FERTILISER TRIALS IN UNTHRIFTY PINE PLANTATIONS AT RIVERHEAD FOREST

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Summary:

Forest establishment was begun in 1926 on hilly, scrub-covered country that had once carried kauri forest. The soils are largely infertile, poor-structured clays, deeply weathered and partly eroded. Symptoms of ill-health have since occurred in a significant proportion of the plantations. Good responses to heavy dressings of phosphate have recently been obtained in the older unthrifty areas of *Pinus radiata* which show some similarities to disordered stands in Australia, but zinc has not yet been effective. Other elements are being tried experimentally, and the results of more economical dressings of superphosphate, applied in small trials and also from aircraft on a semi-practical scale, are awaited.

Introduction:

Almost from the time the first plantings were made at Riverhead Forest, the poor health of some of the stands there has been the cause of concern. In earlier years, symptoms of unthriftiness were recorded and some experimental work and soil and foliage analyses were carried out. As the forest developed, and its potentialities as a management area became more obvious, it was necessary to try to improve the quality of these poorer stands.

An experimental programme was begun by the Forest Research Institute in 1950, and sufficient progress has since been made to justify larger trials by regional staff on a semi-practical scale.

In this article, a short account is given of the plantation and its development, followed by an outline of the experimental work in soils and tree nutrition which has been done so far in some parts of the forest where tree growth has been unsatisfactory.

Locality data:

Riverhead State Forest, Auckland Conservancy, has a total area of almost 12,000 acres, and is situated at the head of the Waitemata Harbour, some 20 miles by road north-west of Auckland city. The country is hilly, with moderate relief and a fairly complex drainage pattern, and lies between 100 and 600 feet above sea level.

The climate is equable, with a mean annual rainfall of 56.4 inches well distributed throughout the year, long, frost-free growth seasons, and relatively mild winters. The growth season (September-February inclusive) has an average rainfall of 24.6 inches and a mean temperature of 58.1°F. Mean annual temperature is 55.8°F. and the mean temperature of the coldest month (July) is 48.5°F. Using Thorn-

thwaite's classification (Garnier, 1950), the climate can be termed humid mesothermal in character.

The geology of the district has been described by Bartrum (1924). Within the forest area, the underlying rocks are sedimentary—mainly claystones, mudstones and sandstones, with locally important conglomerates—belonging almost entirely to the Waitemata series, which are apparently Upper Miocene in age. In the warm, humid climate, chemical breakdown of the comparatively unresistant strata is particularly rapid, and the surface rocks are well weathered to a considerable depth.

Soils:

The soils derived from this material are for the most part stiff clays, poor in structure, which tend to poach in winter and to bake hard and crack in the summer months. Iron pans occur locally, with marked effects on surface drainage. Fertility is generally low, and there are deficiencies of phosphate and calcium, and probably minor elements such as molybdenum.

The main soil types in the forest are Waikare clay and Mata clay hill soils, described as secondary podzolic soils in a semimature to submature stage of development (N.Z. Soil Bureau, 1954). In common with many other north Auckland soils, they have developed beneath a mor-forming forest vegetation. At Riverhead, the occurrence of pieces of gum near the soil surface, the occasional charred tree stumps, and the advanced stage of podzolisation which is characteristic of the gumlands are evidence that the area once supported extensive forests of kauri (*Agathis australis*). Since there are no records of large-scale kauri milling in the district, it is assumed that these forests were destroyed by fire in pre-European times.

During the period of early settlement, the scrub regrowth of manuka (*Leptospermum scoparium*), fern, rushes and grasses, etc., was repeatedly fired by several generations of gumdiggers. Apart from the resultant chemical degradation, soil was washed by sheet erosion and gullying from the unprotected upper slopes and ridges, and accumulated on and aggraded the lower stream-valley floors. This has had a pronounced effect on the variation in tree growth within the forest.

