THE NATURAL REGENERATION OF PINUS RADIATA ON KAINGAROA FOREST

By J. URE

Introduction

In central North Island districts there are vast areas of untreated *Pinus radiata* which were planted between 1925 and 1935. On suitable sites the rate of growth and elimination of surplus stems has been rapid ; at 20 years a typical fully stocked stand averages 90 feet or more in height and carries some 200-300 live trees per acre of which more than half are useless. This moribund element, which is a normal feature of all untreated stands of *P. radiata*, will always be a focal point for all pests with a taste for this species. Although the possibilities are as grave as the cure is obvious, the backlog of silvicultural work is so enormous that it is quite beyond the capacity of any labour force which can be forseen to-day ; it is imperative therefore that we concentrate on essentials and do not fritter away our resources on a lost cause.

In the first place there are more valuable species such as *P. laricio* and Douglas fir which must receive attention before it is too late. Secondly, new crops of *P. radiata*, both naturally and artificially established, are following in the wake of logging operations ; these young stands occupy manageable areas which can and must be treated.

Early Development of Natural Regeneration

The development of natural regeneration following clear felling has been watched in three areas on Kaingaroa Forest but the prolific regeneration which follows a fire in *P. radiata* has not been observed in any detail by the writer, and no suggestions are offered on this subject, nor should the conclusions reached in this article be applied to such areas.

The climatic conditions of the region are : 56 inches annual rainfall, more or less evenly distributed ; an extreme grass minimum temperature of 10° F. and a maximum shade temperature of 90° F. A ground frost of up to 10° may be experienced in any month of the year. The altitudinal limits of the areas mentioned in this article are 1,500 feet and 2,000 feet. The soil, derived from Kaharoa pumiceous rhyolite overlying older pumice showers and probably old soil profiles, is deep and freely drained.

The first area to be dealt with lies towards the western escarpment of the Kaingaroa Plains at an altitude of 1,800 feet. The country is

gently undulating and contains numerous small hollows where damaging frosts occur throughout the growing season. Excluding these adverse climatic conditions, which are of local significance only, the quality of the site is good.

The original crop was planted at 6 by 6 feet in 1918 and had not been treated when clear felling commenced in March, 1946. The average height was 120 feet with a standing volume of 10,000 cubic feet in 200-250 trees per acre.*

The usual flush of herbaceous weeds soon colonised the area in the spring and summer of 1947, together with a few seedlings. The stocking had increased considerably by May, 1948, when a 1% random sample was obtained from the areas felled between March, 1946, and June, 1947; separate samples were taken from 5 consecutive felling periods to assess any seasonal effects whilst obtaining quantitative data on the adequacy of the stocking. A summary of the results of this survey is given in Table I.

TABLE I

STOCKING OF NATURAL REGENERATION OF *P. RADIATA* KAINGAROA FOREST, MAY, 1948.

Period of felling	Trees per acre including dead	Trees per acre over 1ft. high	Percentage dead and dying trees	
			From *Hylastes*	From other causes
March to June, 1946	5300	3200	17	8
July to October, 1946	5000	2400	15	10
October to December, 1946	5800	2400	8	13
December to March, 1947	2100	600	8	12
March to June, 1947	1600	100	7	11

The distribution was patchy with many dense groups carrying 50 or more seedlings per square yard, contrasting sharply with very sparsely stocked areas where there was less than 1 per square yard. Hollows subject to damaging frosts were always poorly stocked, as were well worn snig tracks and the immediate vicinity of hauler stands.

* All volumes quoted are to a 6-inch top inside bark.

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The variation between the separate plots was too great to allow any significance to be attached to the variation in stocking on areas felled between March and December, 1946. The sharp drop in stocking evident on areas felled between December, 1946, and June, 1947, may be significant, but the development of the crop here is so markedly behind the other areas, and recent germination so common, that this is considered unlikely. Although no further information has been collected, an ocular estimate confirms the impression that there is no practical difference in stocking between areas felled at different times of the year.

The casualties caused by all agencies combined do not exceed 25% which, because of the original high stocking, is negligible. The majority of the deaths were caused by *Hylastes ater*, Payk, with the peak death rate two years after felling and a sharp drop in the third year, due to the increased vigour of the trees rather than any pronounced drop in the population of the insect.

