A MODIFIED TREE CLASSIFICATION FOR USE IN GROWTH STUDIES AND TIMBER MARKING IN BLACK HILLS PONDEROSA PINE

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A satisfactory silvicultural management of ponderosa pine stands requires a judicious selection of trees to be left in the reserve stand. The timber marker must know what type of tree has the greatest growth potentialities and what type of tree will respond but slightly upon being released. The silvicultural problem in marking therefore is one of recognizing the combination of characters, age, and crown vigor, which indicate high or low growth capacities. The trees selected for cutting should be those which have ceased growing or which have lost their ability to respond to an increase in light, nutrient substances, and soil moisture. The trees of merchantable size which are left to form the nucleus of the second cut should be those which will respond most to release and maintain their productive capacity for the greatest number of years.

IN the summer of 1936 the Rocky Mountain Forest and Range Experiment Station undertook an investigation of the growth and yield of selectively cut stands of ponderosa pine in the Black Hills of South Dakota and Wyoming. One of the important factors involved in such a study is to determine the reaction of individual trees composing the reserve stand to release by a selection cutting. Such a study is based upon the hypothesis that the growth rate of a reserve tree is dependent not only on the amount of release resulting from cutting adjacent trees but also upon the age and vigor of the individual tree left.

When the type of tree most likely to maintain a high rate of growth can be recognized with a fair degree of certainty the forester can mark a stand so as to leave it in the highest productive state. Trees left in the reserve stand are an investment and a bad investment is nearly as wasteful of timber and land resources as absolute depletion. In theory, the aim of the forester intent on the management of a forest property is to produce the highest quality and quantity of timber in order to produce the highest financial returns and yet maintain the soil at its highest productive capacity.

By a system of marking that removes the poor vigor classes the stand will gradually be improved in growth rate from that of the wild state to that of a well managed stand. Marking by a tree classification is merely the application of a principle long in use by plant and animal breeders. No successful stockman retains stunted and diseased stock for a breeding herd, nor does he purchase that type of stock to use as feeders to convert surplus feed supplies into marketable stock.

Timber marking has been described as an art. Unfortunately, an art is largely dependent upon the development of native ability based upon knowledge and balanced with equanimity. A tree classification based upon facts provides the knowledge. It is a tool that will aid inexperienced men to become proficient in timber marking, and perhaps aid those who have already acquired the so-called art. It is a useful instrument for the measurement of growth and the prediction of future yield. It does not provide fool-proof rules for marking, however, because other factors must be taken into consideration, such as disease, defects, injuries, character of the stand, and the volume required for cutting.

A number of tree classifications, applicable to even-aged stands were developed in Europe such as those by Kraft (*5*), Heck (*3*), and Schotte (*6*). Taylor (*8*) developed a tree classification for lodgepole pine. Dunning (*1*) pointed out the need for a tree classification to fit ponderosa pine stands in California and later (*2*) published a classification for that species. Keen (*4*) found, in studying the relative susceptibility of ponderosa pine to bark beetle attack in the Pacific Northwest, that it was desirable to set up a more detailed classification which had greater sensitivity in reflecting insect susceptibility than was obtained by Dunning's classification. Keen's system sets up four age groups (1, 2, 3, and 4) and within each age group four vigor groups (*A*, *B*, *C*, and *D*) making a total of 16 tree classes. Although Keen's classification was based primarily upon susceptibility to bark beetle attack, it embodies a basic hypothesis—that young trees grow faster than old trees and that for a given age full-crowned trees grow faster than those with short, sparse, or one-sided crowns, and that trees with dense, vigorous appearing crowns grow faster than those of apparent poor vigor.

The purpose of this investigation was to determine, when Black Hills ponderosa pine trees are classified according to Keen's classification, whether that classification is a reliable criterion of the relative growth capacities of those trees both in uncut and selectively cut stands. In this instance only the diameter growth of trees of the various age and vigor classes is considered. No attempt has yet been made to correlate seed production, mortality, disease, defect, log or lumber grades, and susceptibility to insect attack with age and vigor classes.