The forest and its condition:

Establishment of the plantation was begun in 1926 and, under the necessity of giving employment during the depression years, continued at a rapid rate. By 1933 some 10,200 acres—95 per cent. of the present forested area—had been planted. In the early years a number of species and establishment techniques were tried, but the large-scale plantings, from 1927 onwards, were with *Pinus radiata* (now occupying about 7,000 acres), *P. nigra* (1,900 acres) and *P. ponderosa* (660 acres).

In view of the variable pattern of soils and sites referred to above, it is not surprising that the stands today show marked variations in quality, although in evaluating some species, considerations of provenance, establishment and tending are also of importance.

On the whole, however, tree growth follows a recognisable pattern. On the lower country, and particularly in valleys and on stream flats where soil has accumulated, stand development has been very good. At age 25 years, individual *P. radiata* trees exceed 30 inches d.b.h, and heights of 135 to 140 feet have been recorded. By contrast, on upper slopes and on ridges at lower elevations from which topsoil and sometimes subsoil has been washed, the stands are often poor and unthrifty, if not stunted and malformed, and the country carries a heavy and occasionally almost impenetrable undergrowth of scrub. Between these two extremes there are large areas of stands of intermediate quality.

In an assessment of 7,600 acres of *P. radiata* made in 1955 by Conservancy staff, it was found that roughly half the area (3,700 acres Types I and II) carried stands containing an estimated 24 million cubic feet of timber to a 4 inch top i.b. A further 5 million cubic feet was estimated on 3,320 acres classed as Type III, and 540 acres were considered to be unmerchantable (Type IV). These figures for the older radiata pine compartments are illustrative of the potential productivity of the forest, since many of the intermediate-type stands are of good form, and have shown good responses to the stimuli of thinning and trial fertiliser treatments.

On the easier country, the soils are capable of supporting fair pastures when cleared of scrub, cultivated and adequately topdressed, and good quality dairy farms lie adjacent to the forest. This challenge to improve the productivity of unthrifty plantations has an interesting parallel with a case in South Australia described by Boomsma (1949).

History of the poor-quality stands:

The failing health of young trees, particularly *P. radiata*, in some parts of the forest was first reported in 1932, when needles on individual trees four and five years from planting were found to be fused. By 1936 a wide range of symptoms had been recorded. Dominant trees were growing rapidly in height and diameter, but were said to be developing the characteristics of older trees growing in the district on similar soils—sparse foliage held at the branch-ends and on terminal shoots, with almost bare main stems and laterals. Spirally-coiled needle-bundles and persistent needle-sheaths were also observed, although needle fusion was only one of the symptoms of debility which were said to be affecting over 60 per cent. of the radiata pine plantings. Terminal hypertrophy, resinosis, and dieback of main leaders at a height of about 20 feet were also reported.

In 1937, foliage analyses were carried out by the Cawthron Institute,

Nelson, to determine whether the fused needle condition was associated with a deficiency of boron. However, the boron content of unthrifty foliage and healthy samples from trees at Riverhead and elsewhere was found to be similar (about 11 p.p.m.).

Preliminary field trials:

Field experiments with the object of finding a remedy for needle fusion were begun in 1939 by the Plant Diseases Division of the Department of Scientific and Industrial Research. Single trees of *P. radiata* were given soil dressings (superphosphate and copper and zinc sulphates) and stem injections (aqueous solutions of borax, cobalt chloride, sodium phosphate, and the sulphates of copper, zinc, manganese and magnesium), at different concentrations. A number of needle-fused *P. taeda* trees were also selected for treatment with soil dressings (borax and copper and zinc sulphates), sprays (copper sulphate), and injections (zinc sulphate).

Some trees in these exploratory trials showed apparent recovery from needle fusion, but this was as frequent in the controls as in treated trees. Up to 1941, when observations unfortunately had to be discontinued owing to the war, results were described as negative, but the trials had not been sufficiently exhaustive to rule out the possibility of deficiency of one or more of the materials used.

Progress 1950-1952:

Experimental work at Riverhead was resumed in 1950, when a comprehensive plan for empirical and systematic studies was prepared by the Forest Research Institute.

