

New Zealand woods. Most of the work has been carried out by him for the Forest Products branch of the State Forest Service.

Mr. Barker's work included the following:—

- (1) A Structure Study of *Pinus radiata*.
- (2) A Study of the Tracheids of *Pinus Laricio* and of the fibres of Makomako (*Aristotelia racemosa*).
- (3) The Living Tissues in the Wood of Rimu (*Dacrydium cupressinum*).
- (4) The Anatomy of the Chief Native Commercial Woods of New Zealand.

An article by Mr. Barker is contained in this issue.

THE VALUE OF GROWTH RINGS IN NEW ZEALAND MENSURATION STUDIES.

(Frank E. Hutchinson, B.Sc.F.)

The scientific forest mensuration which is now being brought into practice in New Zealand is based, naturally enough, on the principles which have been worked out mainly on the continent of Europe during the past five hundred years, with the addition of many improvements in methods of application developed within the last twenty-five years by the admirable work of the United States and Canadian forest authorities.

For all purposes concerned with growth and yield, the methods elaborated for northern hemisphere forest mensuration have been based on the growth rings as shown on the cross-sections of the trunk. These rings have been found to furnish a true and reliable record of the past growth of the tree, upon which record can be built up data concerning yield and increment from which accurate conclusions can be drawn regarding the economic rotation, and the comparative financial profit which may be expected, as between different species and different sites—factors which are the very foundations of all forest working plans.

The methods which have become adopted as standard for work in the northern hemisphere were developed to suit a forest whose constituent species were almost entirely trees characterised to a marked degree by a smooth and regular circumferential habit of growth, and growing in a climate of continental extremes of temperature, causing a short but hot, and more important, an uninterrupted growing season, followed by a winter of such severity that all growth is at a definite and complete standstill until the following spring. Under these climatic limitations, the trees, characterised by the smooth, even shape of

their boles, have taken to laying on their annual increment in the form of a layer or ring which, under average conditions, is clearly visible, owing to the juxtaposition of thick-walled cells of the late growth of one season against the lighter thin-walled cells of the following season, and which is so even in form and in thickness as a rule throughout any cross-section, that it can safely be used as an indicator of volume, and it is entirely upon this function of the growth rings as volume indicators, that the whole of their usefulness in forest mensuration is founded.

In applying these methods of volume calculation, then, to New Zealand forests, it is necessary first to be sure that the same conditions which make for dependability of the growth rings as indicators of volume by time periods exist in New Zealand forests as in the north temperate forests for which these methods were evolved. If these conditions are not present, then evidently the whole of the data that may be gathered may be clouded with such uncertainty as to greatly negative its value.

There are, as has already been referred to in passing, two essential conditions which must be fulfilled if the growth rings are to be of any value from the standpoint of mensuration studies. First, the conformity of the rings must be such that an easily applied measurement of them will give, by a simple formula, a correct function of the volume increment desired. It is almost essential, therefore, that the wood be laid on smoothly, evenly and uninterruptedly throughout the whole of the circumference of the bole at any given cross-section. If the wood be laid on in such manner as to cause fluting or scalloping of serious nature, or if the wood is not laid on continuously or evenly all around the trunk, it is evident that an increment boring or even a complete section will yield data of highly questionable value for the purpose of volume computation. Second, it is imperative that the rings can be relied upon to furnish an accurate index of time. If the rings are not annual, they must at least be regular, so that they may be interpreted chronologically. Without such definite relation the value of the growth rings for mensuration purposes is exactly nil.

Are these two conditions fulfilled in New Zealand in such measure, upon the average, as to enable these methods of computation based upon the growth rings to be generally used?

The results of a considerable quantity of stem analysis work on both native and exotic forest in the South Island have led to the conclusion by the writer that in many cases these two essential conditions are not present, and the investigator must proceed with caution lest a great deal of the value of the work be vitiated.

The native bush of New Zealand, as far as commercial forestry is concerned, is of two main classes—the taxad bush and the beech forests. Discussing first the taxad forest, the principal trees are all podocarps and dacyridiums (excepting the kauri, of which the writer has no personal knowledge), and are sufficiently alike in habit and general characteristics to be handled as a class, except where specific mention may be necessary.

