# THE GROWTH OF PINUS RADIATA IN IN UNTHINNED STANDS*

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*Summary*

*The variation in growth of* radiata pine *on different sites in New Zealand is discussed. Comparison is made of tree mortality in the pumice region of the North Island with that experienced in other parts of the country. Some observations are made on the incidence of malformation and on the yield to be expected from unthinned 30 year old stands.*

*Introduction*

Radiata pine plantations in New Zealand have amounted to some 560,000 acres. Ninety per cent. of them are now at least 20 years old, only a few thousand acres have been thinned and the chances that more than an equal area of the remainder will receive any further silvicultural treatment are now negligible. The result is that some half million acres of radiata pine will be harvested without having received any thinning at all.

Large scale felling of plantations started about 1940 and some thousands of acres have now been cut over. It might be thought that there was a wealth of data from which to review the growth of radiata pine in unthinned plantations in New Zealand, but the number of serious gaps is disconcerting. Little attention was paid in the past to the measurement of stands, accurate and standard techniques have only been developed in the past two decades, and the normal course of growth has been confused by extraordinary events such as drought and insect attack. Above all, as far as the Forest Service is concerned, there was prior to 1948 a serious lack of plots for continuous observations over a series of years. Deductions and estimates can therefore only be based on a series of short term observations (many consisting of one measurement only) spread over stands of different ages in various localities. In addition the coverage of plots recorded to date is uneven both for age classes and localities and so much of the review can only be of a tentative or general nature. So far as is known the only extensive series of plots under continuous observation for some years is in one of the large privately-owned forests in the North Island pumice country; the data have not yet been made available.

In referring to growth, the conception of site index, widely used in America, and recently applied by Lewis (1954) to New Zealand radiata pine, will be adopted. The site index is the top height (the

* Paper read at Eighth New Zealand Science Congress, Auckland, 1954.

mean height of the 100 trees of largest diameter) at 20 years. In terms of the Forest Service 1949 Yield Tables for Rotorua site indices of

| | | | | |
|---|---|---|---|---|
| 90-110 | correspond | to | Site | I |
| 73- 89 | ,, | ,, | ,, | II |
| 56- 72 | ,, | ,, | ,, | III |

*Height*

The assessment of site in terms of height growth is comparatively easy and free from disturbing factors. A site index of 100 corresponds to top heights of 137 ft. at 30 years, and 151 ft. at 40 years, and an index of 65 to top heights of 93 ft. at 30 years, and 107 ft. at 40 years—the great majority of stands lie within these limits.

There appears to be a rough correlation of site with latitude. Data from a limited series of plots in the north part of the North Island show average indices of 85 or over—the better parts of Waipoua, Riverhead, Tairua, Kaipara, Athenree, and Maramarua Forests all show sample average indices of 88 or over; and Rotoehu Forest has an average of 100-110. Passing to the south the average figure for Golden Downs Forest in Nelson is 82, and for the small number of plots observed in Southland it is 72. The poor tree-growing conditions in Balmoral and Eyrewell Forests on the Canterbury Plains are reflected in indices of the order of 60.

As might be expected altitude plays a considerable part among the climatic site factors. At Kaingaroa there are indications that between 1,400 and 2,400 ft. it accounts for a fall of about 20 ft.; the radiata pine at Karioi, at over 2,000 ft. in the centre of the North Island, has an index of only some 70 ft., while in Beaumont Forest in Southland, Cruttwell (1952) found a difference of 30 ft. in the heights of stands at 500 and 1,500 ft.

It is only recently that any detailed attention has been paid to the variation of stand quality with soil. The results of the first studies in Northland (Levy and Sutherland 1954) and in Tairua Forest (Weston and Vucetich 1954) show remarkable variation in the quality of radiata pine on different soil types, and emphasize the need for caution in accepting generalizations involving other site factors.

*Stand Density—Numbers and Basal Area*

It is a commonplace saying about radiata pine that it "thins itself"; and it is in attempting to find the statistical basis for this statement that we encounter the major difficulties referred to above—the lack of continuously observed plots, variation in site factors, and extraordinary events.