Attention was first concentrated on the radiata pine compartments in a section of the forest, in an attempt to relate the condition of the crop to environmental factors and establish the causes of sickness. An intensive sampling survey disclosed a complex mosaic of quality classes varying from first quality trees of extremely good form to moribund trees often growing quite near the good stands. Good growth was closely correlated with lower altitudes, with the relative abundance of sporophores of various mycorrhiza-forming fungi, and to a lesser extent with topsoil depth.

Numerous analyses of soil and foliage samples were carried out at the Soil Research Station (Department of Agriculture), Rukuhia, and the Forest Research Institute soil laboratory. Calcium and phosphate were found to be generally deficient by agricultural standards, but because good tree growth was apparent where these deficiencies occurred, some additional factors seemed to be involved in the areas of poor tree growth. Needle analyses suggested a zinc deficiency, and other minor elements were also suspect.

Following these results, an experiment including radiata, slash, and loblolly pines was laid down in 1951 on cleared land to test the effectiveness of fertilisers and cultivation at the time of planting. Treatments included superphosphate and rock phosphate, each broad-

cast at rates of 3 and 5 cwt. per acre and dressed at 2 oz. per tree, and 1% zinc sulphate solution applied after planting, the trials being repeated on land that had been cultivated with discs. Up to the present, trees of all species in phosphated plots have shown distinct improvements in height-growth, foliage colour and general thriftiness, though the effects of zinc and of cultivation have been inconclusive.

The 1952 trials:

During a New Zealand tour made at the invitation of the Forest Service in the summer of 1952, Dr. T. N. Stoate of Western Australia visited Riverhead. He recognised in the poor stands of *P. radiata* planted in 1927-32 a number of disorders described from Australia, including several in a group responding to phosphate, namely "yellowing"; "dead top" and "broom bush" (Kessell and Stoate, 1938; Stoate, 1950). In addition, trees showing die-back of main stems similar to a "zinc" condition were noticed, particularly along fire-break edges, but also inside the plantations themselves.

No attempt will be made here to describe in detail the range of symptoms which could be seen at this time in these unthrifty stands. It has been convenient to adopt tentatively some of the picturesque terms coined in Australia for conditions which are recognised and sometimes remediable there. However, some of the symptoms in New Zealand stands are puzzling in terms of Australian experience, and it seems that careful descriptions of local disorders must be attempted and classified before categorical judgements can be made.

In four selected localities on ridge and upper-slope sites, a total of 14 square-chain plots were established in sick stands which represented the range of disorders mentioned above. The following treatments were applied, in May/June 1952:

(a) Superphosphate compound, broadcast at the rate of 20 cwt. per acre. (Standard superphosphate was unobtainable at the time of treatment. The compound, which contained 75% superphosphate, 15% ground Nauru phosphate, and 10% ground serpentine rock, had a water-soluble phosphoric acid content of 6.9% and a water-insoluble phosphoric acid content of 21.5%.)

(b) Zinc sulphate, in 2½% aqueous solution, sprayed on to whatever foliage could be reached, and on to the bark.

(c) Zinc sulphate crystals, broadcast on the ground beneath tree crowns, using about ¼ lb. per tree.

Treatments (a) and (b) were also tried in combination.

In these first trials, the objects of the high levels of application were to see whether responses could be obtained and, if successful, to provide a yardstick against which to judge more economic treatments in future work. Responses were to be estimated visually.

Results of the 1952 trials:

(i) *Phosphate:*

A response to superphosphate compound was seen during the growth season following treatment. By March 1953, the foliage of many spindly-topped and unthrifty trees in phosphated plots showed a distinct contrast between the older needles, which were generally short and slate-green to yellow-green in colour, and the new needles, which were up to twice as long (about 4 inches), thicker, and a more normal dark green colour (see Fig. 1). This improvement was reflected in the general density of foliage in treated plots (see Fig. 3a), although the response at this time was much more marked on some trees than on others.