Susceptibility of ponderosa pine to attack by the Black Hills beetle (*Dendroctonus ponderosae* Hopk.), the most common and destructive bark beetle in the Black Hills, should be thoroughly investigated. It is believed, however, that the present practice of doing bark beetle control work immediately upon the appearance of an attack by the Black Hills beetle precludes any benefit that might be derived from timber marking by a tree classification.

Methods of Study

In a number of uncut stands, scattered throughout the Black Hills and Harney National Forests, 20 trees in each of Keen's 16 age and vigor classes were classified, crown and bark characteristics described, and age and accretion borings made. Each tree was bored at breast height with an increment borer at points diametrically opposite. One core was taken to the center of the tree and the rings were counted to determine age at that point. Total age was determined by adding 17 years to the breast height age.[1] The other increment core was made long enough to include 25 annual rings. The radial growth, inside bark, for the preceding 25 years was measured on both cores from each tree, in the laboratory, with the aid of a microscope core-measuring device. Diameter growth, inside bark, was obtained by adding the two radial measurements. The average diameter increment was computed for each age and vigor class. The difference between growth rates of age and vigor classes were found to be significant as will be shown later. The bark and crown descriptions were analyzed for each age and vigor class and Keen's descriptions modified as found necessary to apply to the local characteristics of Black Hills ponderosa pine.

[1]The average number of years for ponderosa pine seedlings to attain a height of 4½ feet was determined as a phase of a growth and yield study by counting the annual rings at the root collar of 720 open grown seedlings in selectively cut stands.

Table 1.—Average d.b.h. Increment, Inside Bark, in Inches by Age and Vigor Classes of Black Hills Ponderosa Pine in Uncut Stands. Each Average is Based Upon 20 Trees in Each Age and Vigor Class

	Vigor class			
Age class	A Inches	B Inches	C Inches	D Inches
1	3.64	2.50	1.68	1.48
2	2.72	1.92	1.42	1.13
3	1.72	1.26	0.99	0.74
4	1.16	0.79	0.52	0.40

The modified tree classification was then applied to trees in a number of stands that had been selectively cut 25 years before. To each tree was ascribed the age and vigor class which it was estimated to have had at the time of cutting. The diameter growth, inside bark, for the 25 years subsequent to cutting was determined from increment cores as described for the uncut stand. A comparison of diameter increments of age and vigor classes for both uncut and selectively cut stands was made.

Results

The average d.b.h. increment, inside bark, for the 25 years, 1911-1935 inclusive, was computed for each of the age and vigor classes for the uncut stand and is given in Table 1 and Figure 1. An analysis of the variance of the diameter increment within and between age and vigor classes is given in Table 2. The F^2 value of 22.25 for the variance between diameter incre-

Table 2.—Analysis of Variance of Mean d.b.h. Increment in Inches for a 25-Year-Period (1911-1935 Inclusive) of 320 Ponderosa Pine Trees of Uncut Stands Classified According to Keen's System

Source of variation	Degrees of freedom	Sum of squares	Mean square	F	Significance
Total	319	292.79	0.92	....	....
Within classes	304	69.22	0.23	....	....
Between means of age-classes	3	118.79	39.60	22.25	High
Between means of vigor classes	3	88.79	29.60	16.63	High
Interaction	9	15.99	1.78	7.74	High

[2]*F*, is a measure of significance. See (7).

ments of the 4 age-classes is highly significant (7). An F value of only 6.99 indicates that only once in 100 similar sets of observations would such a difference as shown here be likely to occur by chance. Both the variances, that between mean diameter increments of vigor classes and that of interaction of age and vigor, are highly significant as indicated by the F values of 16.63 and 7.74 respectively. These results imply that the observed differences in diameter growth within and between age and vigor classes are probably the result of true differences in rates of diameter growth rather than the result of chance variation.