In regard to the first of the two conditions put forward as essential, the matter of evenness and symmetry of form, most of these trees are clean and smooth enough to present no great difficulty. The matai and miro in particular are characterised by trunks as clean and cylindrical as any to be found in other softwoods throughout the earth, while the kahikatea, once the great root buttresses are surmounted, is usually smooth and even in form. The rimu, however, which is by far our commonest tree, is characterised by a fluted habit of growth, well known to every forester and bushman, in which the cambium seemingly dies at certain points of the circumference, extending upward on the trunk for many feet, while the growth on the rest of the perimeter is maintained and expanded, leading to the formation of deep “rind galls,” which in old trees may extend fully half-way from the outer circumference to the pith. This characteristic is found mainly, though not entirely, on large trees, twenty-four inches D.B.H. and upwards, and is, therefore, characteristic of the King Country forest, while in the Westland bush, where the average tree runs less than that figure, it is less common, though still by no means inconsiderable.

It is obvious that on trees of this nature the growth ring-radial measurement would not give a true indication of volume increment without the introduction of a reducing factor which would vary in almost every case, and which would be arrived at only with such difficulty as to preclude its usefulness.

This is an obvious difficulty confronting the investigator in the rimu bush, and may perhaps be avoided to a certain extent by the selection for investigative work of well-formed trees only. A considerably more serious problem, however, is presented by the characteristic unevenness of growth on different areas of any section, which is revealed on the stump or other cross-sections of all the chief taxads of New Zealand, with the exception of the miro. This characteristic, for which it is difficult to find a suitable term, consists in the individual rings, even on apparently well-formed trunks, being of unequal thickness or width at different points about their perimeter. The formation is quite typical, and, failing a diagram, might perhaps be best described thus:

In any given sector of the stump section

one may expect to find that in one point a small group of perhaps ten to twenty consecutive rings are pushing out toward the periphery in a manner very reminiscent of the contours of a broad shingle fan, with a radius considerably shorter than that of the trunk itself at this point, so that a broad, rounded salient of wide rings is formed. This salient ceases very abruptly, and the rings immediately contiguous outside will be found so narrow and closely appressed as to be quite undistinguishable even with a hand lens. Proceeding immediately to right and left, however, these same rings which are so closely appressed will be found to broaden by means of an inward swing until they become quite distinct, and perhaps one-tenth inch in width. The formation assumed is a flanking enclosure of the first salient, forming re-entrants on either side, or to complete the topographical allusion, the formation is of two shingle fans from the opposite hill-side encroaching inward on about the same magnitude as the first encroached outward. Followed completely around the trunk, therefore, any individual ring or small group of rings presents a more or less regular series of broad scallops alternating with a similarly more or less regular series of closely-packed and indistinguishable rings.

This form of irregular growth is found very frequently, on rimu, totara, kahikatea, and less frequently, perhaps, on matai, though so far as investigation by the writer in Westland reveals, it is rare or non-existent in miro, and it is more pronounced on the stump section than on the top end of the log. There would seem to be no good reason for this form of development, which apparently does not occur as a general thing in forests of the north temperate zone, but it may be connected in some way with the cause of the “fluting” on the rimu previously referred to, as it is more noticeable in the over-mature King Country bush than in the younger Westland forest, though it is by no means absent from the latter. It is certainly not a development of old age, however. The stumps of the King Country trees, which record from five to ten or twelve hundred rings, reveal that this habit of growth had become established by the time the first one or two hundred rings had been formed, that the period of most striking scalloping was about the time of the four to seven hundred ring formation, and that after that time growth fell off, so that the scalloping was reduced to a much smaller scale.

Whatever the cause of this peculiar formation, its effect, from the standpoint of forest mensuration, is evident. The variation in width of any individual ring is as much as one to ten within a few inches. Graphic plotting of any radial measurement on the stump shows an alternation of rapid and almost quiescent

growth, while measurements along radii only a short angle apart will show a similar alternation, except that the incidence of broad and narrow rings is reversed in many cases.