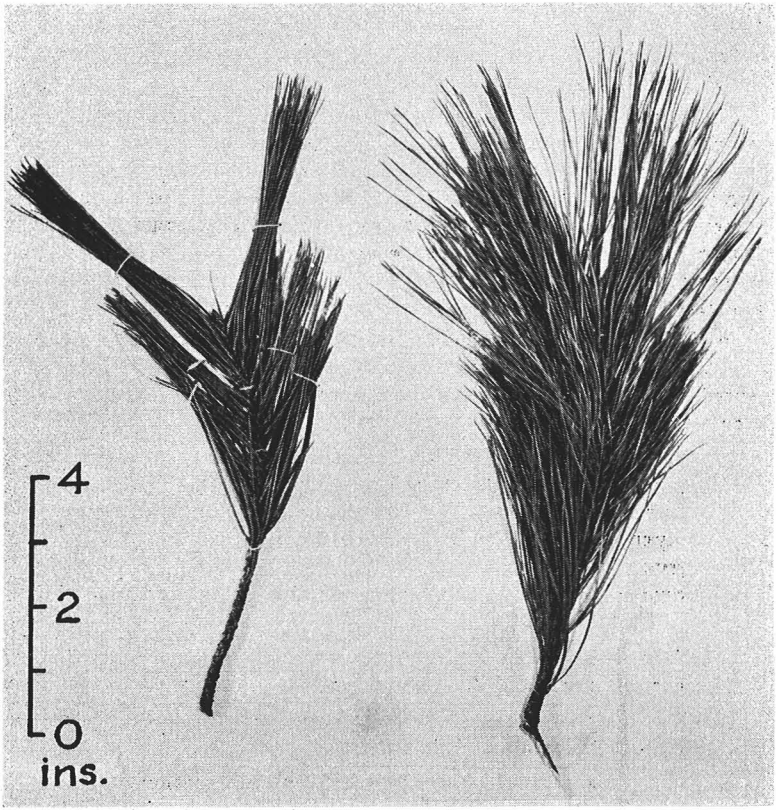


Fig. 1: *Pinus radiata:* Typical sprays of foliage taken from the lower branches of trees in a plot heavily treated 10 months previously with superphosphate compound. Age 25 years.

During the following two growth seasons (1953-1955), responses were sustained and improved, with further definite increases in crown densities, and a general deepening of foliage colour.

By 1955, all trees on phosphate plots had benefited, and a conspicuous feature of most of them was their increased vigour as shown by the lengths of the terminal and upper lateral shoots, and the production of healthy cones. In one plot which had attained an average height of about 35 feet in the 20 years prior to treatment, individual trees increased their heights by from 3 to 4 feet in the 1954-55 growth season alone. Increment cores taken from the lower part of the stems showed increased radial growth-rates, and on some trees the outer bark, which for years had been comparatively smooth and unfissured, was beginning to rupture longitudinally to reveal the fresh reddish-brown inner bark layers.

In the best plots the undergrowth, which had been cut at the time of treatment and had regenerated vigorously, was beginning to be shaded out as the canopy closed. The upper soil layers showed signs of intense earthworm activity.

As an example of this type of response, a comparison between the appearance of the same plot 10 months and 4 years respectively after treatment is given in Fig. 3. By contrast, the condition of an adjacent control plot at the latter date is shown in Fig. 2.