Table 3 and Figure 2, show the average d.b.h. increment, inside bark, by age and vigor classes for a 25-year-period, 1911-1935 inclusive, of 653 trees growing in a number of selectively cut stands. Since they show a similar differentiation in growth rates by age and vigor classes, excepting for that between age classes 1 and 2, no analysis of variance was made. Trees of age classes 1 and 4 were scarce in the cut-over stands studied.

It is readily seen (Table 3) that the growth rates of age-classes 1 and 2 in the selection stand are similar. This may be the result of one or more factors or a combination of them. First, the number of trees upon which the averages for age-class 1 are based is small. Secondly, the trees of age-class 1 may have had all the light, nutrient substances, and soil moisture that they could utilize before the cutting. It should be remembered that before a tree can be released by a cutting it must be in actual competition with the tree or trees cut. Third, errors may have occurred in estimating what the age or vigor classes were at the time of cutting, and this procedure undoubtedly resulted in some errors.

A comparison of the average diameter increments for a 25-year-period, in uncut and selectively cut stands, (Figures 1 and 2) indicates that the release of a tree in age-classes 2, 3, and 4 by a selection cutting has the average general effect of accelerating the growth rate equivalent to that of trees in an uncut stand having the same vigor class but one age class younger. This does not mean, however, that the growth rate of trees of *C* and *D* vigor is sufficient to warrant their retention in the reserve stand in place of trees of *A* and *B* vigor. It has already been pointed out that trees left in the reserve stand are an investment from which maximum returns are desired. It is apparent (Figure 2) that the value of dividend returns in the form of increased growth is much greater from trees of *A* and *B* vigor than from those of *C* and *D* vigor.

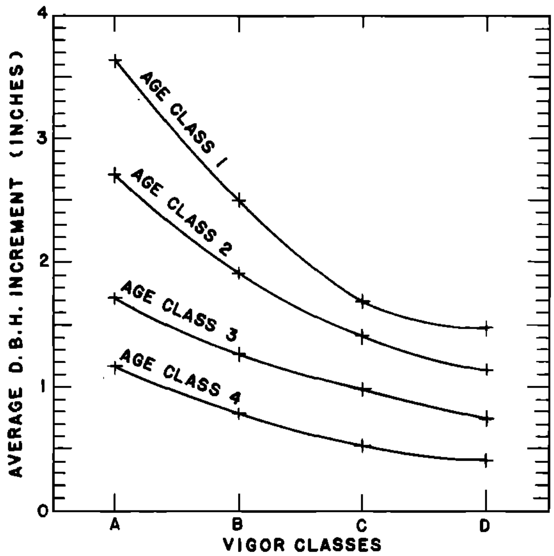


Fig. 1.—Average diameter increment, inside bark, by age and vigor classes for a 25-year-period (1911-1935) of Black Hills ponderosa pine in uncut stands. Each average is based upon 20 trees.

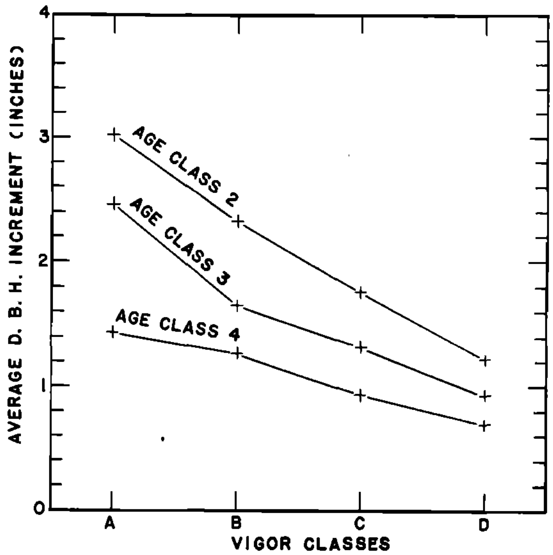


Fig. 2.—Average diameter increment, inside bark, by age and vigor classes of Black Hills ponderosa pine for a 25-year-period (1911-1935) following release by a partial cutting.