The influence of aspect on the early development of regeneration is clearly demonstrated in another area on the same soil type as the first, but divided more or less equally between the steep sides of a deep gully running east and west. The original crop was planted at 6 by 6 feet in 1918 and carried 280 trees per acre and a standing volume of 10,000 cubic feet when clear felling commenced in August, 1948. A volume of 6,400 cubic feet was extracted by skyline.

Sampling of this area in December, 1949, was designed to test the adequacy of the regeneration and, incidentally, the effect of a southerly aspect compared to a northerly one. The stocking on the area felled between November, 1948 and February, 1949, was 5,800 per acre on the slope facing the sun and 1,800 on the opposite side. The average height on the sunny slope was about a foot and on the shaded aspect 6 inches.

On the sunny slope about half the ground not covered by heavy slash had been invaded by the usual herbaceous weeds and a few specimens of *Pomaderris phylicaefolia* and *Coriaria ruscifolia*. On the dark side the weed growth was more vigorous, increasing towards the bottom of the slope where it became quite dense. There were many individuals of the following species present : *Coriaria ruscifolia*, *Coprosma* spp., *Hebe salicifolia, Olearia* spp., *Pittosporum tenuifolium* and *Pteridium esculentum*. There is no reason at this stage to suspect failure of the regeneration on the dark side of the gully, but the vigorous weed growth may have to be cut back when the first thinning is applied.

Most of these points are purely academic, as it is evident that adequate natural regeneration can be expected on a good site after clear felling a parent crop 28-30 years old. Regeneration fails or is scanty in frost hollows, and may be limited on steep slopes with a

southerly aspect. There is some danger, however, that the stocking may be considered inadequate one year after felling and planting commenced whilst germination is still taking place, with the result that money will be thrown away, if the stocking is later doubled by natural means.

Future Treatment

Nature, unaided, provides a new crop of vigorous well rooted trees which compare more than favourably with a planted crop of the same age. Although the original untreated crop contained many undesirable parents there is no guarantee that nursery stock is free from such contamination as long as seed, however carefully it may be selected, is collected from untreated stands. The need for early treatment of natural regeneration is obvious not only to maintain full vigour but also to eliminate trees of poor quality as soon as possible. As some work of this type has already been carried out on Kaingaroa the conclusions reached may be of some interest to others with a similar problem.

The first point of importance is the rapidity with which regeneration forms a thicket with attendant loss of vigour in all trees. The decrease in effective crown surface is swift, and the change from a vigorous crop to an unthrifty, etiolated state can take place in one growing season. Consequently the timing of the first thinning is of vital importance if full vigour is to be maintained ; furthermore, the intensity of this thinning cannot be decided without considering later thinnings and their spacing throughout the rotation, if the maximum returns are to be obtained from the minimum addition of capital.

Some indication of the possible development of a thinned stand may be obtained from marginal trees which enjoy conditions at least approaching full growing space. Such trees are liable to have thicker bark and a more pronounced butt swelling than those growing inside the stand, but it may be assumed that the effect of these irregularities on the breast height diameter would be cancelled out by the fact that marginal trees are subject to crown and root restriction on three sides. It was assumed therefore that diameter growth equal to that of marginal trees, could, by several thinnings, be obtained from the stand as a whole.

The mean diameter of 100 marginal trees was found together with the mean of 100 main crop trees within the same 29-year-old compartment ; gross malforms of large diameter were not included in the 100 marginal trees measured. As a check, the process was repeated in a 22-year-old stand on a better site. In the first instance, the difference in mean diameter was found to be 7.9 inches, which is equivalent to 12 years growth, that is between the ages of 17 and 29 years.
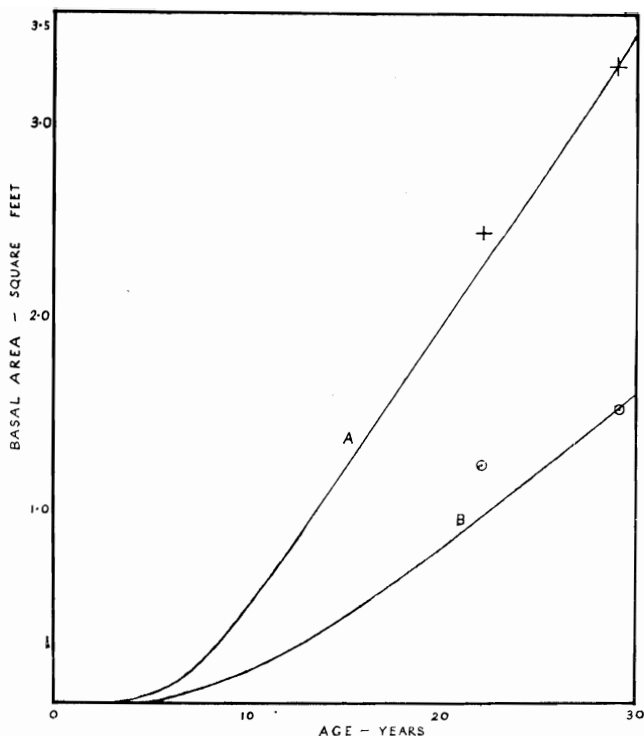
Fig. 1. Basal area/age curves for :—
(A) The mean marginal tree, possibly equal to the mean tree of a thinned stand.
(B) The mean main crop tree of an unthinned stand.