In the nineteen twenties and thirties mortality in the pumice region of the North Island, where the most observations have been made, was not remarkable. If the 21-25 age class is taken as near the critical point, an early yield table (Pollock 1943) for average Site I and Site II shows for a stand 23 years old (Site Index about 91) a stocking of 365 stems having a basal area of 275 sq. ft. If these figures are representative—and they are partially confirmed by an independent yield table and a few plot observations—it would appear that mortality during that period was less than normal for the pumice stands. But during the next decade the effect of drought and *Sirex noctilio* caused a large decrease in stocking; some indication of its extent may be obtained from the following figures for Kaingaroa Forest:

TABLE 1

| | *Total number of live trees.* 6 x 6 ft. | 8 x 8 ft. | *Basal area. Sq. ft.* | *Source* |
|---|---|---|---|---|
| 1943 Pollock's Y. T. Age 23 | 365 | | 275 | For Rotorua Conservancy Sites I and II. |
| 1946 Foster (1947) Age 22 | 450 | 220 | N.A. | From assessment results. |
| 1948 1923-27 age class. Average age 23 | 287 | | 251 | From 40 plots in stands classified as fully stocked. |
| 1951 1926-30 age class. Average age 23 | 166 | | 191 | 26 plots in stands previously classified as 80% and 100% stocked. |
| 1953 Average age 25 | 154 | | 205 | 26 plots as above. |

Similar abnormal reductions, both more and less, have been noted in other North Island forests. But elsewhere the stands in the 21-25 year age class did not suffer such serious mortality over the period 1948-53:

TABLE 2

*Stocking Figures*

| | *Age Years* | *Stems per acre* | *Basal area sq. ft. per acre* | *Source.* |
|---|---|---|---|---|
| Auckland | 21-25 | 285 | 234 | 7 plots 1950-53. |
| Karioi F. | 21 | 385 | 277 | 912 acres assessed 1948. |
| Golden Downs F. | 21-24 | 378 | 271 | 12 fully stocked plots, 1951. |
| Nelson | 21-25 | 310 | 259 | 24 random plots, 1952. |
| Southland | 20-24 | 406 | 287 | 4 plots 1950-53. |

These numbers of plots are inadequate (only those of the Golden Downs random set are considered statistically representative); they are inserted to give some idea of a supposedly normal stocking for the age class 21-25 years.

One of the fastest tempos of mortality of late years has been at

Rotoehu Forest in stands originating from 6 x 6 ft. planting from 1939—Site Index 100-110:

*Mortality at Rotoehu Forest.*

| *Age* | *Total number of trees per acre* |
|---|---|
| 5 | 1,030 |
| 6 | 880 |
| 8 | 600 |
| 10 | 420 |
| 12 | 300 |
| 14 | 220 |

In the north part of the North Island, of which the pumice stands provide the focus, the general trend of mortality in the past decade has been:

Mortality starts earliest and progresses faster on the better sites and in the denser stands.

The age class 20-25 has been the most susceptible.

Mortality is heaviest in suppressed, sub-dominant, and co-dominant stems, in that order. (It has also been observed that the mortality from defoliation by *Selidosema suavis* in Canterbury decreased progressively as the crown class improved, i.e., from suppressed to dominants.)

Malformed stems have died to a greater extent than normal trees.

The growth of basal area in an unthinned stand of radiata pine has been the subject of much conjecture in recent years—whether it rises in a steady curve, fluctuates, or reaches limiting values. A comparison of plots all over the country (Lewis 1954) shows that a steady rise is probably true as a general trend and that very high values can be reached (over 600 sq. ft. has been observed in one small area); but major fluctuations and retardations do occur from various causes corresponding to the enhanced mortality. In many of the pumice and other North Island stands basal area has shown a drop in most age classes in the past ten years, particularly in stands of the 1925-1930 period, with at least a partial recovery (note the positive increment between the 1951 and 1953 values in Table I). It is too early to say yet to what extent this fluctuation is abnormal and how it will continue. But it is considered that basal area will rise again appreciably above present figures; in the past ten years many older stands on the pumice of, say, the 1915-1925 class, have retained more trees than the heavily affected 20-25 year old plantations. Whether the acceleration of mortality in the past ten years can be attributed wholly to the 1946 drought and the subsequent build-up of *Sirex* is a matter for further research. The primary cause may be connected with the water relations of the tree, but experimental evidence at present is quite inadequate.