Under these conditions it is most difficult indeed to prepare curves of diameter and volume growth by time periods according to ring counts by sectional analysis. It would involve the measurement of several radii on each section, followed by a laborious mathematical averaging of the results obtained, while for empirical increment studies, the customary borings with the Pressler instrument are of little avail. These points were strikingly brought out to the writer when recording stem analysis of rimu in Westland in 1924, when the variations in rate of growth shown by identical ring groups recorded at different radii were so great as to cause a sense of futility in the investigator.

In addition to this very real obstacle, which is most certainly present in a great number of cases, the investigator having surmounted this difficulty to his own satisfaction, by the averaging of radii, selection only of uniform trees, or other method, is then confronted with the question of the time factor represented by the growth rings. Do the rings laid down on the trunk represent each the growth of one year? The writer holds that such has not yet been satisfactorily established, and holds, further, that lacking definite proof in either direction his observation leads to the theory that the rings in our taxads are not annual, but represent recurring periods of growth and quiescence, which represent not a calendar year each, but probably only a portion of a year, so that two or three rings may be formed every year. The evidence tending toward such a belief is considerable. First of all the climate of that part of New Zealand covered by the taxad forest is of such nature as to make for intermittent rather than regular growth. There is not found here, as in the north temperate zone, two distinct seasons—one warm, the other cold—but rather, a period when generally the average temperature is rather low, and a period when the average is rather high, both averages being within comparatively narrow limits, while it is very common to have considerable periods in the warm season when the temperature is as low as is usually recorded in the winter, and conversely periods during the winter, when regular summer temperatures and weather will be experienced. The first snow ever seen by the writer fell on a Christmas Day, and lay for two days near sea level in Canterbury, while conversely pastures often get a fresh period of growth in June and July following some considerable period of mild, balmy sunshine. In other words, it is the weather, and not the climate, which may be reasonably expected to delimit the growth

periods, and the weather of New Zealand is, as is well-known, exceedingly changeable. Here exist no period of hot days and sultry nights without a break for some months at a time, followed by an equally regular and unbroken period of below-freezing temperatures both day and night such as characterise the continents of the north.

Experimental work in regard to the nature of growth of the taxads done from 1922 to 1924 by the Biological Department of Canterbury College, while not conclusive in many respects, at least established definitely that in Canterbury, which region has the most distinctly marked seasons to be found in New Zealand, the growth of the chief taxads is sometimes, if not regularly, intermittent. Two general periods of growth were recorded, one a spring growth followed by a short resting period in December, then a second growth of approximately equal activity. Furthermore, it was definitely established that if two growths occurred during the year, two rings of wood were formed in the twigs concerned. The growth periods were not altogether coincident on all parts of the same tree, however, the second growth not being always made on shaded branches, while sporadic growth on some twigs at various times was recorded. The investigation as conducted failed to definitely establish what ring or rings were laid on in the main trunk at the times of branch activity, but at least it casts serious doubt on the assumption that all rings are annual rings by definitely establishing that in the branches all rings are not annual rings, but may represent two rings or more per year.

Further doubt as to the validity of the "annual ring" theory is cast by the existence of what may be called "split rings" or fused rings, in which one of the narrow limiting bands of thicker walled cells divides into two bands of equal size and general character with a band of thin walled cells intervening. Recent wood structure work at Canterbury College has disclosed this feature in kahikatea, and it is hoped that further investigation will shed more light on the incidence of this phenomenon. This is surely a most remarkable occurrence if the rings are truly annual, and this chance discovery of such a form of growth is considered by the writer as possibly furnishing a clue to the nature of the scalloping previously referred to as being so evident in several of the taxads. Such development is visible only under the microscope, so that field investigators would not have it brought to their notice, but the matter seems worthy of investigation. If, as the writer suspects, this splitting of the rings is a common occurrence, it will go far toward proving the claim that growth occurs as a series of loosely defined and overlapping periods of cambial activity not definitely related to calendar periods, a matter, by

the way, which can be conclusively proved by dendrograph studies.