A basal area/age curve was drawn from the diameters quoted for Site II in the provisional yield tables for unthinned stands in this region. This curve passes through the mean diameter of the 100 main crop trees sampled. A similar curve was drawn to pass through the mean diameter of the marginal trees, the shape of the curve being obtained from a basal area/age analysis of an open grown tree on the same site. The marginal tree curve has been taken to represent the mean diameter of a thinned stand throughout its life, assuming that full growing space is available.

Drawing on local knowledge of untreated stands and experience with a few late thinnings, the approximate stocking at any age has been estimated. To plunge further into the fog of uncertainty, volumes have been calculated throughout the rotation by using the mean diameter curve, the heights quoted in the yield tables, and a

shelter belt volume table. On this somewhat sketchy basis a tentative treatment is outlined in Table II. The first objective is an intermediate yield of pulp wood in sufficient quantity to be economical ; this will be available about 15 years after clear felling the parent crop. The requirements of the crop should be the deciding factor throughout, but some plan is essential to prevent undue emphasis being placed on silviculture on the one hand or economics on the other.

TABLE II.

A TENTATIVE TREATMENT FOR *P. RADIATA*, SITE I OR II.

Age	Mean Height ft.	Mean Diam. in.	Operation	Standing vol. to 6in. top i.b. cu. ft.	Inter- mediate yield cu. ft.
0			Clear fell parent crop.		
3-4	5		Thin to 1,000 per acre.		nil
8-9	30-40	8	Thin from 1,000 to 300 per acre.		nil
14-15	65-70	14	Thin from 300 to 150 per acre.	6000-7000	2500
20	90	19	Either clear fell or thin from 150 to 80 per acre.	8000	2500
30	120	25	Clear fell.	10,500	

Experience in Kaingaroa Forest suggests that the time for the first thinning is 3-4 years after clear felling the parent crop, or when the regeneration is about 5 feet in height ; at this stage losses from *Hylastes ater* and other causes are past their peak and only isolated deaths occur. The ground vegetation has changed from annuals to perennials and little further addition to the stocking can be expected. Any trees less than one foot in height, shoots from stumps and further seedlings will all be outgrown by the main crop trees. The effect of this understorey can only be found by experience ; it may be beneficial by cleaning up the main crop, or it may cause loss of vigour through root competition.

If the crop is left for another year serious suppression and loss of mechanical stability will take place, the cost of the thinning will be greatly increased and many deaths are liable to follow in the main crop trees. Alternatively the first thinning could be given when the crop is two years old or about 2 feet high, but this would carry the risk of death by *Hylastes* attack for many of the main crop trees, and an inevitable increase in stocking from small trees passed over during the thinning, thus nullifying the benefits of the thinning.

It has been estimated that the first thinning to give an intermediate yield will be about year 15, and to ensure full growing space to this age a spacing of 11-12 feet would be required, with trees whose quality cannot be assessed at the time. Such a low stocking offers

little scope for the subsequent elimination of malforms and would inevitably encourage coarse branching and excessive taper from the very beginning.

A spacing of 6 to 7 feet will allow 5 to 6 years of growth without significant loss in increment. This statement is based on many observations of stumps in unthinned stands planted at 6 feet spacing which show that the basal area/age curve flattens out at about 7-8 years. In addition a 7-year-old stand planted at the same spacing has been studied, and its physical condition confirms the story depicted in the stumps of the older stands. A second unproductive thinning, carried out before the stand reaches merchantable size, appears to be essential if we are to steer a satisfactory course between early wide spacing and resultant poor form on the one hand and loss of increment through overcrowding on the other. A good selection will be possible from the 1,000 odd trees present at the time of the second thinning, and poor type trees will be eliminated before they ruin better trees in their vicinity. This thinning will fall conveniently between the first and the third, both of which are fixed.