Description of Keen's Classification Modified to Apply to Growth Capacities of Black Hills Ponderosa Pines[3]

Age Groups

Trees are first divided into the four general age groups of young, immature, mature, and overmature. On the average site of ponderosa pine in the Black Hills of South Dakota and Wyoming, the characteristics of each of these groups are as follows:

Age Class 1. Young trees—commonly referred to as "blackjacks"; usually less than 75 years of age.
- D.b.h.: Rarely over 10 inches.
- Tops: Usually pointed, but may be rounded when open grown; making good height growth.
- Bark: Rough, fissured, dark-brown to black.
- Branches: Upturned and in whorls.

Age Class 2. Immature trees—age approximately 75 to 150 years.
- D.b.h.: Rarely over 16 inches.
- Tops: Usually pointed, open grown trees may have rounded tops, trees still making height growth.
- Bark: Fissured, usually dark brown to reddish brown, yellowish tinge showing at bottom of fissures, occasionally reddish brown or yellowish plates forming at the base.
- Branches: Usually upturned and in whorls.

Table 3.—Average d.b.h. Increment, Inside Bark, in Inches by Age and Vigor Classes of Black Hills Ponderosa Pine Released by a Partial Cutting 25 Years Before Measurement (1911-1935 Inclusive) and the Number of Trees Upon Which the Averages are Based

	Vigor class							
	A		B		C		D	
Age class	Number	Inches	Number	Inches	Number	Inches	Number	Inches
1	8	3.01	25	2.29	5	1.95	3	1.02
2	63	3.01	163	2.32	122	1.76	29	1.23
3	26	2.46	99	1.65	56	1.32	18	0.94
4	2	1.44	22	1.27	10	0.94	2	0.70

[3]Grateful acknowledgment is made to F. P. Keen of the Bureau of Entomology and Plant Quarantine for the use of material from the descriptions of his tree classification and for the use of his chart of age and vigor classes.

Age Class 3. Mature trees—approximately 150 to 300 years old.
- D.b.h.: Rarely over 28 inches.
- Tops: Usually rounded or still pointed, although height growth practically ceases at about 160 to 170 years.
- Bark: Usually yellowish brown up to or above first 16-foot log, moderately sized plates between fissures; upper bole light reddish brown; on some exposures yellowish brown bark is scaly, fissures faint or entirely absent.
- Branches: Incomplete whorls, nodes indistinct; nearly all branches horizontal (occasionally drooping) with lower ones drooping.