So far as can be seen the decrease in numbers of trees and the growth of basal areas has progressed at a slower and steadier rate in other parts of the country, notably in the South Island. It is convenient to think that the higher the life tempo as produced by favourable climatic and other site factors the more unstable is growth progress, and that a more rigorous climate involving a resting season makes for longevity and high production; but here again the observed data are neither complete nor conclusive.

*Malformation.*

Malformation is the term commonly used to denote misshapen stems, either forked trees or those with "kinked" boles arising from the death of the leading shoot or its suppression by one or more side shoots. It is a matter of common observation that the more severe the climate the greater the proportion of malformation, and examples can be seen in the higher parts of Kaingaroa, Karioi, and Naseby Forests. In Kaingaroa the incidence of malformation, in percentage of basal area, was found to be:

| | *Site I.* (S.I.90-110) | *Site II.* (S.I.73-89) | *Site III.* (S.I.56-72) |
|---|---|---|---|
| 1946 assessment survey over 170 compartments | 38 | 45 | 54* |
| 43 mortality plots 1950 | 33 | 44 | 63 |

* Worst areas not assessed.

The extent of malformation however varies widely. For example, in Golden Downs Forest (in 25 permanent yield plots, age 20-25 years, average Site Index 79, measured 1952) only 13 per cent. of the total volume was accounted for by malformed trees (reckoning their volumes as the same as those of normal trees of the same d.b.h.). As for the causes of malformation, insects, climate, and genetical and nutritional factors can all play their part, but so far little information is available of their relative weight on any specific site.

The percentage of malforms is apparently not affected by planting or survival densities, but in the wider spacings there is a higher survival of malforms which are enabled to grow on and account for an appreciable percentage of the standing volume. Macarthur (1952) found the following percentage of stems and timber volumes in plots of various degrees of stocking in Kaingaroa Forest:

TABLE 4

*Percentages of malforms and average stem diameters in plots of various spacings.*

| *Initial stocking, per acre* | *Stocking of live trees at 28 years per acre* | *Per cent of malforms by stems* | *Percent of 6 in. top vol. on malforms* | *Mean diam. of 60 largest trees, all classes, Ins.* |
|---|---|---|---|---|
| 1,003 | 261 | 11 | 4 | 18.7 |
| 565 | 218 | 23 | 7 | 19.1 |
| 457 | 183 | 22 | 10 | 19.6 |
| 355 | 165 | 38 | 23 | 20.5 |
| 218 | 119 | 39 | 27 | 21.3 |

A redeeming feature is that malformed trees appear to be more susceptible to adverse influences than normal trees. In Kaingaroa

Forest in 1950, of trees that had died within the previous year in 59 mortality plots (all sites combined), 78 per cent. by basal area were accounted for by malforms and only 22 per cent. by normal trees. In 1951 and 1952 the figures for deaths of normal trees in 80 and 100 per cent. stocked stands were 18 per cent. and 11 per cent. respectively. Of course not all malforms are unmerchantable, but in terms of a 6 in. top volume they only yield 60-70 per cent. of the volume of normal trees, and under ordinary extraction conditions probably a good deal less, as logging waste will tend to be higher. The onset of abnormal mortality that was associated with *Sirex* attack from 1946 onwards was therefore concentrated first in the most undesirable trees, the malforms and the weaker members of the stand. The effect is that of low thinning, possibly more or less than is desirable, which certainly in its less intensive form will result in an improved stand in the course of a few years.

*Volume.*

Volume production is closely associated with basal area, and over the short period during which reliable observations have been available it has fluctuated accordingly. In North Island areas in the past 10 years 6 in. top volumes for 30-35 year-old stands on Sites I and II have ranged from 7,000 to 11,000 cu. ft. per acre. Locally, where mortality has been exceptionally severe, volumes may fall to 5,000 cu. ft. per acre or even less. These figures have been conditioned by the abnormal mortality from *Sirex* and other causes, and even in the better areas are rather less than the yields predicted by full stocking yield tables based on stands apparently matured by steady and uninterrupted progress. Whether the North Island stands that have undergone a natural thinning will, if left alone, later produce volumes greater than or equal to those showing a steady increase cannot be predicted with certainty. There has certainly been a response in the way of enhanced increment on the remaining trees in the past few years.