The first thinning, as recommended above, was applied to 80 acres of regeneration in Kaingaroa Forest during the winter of 1949, commencing with an area of rolling country near Waiotapu where the stocking was particularly good. There were no groups of excessive stocking nor were there any sparse areas. This good distribution was probably due to the relatively close utilization, the favourable character of the site (I), and the strong growth of bracken which invaded the area, eliminating the possibility of later germination. A small gang under a leading hand worked over the area in 85 man-days i.e., 3.7 man-days per acre ; as this was an unusual operation, extraordinary supervision was given, namely 44 hours. The same gang then covered the area sampled in May, 1948. The stocking in this area was considerably less on the whole than at Waiotapu, and there was no competing weed growth to be cut back ; consequently the costs here were substantially lower being only 0.9 man-days per acre, with only 4 hours supervision spread throughout the 7 days spent on the area.

These two areas probably represent the extremes for this type of work and it is unlikely that the costs for the former will be exceeded in normal practice, nor is it likely that the latter will be bettered under existing wage conditions. The work is best handled by a small gang under a responsible leading hand, and, as demonstrated, very little supervision is necessary ; furthermore the work lends itself readily to some scheme of incentive payment.

Very little selection is possible at this first thinning beyond obvious measures such as the removal of deformed, slow-growing or unthrifty trees. It may be possible to differentiate at least two types of vigorous tree, one being definitely bushy and dark green while

Fig. 2.—Three-year-old regeneration of P. radiata before thinning, Kaingaroa Forest.

Fig. 3.—The same, after thinning.

Photos: J. Ure

the other is a lighter green with an open crown. The former is suspect from the utilization point of view, but may be a better tree in other ways. With the passage of another 5 or 10 years we may know a little more on this point.

The second thinning should be given when the crop is 8 or 9 years old or 30-40 feet in height, when it will have formed pronounced crown classes and the better trees can be more readily recognised. Branch suppression is probably effective up to 3 or 4 feet and shade leaves are formed up to 10 feet, so that low pruning can be applied to selected trees without causing any undue loss of vigour. High pruning should be carried out at the appropriate time only if enhanced returns are assured for the "clears" produced.

The stand should be thinned to no more than 300 trees per acre ; experience will show what stocking is most suitable for this phase, the objective being maximum stocking with maximum volume at 14-15 years of age. The cost of this thinning will be in the vicinity of 6 man-days per acre with $1\frac{1}{2}$ man-days for low pruning. The use of power saws would more than halve this.

14-15 years after clear felling the parent crop, the young stand will be about 67-70 feet in height with a mean diameter of 14 inches. The stocking should now be reduced to no more than 150 trees per acre giving a yield of 2,500 cubic feet of pulp wood and possibly a few saw logs. The felling and extraction of this volume should pay for itself and possibly leave a surplus. A reduction in cost might be obtained by having ready-made snig tracks at suitable intervals which can be put in during the first thinning when all the country can be seen at a glance ; they will not cost anything at this stage as it is quicker to clear a path than it is to leave trees at the required intervals.

The volume at 20 years will be about 8,000 cubic feet per acre, enough to justify clear felling should this be desirable. Alternatively, a further thinning may be carried out and the stocking reduced to 80 per acre, with a yield of 2,500 cubic feet in saw logs. This quantity can be extracted economically from accessible areas. The ruling market and management conditions will decide which alternative should be followed, but the increment and increase in quality to be obtained from another 10 years growth concentrated in 80 trees per acre will reduce logging costs considerably and should raise the financial yield.

At 30 years the mean height will be 120 feet, the diameter about 25 inches and the standing volume about 10,500 cubic feet per acre. Logging costs will be substantially less than anything possible in an untreated stand of the same age because the standing dead and unmerchantable stems found in all untreated stands will be absent, and fewer trees will have to be extracted to obtain the same yield.

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Silviculturally we cannot afford any more neglect, but will it pay to thin in terms of hard cash ? Treatment on the lines described above should satisfy both viewpoints and give the maximum returns for the minimum addition of capital.

Summary

Against a background of vast areas of untreated and unhygienic stands of *Pinus radiata*, now rapidly approaching maturity, come new stands, springing from natural regeneration.

The early development of these second rotation crops is discussed, the application of the first thinning described and a tentative future treatment outlined.