Lastly, for the benefit of those who cling tenaciously to the "annual ring" theory, it may be stated, by way of analogy, that the researches on *Pinus radiata* by D. T. MacDougal* in California and Hutchinson† in Canterbury prove definitely that this tree, both in its native habitat and here in its new home, characteristically forms two or more rings per year often regularly for many years in succession.

In view, therefore, of these matters, it is considered that the basing of any data in regard to growth and yield of our native taxads upon growth ring measurements is utterly unreliable, and any results so obtained of no value, due firstly to the fact that the form of development of the rings is such as to give no true function of the volume, and secondly to the fact that all indications of our very scanty investigations are that the rings formed are not annual at all, but seasonal, and not definitely connectable with calendar years.

So much for the taxad forest. With regard to the native beech forests, the position would seem to be happier, at least in the main. The great forests of commercial beech stands occur principally in the South Island, and are of two main species—*Nothofagus fusca* and *N. menziesii*. Both these species develop boles of smooth and symmetrical form, and possess rings which are even, regular, and distinct, so that the field investigator finds little difficulty in obtaining satisfactory analyses. This applies at least to the beech stands of both the above species investigated by the writer in the Buller Valley. Whether or not the rings formed by the beeches in this region are annual is not yet definitely established, but the arguments against such a supposition which hold for the taxad forests do not apply in this case. True, the trees are evergreen, and the climate is the same for the beeches as for the taxads, but superficial observation seems to establish that there is a definite period of growth commencement in the spring similar to that of deciduous trees, and in the absence of evidence to the contrary, it would seem quite reasonable to assume that the rings are annual in nature. Granted this point, it is obvious that these two species may be safely handled for mensuration purposes on growth ring measurements. The even, regular nature of the ring makes its width a true indicator of volume, while the annual nature of its formation gives it a true time index.

Caution is necessary, however, in extending this principle to the other New Zealand beeches. While no matter has yet arisen to

cast any doubt upon the annual nature of the rings, where distinguishable, considerable trouble has been experienced in the definition of the rings on log sections in the case of *N. truncata*, the Clinker Beech of the Pelorus Valley, in regard to which the rings are often so vaguely indicated as to render accurate counting very difficult. Faint strands of parenchyma so confuse the field of vision as to give rise to an impression of elusiveness and lack of finality. The rings of the black beech, *N. solandri*, as found in the Pelorus Valley, are free from this defect, being usually plainly delineated, but in this case the form of growth precludes an over-ready acceptance of increment borings or radial measurements. The characteristic warty ridges and long spiral groovings of the black beech trunk, as shown when the bark is removed, are all faithfully recorded in the outline of the rings, which in cross-section reveal a series of sharp flutings, undulations, or crenellations very similar to the cogs mounted on a gear wheel. These patterns, as shown on successive concentric rings, do not increase in size, and consequently give rise to spiral obliquity of longitudinal arrangement causing the well-known interwoven grain of this timber. It is evident that decade measurements along any radius of a section will not give a true function of volume growth, since for one decade the radius might cut squarely through the point or base of one of these "cogs" or crenellations, while the next decade would record a measurement at an angle highly oblique to that of the rings as it passed along the side of such a cog. For this reason growth-ring measurements on black beech seem open to considerable question.

Turning now from the native forests to the exotic conifers which are now so greatly in evidence throughout New Zealand, and to which this Dominion is seemingly very largely committed both in State and private forest enterprise, there is little to be feared in regard to the first condition. The exotic trees which are being planted are in large measure the selfsame species upon which the methods under discussion were developed, and here, in their new habitat, they have persisted in their characteristic smooth, clean-butted and evenly cylindrical bole, forming smooth, circular rings of even thickness, whose radial measurement, except in abnormal cases, furnishes a true function of the volume.

The third generation of one at least of these introduced conifers is now approaching maturity in many cases throughout the country, and no departure from this characteristic form has yet become evident, nor would there seem to be any good reason to presume that any change of form might be expected to develop. Measurements of growth rings can, therefore, be confidently relied upon to furnish a true index of volume growth.

* Publication of Carnegie Institute, 307 and 350.