In stands over the age of 30 years a number of plots have been measured which have shown high yields, up to 23,000 cu. ft. to a 6 in. top. There is a general characteristic of high basal area and more numerous stems than are found today in younger pumice country stands (37 plots in the 31-40 age class averaged 254 stems), but the majority of the high-yielding plots were in the form of small woodlots and are hardly conclusive enough for specific deductions. On a forestry scale no authentic records exist of unthinned stands of 20 acres or more having yielded more than 12,000 cu. ft. per acre to a 6 in. top.

*Planting Density.*

The greater part of the half million acres of unthinned radiata pine was established either at 6 x 6 ft. or 8 x 8 ft. spacing. So far as their relative silvicultural development is concerned there is very little difference in number of stems or volumes at the age of 30 years; mean diameters tend to be a little higher in the wider spacings, and branching becomes progressively heavier though not markedly so. The 6 ft. spacing was designed to produce better quality timber, but the effect of green and loose knots and branch size on timber quality has yet to be thoroughly investigated. In areas where malformation is light, stands of 8 x 8 ft. and 9 x 9 ft. planting have not been shown to be significantly inferior to 6 x 6 ft. planting, and where wind is a danger as in Canterbury they may be the better silvicultural practice.

The degree to which radiata pine asserts dominance is illustrated by the figures for mean diameters of the largest 60 trees in Table 4, there being only 2.6 ins. difference between plots originating from 218 to 1,003 trees. Even more spectacular evidence is to be found in the stands resulting from grown-up nurseries. At Morton Mains, Southland, for example, a grown-up nursery 24 years old which must have originated from at least 20,000 trees per acre showed 915 stems per acre with mean diameters of 8.0 ins. for all stems and 13.6 ins. for the 100 largest stems. In Pebbly Hills Forest a mile away, a 23 year stand of 526 stems originating from 8 x 8 ft. planting, had a mean diameter of 15.3 ins. for the 100 largest stems. Other mortality and stem diameter figures could be quoted, but those given above go to confirm that radiata pine does to a large extent "thin itself", as compared, for example, with Corsican pine. It is not the purpose of this review to discuss the results and possible benefits of thinning or whether unthinned plantations are in a dangerously unhygienic condition.

In stands which follow the general trend the M.A.I. culminates at 25-35 years—the higher the site quality the shorter the period. This may not have the significance it once had in the forestry textbooks, but it does emphasize that in terms of timber volume production radiata pine if left unthinned by man is essentially a short rotation tree.

To sum up:

Yields of unthinned radiata pine of 30 years of age have amounted to 7,000 to 11,000 cu. ft. per acre to a 6 in. top, from sites with indices of 80 and upwards which have carried 150-350 trees. In the past 10 years in the pumice area of the North Island there has been an increase in mortality associated with *Sirex* which has reduced stocking at 25 years to some 150 stems of a basal area of some 200 sq. ft., roughly in the nature of a low thinning. In other parts of the country where growth conditions are less favourable the decrease has been less accentuated or has progressed more steadily, and 250-350 stems per acre are to be found at 25 years.

Whether mortality in the heavily affected areas will decrease cannot be predicted with certainty, but it appears that there will be at least a temporary lull. For the present stands, 70-100 stems at 50 years appear likely. Larger volumes may possible be obtained at greater ages from stands with a low rate of mortality. At present the best estimates are based on country-wide data and incorporated in the Universal Yield Table (Lewis 1954). The effect of 6 x 6 ft. and 8 x 8 ft. spacing on the numbers of trees and merchantable volumes disappears from about the age of 25 years.

Allusion has been made in the foregoing to the many gaps in our knowledge of radiata pine. Variation of the stand with soil type, and soil changes, are almost unstudied, plot coverage for growth data is uneven, with a negligible representation of plots on soil types, such as sand, which may be of increasing importance in future planting. Old stands on a forestry scale over 30 years old are sadly lacking. Variation of tree form with site has not yet been systematically studied, and few conclusions have yet been reached on the relationship between spacing, size and stocking, and timber quality. As a silvicultural system, plant-and-leave clearfell-and-trust-to-luck has so far worked reasonably well, but even with the remarkable pine there may be more in exotic forestry than that.

## REFERENCES

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