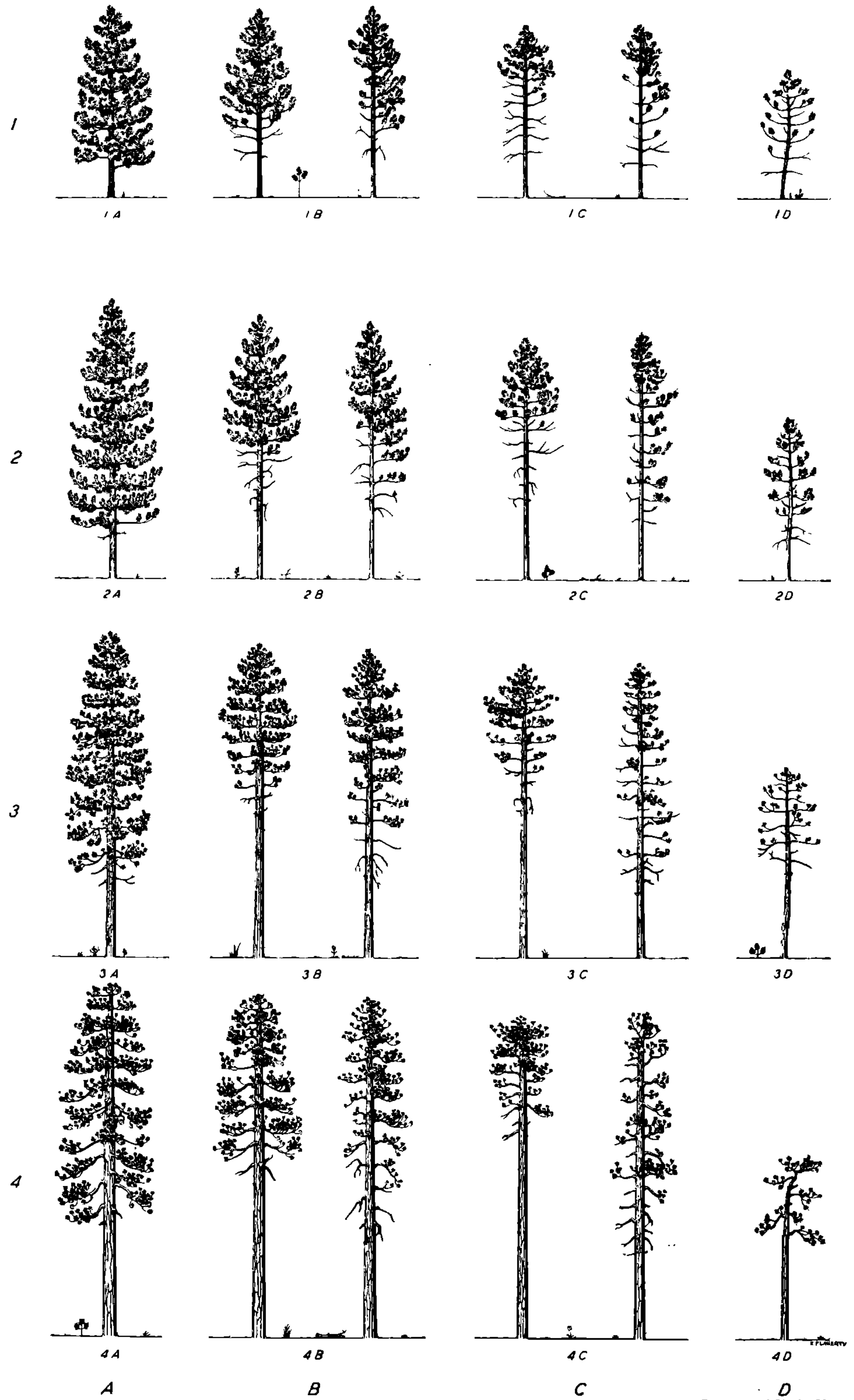
Age Class 4. Overmature trees—usually over 300 years old.
- D.b.h. Usually of larger size, however diameters of age-class 3 and 4 overlap.
- Tops: Usually flat, occasionally rounding, sometimes spiked, making no height growth.
- Bark: Light yellow in color, plates wide, long, and smooth, although on some exposures the bark has scaled off until fissures are faint or nearly absent.
- Branches: Mostly drooping, gnarled or crooked.

Vigor Groups

The size of crown and abundance of foliage are probably the best outward indicators of the relative vigor of different trees of a given age. Therefore, each age class was further subdivided into four sub-groups based upon relative crown vigor. These are designated by letters *A* to *D*. The position of the tree in the stand in the following descriptions is for uncut stands. The positions may be entirely changed in a cutover stand; however, the other criteria of vigor are readily recognized.

A. Full vigorous crowns with a length of 55 percent or more of the total height and of average width or wider; foliage usually dense; needles long and dark green; position of tree isolated or dominant (rarely codominant).

B. Fair to moderately vigorous crowns with average width or narrower, and length less than 55 percent of the total height; either short wide crowns or long narrow ones, but not sparse or ragged, may be flat on one side, position either



Courtesy of F. P. Keen

Fig. 3.—A ponderosa pine tree classification chart for determining relative growth capacity based on age and vigor.

dominant or codominant but sometimes isolated.