† Unpublished.

Regarding the second condition, however, the reliable index of time afforded by the growth rings, a note of caution needs to be struck. Of the exotic conifers so far developed on any large scale, the *P. radiata* is overwhelmingly predominant, and furnishes the great bulk of all commercial afforestation accomplished to date. While no data is at hand as yet which causes any doubt that with the other conifers the rings are of definitely annual formation, it has been definitely established, as previously referred to, that the above-mentioned species, *P. radiata*, frequently forms double, and sometimes triple, rings, in Canterbury at least, so that care must be exercised in all increment studies made on this species in this locality, that due consideration is given to this point. This duplication (or infrequently triplication) consists in the alternation of light and heavy rings of autumnal (dense) wood, the light ring invariably lying nearer to the heavy ring outside it than to the ring inside it.* In stem analysis work, where complete log sections are available for study, it is generally possible to detect these duplicate rings if the age of the tree is definitely known, as is frequently the case in plantations.

Doubtful cases can be frequently checked by referring to the adjacent sections up and down the trunk, where a more definite conclusion may be drawn. If the age of the tree is unknown, except from the growth ring record, an element of uncertainty is introduced which will vary from negligible to an extreme of 100 per cent. in the case of increment borings, where whole section surfaces are not available for comparative study, as instanced by an increment boring to the pith of a 7 in. *P. radiata* being recorded as 14, 21 and 28 years respectively by three foresters of some slight experience with stem analysis work. The correct age was not ascertained in this instance, but the D.B.H. measurement indicates the true count as 14.

Whether this duplication is an innate characteristic of the tree, or is the result of climatic factors is uncertain. The climate of Canterbury is very similar to that of Monterey, but Shreve has so far been unable to correlate duplication of growth rings with meteorological factors in California, though some connection seems intimated. It is a point worthy of study, as if such habit is climatically induced it may be expected that the other pines and *Pseudotsugas* now being largely planted will develop this characteristic. A secondary period of leaf formation in Douglas fir about 1st February is quite characteristic, and if this be found to produce intermediate or secondary

rings, it might show light on the nature of taxad growth rings already discussed.

The gist of the whole matter presented so far in this paper, then, resolves itself into this: That for determination of current or periodic increment, one cause or another intimately associated with the trees themselves renders the northern temperate method of radial growth ring measurement wholly unreliable or questionable, so far as present knowledge goes, in the taxad bush, and open to grave error in regard to *P. radiata* at least, of the exotic conifers, while the exotic eucalypts, which form no distinct rings, are also ruled out. The method works then, seemingly, as far as full reliance and accuracy are concerned, only with the beeches, and then with exceptions in regard to the minor species.

This means that we here in New Zealand will be forced to rely almost wholly upon actual measurement at recorded times for the formulation of our future yield tables. It means, in short, a large scale application of the permanent sample plot method. This is really not a serious hardship. It is the basis of all work of this nature done in the Philippines, Central America, and the East Indies, and much of the work done in India. It will certainly delay, to some extent, our work in the gathering of such statistics, especially in regard to the native bush, but when the data is finally gathered it will at least be definite, and we will know where we stand in matters of growth. There will be none of the uncertainty which always attaches itself to stem analysis work in regard to mortality rate and stand per acre at past ages, rendering all long-time work open to question. The stem analysis method is at best only a short cut make-shift even in the northern temperate forests, as all leading American foresters will agree, intended only to serve until such time as more accurate data from sample plot records is available. Perhaps it is as well that this method in New Zealand is so clouded with unreliability, as it forces us at once to a full acceptance of the longer time, but more accurate and authentic method of permanent sample plots periodically remeasured. In regard to the exotic plantations, the task is easy. The founders of New Zealand were methodical men, and left many records behind of the afforestation work which they commenced. With this data as a base the foundation of yield tables, especially in Canterbury, where the early afforestation schemes were widely developed, becomes comparatively simple. In fact, the only thing hindering the full undertaking of this work in that province is lack of trained men to carry out the work. In other parts of New Zealand plantations on a commercial scale are of much younger date, so that full data is unavailable, but the date of origin, stocking, and other details are available for these recent stands, and there is no reason

* This result, recorded by Hutchinson for Canterbury, is identical with the findings of Shreve (Carnegie Institute Pub. 350) for California.

why a widespread system of permanent plots should not be established at once, covering the whole of New Zealand's exotic forests, and constantly extended as the work progresses. By this means, at the end of one rotation a wealth of data will be available from which we can draw conclusions of utmost value regarding the whole field of tree growth in New Zealand.

