,504
131 - 200	19,738	10,028	1,178	2,318
201 - 240	24,852	11,145	972	2,741