C. Fair to poor crowns, usually flat on one or more sides, very narrow and sparse or represented by only a tuft of foliage at the top; foliage usually short and thin; position usually intermediate, sometimes codominant, rarely isolated.

D. Crowns of very poor vigor; foliage sparse and scattered or only partially developed; diameters decidedly subnormal considering age; position suppressed or intermediate.

Figure 3 is a tree classification chart for determining growth capacity of Black Hills ponderosa pine based on age and vigor classes.

Application to Timber Marking

Rules for timber marking of necessity must be flexible to fit varying conditions of stand character and lumbering requirements. Observance of the following suggestions for timber marking may be of assistance to the beginner. Their use should result in silviculturally improved reserve stands whose yields may be increased as a result of a better growing stock.

Age Class 1. Trees should seldom be cut except for poles, posts, and props, and these should be in the form of a thinning by removing vigor classes *C* and *D*.

Age Class 2. Leave trees of vigor class *A* and *B*. If trees of *C* and *D* vigor must be left in reserve stand they should be released as much as possible.

Age Class 3. Mark all trees of *C* and *D* vigor of merchantable size. Additional cutting for poles, posts, props, ties, and fuelwood should remove trees of these vigor classes that are undesirable for sawtimber. Trees of these classes are a poor investment and should be removed so that space they occupy may be utilized by younger trees of greater growth capacity. Leave trees of *A* and *B* vigor excepting when needed to fill out required volume of sawtimber.

Age Class 4. Cut all trees in this age class except when needed for seed trees. In such instances reserve trees should be of *A* or *B* vigor.

Exceptions to the above rules should be made in the case of *A* and *B* trees having fire scars, cat faces, injuries due to lightning, porcupines, mechanical agencies, crook or sweep, and those having external evidence of being infected with western red rot (*Polyporus Ellisianus* (Murr.) Long).

Summary of Results

1. Keen's tree classification, as modified, is a satisfactory criterion of the relative growth capacities of Black Hills ponderosa pine, either in uncut or in selectively cut stands.

2. The mean difference in diameter growth between age classes and between vigor classes is highly significant.

3. By vigor classes, the highest mean diameter growth is made by trees of *A* vigor, followed in descending order by trees of *B*, *C*, and *D* vigor. By age-classes, the highest mean diameter growth is made by trees of age class 1, followed in descending order by trees of age classes 2, 3, and 4.

4. In general, the effect of average release by a selection cutting on diameter growth is to accelerate the growth rate equivalent to that of trees in uncut stands having the same vigor class but one age-class younger.

5. Suggestions are made for applying a tree classification to timber, which if followed should result in silviculturally improved reserve stands whose yields may be increased as a result of a growing stock of high growth capacity.

Literature Cited

1. Dunning, D. 1922. Relation of crown size and character to rate of growth and response to cutting in western yellow pine. Jour. Forestry. 20:379-389.
2. ———. 1928. A tree classification for the selection forests of the Sierra Nevada. Jour. Agric. Research. 36:755-771.
3. Heck, C. R. 1904. Freie durchforstung. 115 pp. Berlin. Julius Springer.
4. Keen, F. P. 1936. Relative susceptibility of ponderosa pine to bark-beetle attack. Jour. Forestry. 34:919-927.
5. Kraft, G. 1884. Beiträge zu lehre von den durchforstungen, Schlagstellungen und lichtungshieben. 147 pp. Hanover, Klingworth.
6. Schotte, G. 1912. Om gallringsförsök (über durchforstungsversuche) Meddel. Statens Skogsförsöksanst. (Sweden). 9:211-269.
7. Snedecor, George W. 1934. Calculation and interpretation of analysis of variance and covariance. 96 pp. Ames, Iowa.
8. Taylor, R. F. 1937. A tree classification for lodgepole pine in Colorado and Wyoming. Jour. Forestry. 35:868-875.