And in the case of the native bush, the writer considers the need for an extensive system of sample plots is fully as great, and even more urgent, for in this case we have no records whatever. Only until such a system of carefully measured and remeasured plots or cruise lines has been in existence for five or ten years, covering many types of bush, will we be able to decide with any basis in sound fact whether we have any increment in our native forests; whether many of our younger stands of *pōle rimu* such as are now being ruthlessly butchered, would or would not make sufficient increment within one or two decades to justify their being withheld from milling for the present; and finally whether, providing we can establish a taxed crop of reproduction, it can be expected to reach maturity within any reasonable time.

THE ANATOMY OF NEW ZEALAND WOODS.

PART I.: LABORATORY TECHNIQUE.

(C. S. Barker.)

Introduction:

This paper represents the results of experience gained during the past year in a microscopic study of the structure of various native and exotic timbers of New Zealand.

The work commenced in a small way during 1925 in the School of Forestry as an advanced study in Wood Technology, having for its object the formation of a scheme of identification for these woods. Little time was available for the project, however, and only a very small beginning had been made by the end of the College session of last year.

At this time the State Forest Service of New Zealand made available a sum of money for work in this subject in co-operation with the School of Forestry, and under this arrangement the whole of the long vacation of 1925-6 was devoted to this work, and it has been carried on throughout the session.

The aim of the project is, as has been stated, primarily to obtain an authentic system of wood identification; but further than this it includes a study of the whole basic structure of our native woods, with a view to obtaining definite information regarding their anatomy

—the types, arrangement, proportion and relative size of the component cells. These factors have a very distinct bearing on the possible use of the various woods for purposes such as wood pulp, the designing of saws, etc., and also have much to do with the ease or otherwise with which the woods may be seasoned or artificially impregnated against decay.

In presenting the results of this study it has been thought advisable to commence right from the very beginning of the project, and explain in some detail the whole of the technique which has been evolved for preparing the woods for microscopic study. The reason of this is that while microscopy has been long practiced in the sciences, comparatively little work has yet been done on woods, and the literature available dealing with the sectioning and mounting of wood specimens is exceedingly limited. Some useful data on microtomy was obtained from Cross and Cole's book, "Modern Microscopy," and Chamberlin's "Methods in Plant Histology," and some work of value in regard to the whole field of work with wood was found in Jeffrey's "Anatomy of Woody Plants," and Brown's "The Preparation and Treatment of Woods for Microscopic Study," in the Journal of the Torrey Botanical Club of April, 1926. Aside from these general guides, the whole of the technique had to be evolved as a result of experiment, and is presented here hoping that it may prove of benefit to all students on this work in New Zealand.

Preparation of Wood for Sectioning:

Before the wood is in a proper state for sectioning a considerable amount of preliminary work is involved. The wood has to be cut into suitably-sized blocks, the air removed and the tissues softened.

Wood for microscopic study must be more or less typical of the species, this being essential if only one piece from one tree is to be worked upon. It must be from a clear and even textured part of the stem, and, of course, free from knots and spiral twists. If it can be procured, green wood is preferable to dry; but if only seasoned wood can be had, it must be from the interior of largish pieces, the reason for this being that the exterior parts of seasoned wood most probably have seasoning checks, and even if these are of a minute character, it would be disastrous for good work.

Preparation of the Wood Blocks:

The blocks must be shaped in the planes in which the sections are going to be cut. It is of the greatest importance that these surfaces be truly transverse, radial and tangential, especially when a plain metal jaw holder is used. A sharp chisel was found to be the best tool to use. The blocks were studied with a hand-lens in the case of species that had nar-