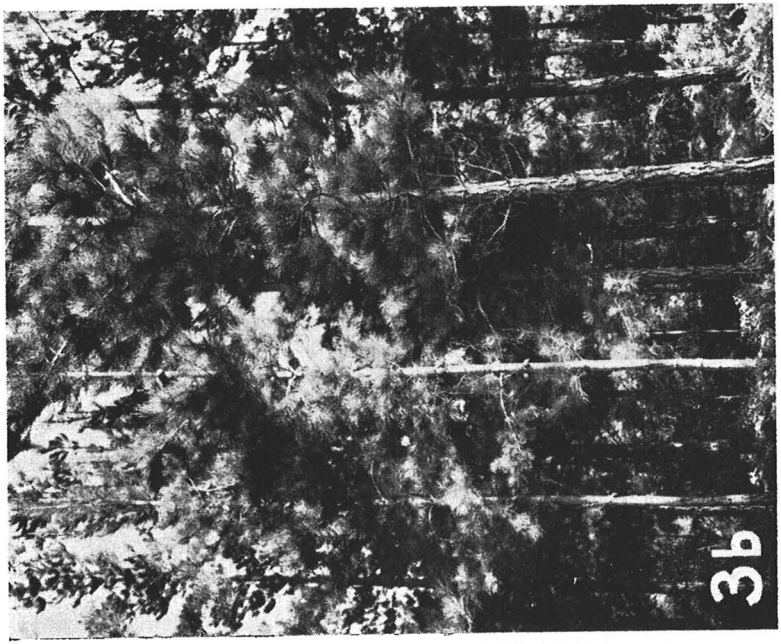
Lest it be thought that such heavy dressings of phosphate would produce responses in unthrifty stands on any soil type, it may be mentioned that similar trials were laid down at the same time in Woodhill Forest, which borders the coast some 10 miles west of Riverhead. The soils here are drift sands, often shallow, overlying clay loams, and pastures sown on them adjacent to the forest show good responses to phosphate topdressing.

Radiata pine plantations produce good volumes at Woodhill, and at 15 years have taken possession of the site, but the trees tend to be slender and whippy, foliage in unthinned stands is sparse, and die-back and occasional deaths occur. Trees with apparently similar symptoms at Riverhead responded well to phosphate; in the Woodhill trials no visible response was obtained.

(ii) *Zinc:*

Up to the present, no responses to zinc have been seen in either old or young radiata pine at Riverhead.

This is also true for the numerous zinc trials that have been made in several other North Island radiata pine forests. A 2½% aqueous solution of the sulphate, sprayed on to foliage, has been the most usual treatment, and the stands range from young plantations and regeneration showing die-back and malformation to old trees in various states of ill-health, on a variety of sites. In one or two cases visual impressions of slight or partial, though transitory, responses have been reported, but no measurable or lasting benefits have yet been obtained.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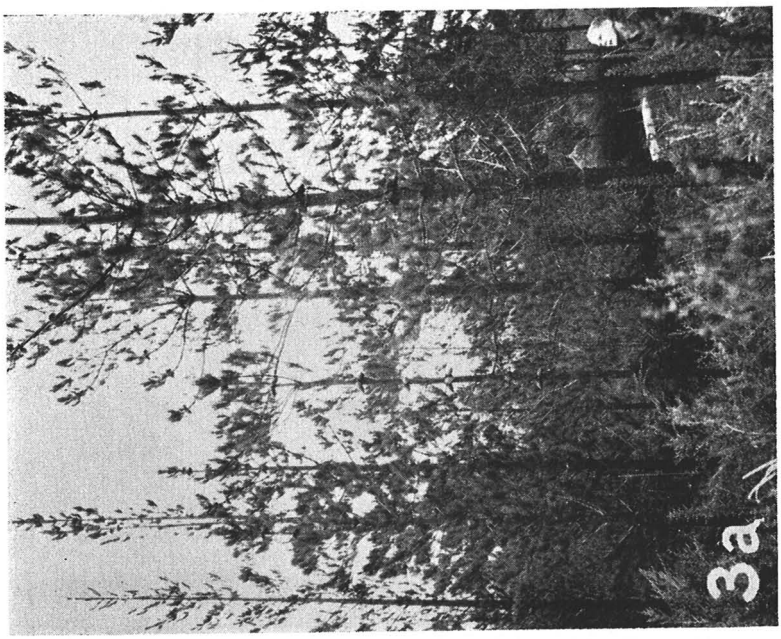
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This of course contrasts with the startling responses to zinc of *P. radiata* and *P. pinaster* on certain soil types in Western Australia, and also in South Australia where spraying has for some years been standard practice in the establishment of plantations, as a preventive against die-back (Kessell and Stoate, 1938).

However, delayed responses to the 1952 treatments are still possible at Riverhead, and zinc has again been included in the latest series of plots established there.

A trial with lime:

Lime has not so far been used at Riverhead Forest. However, a trial was made locally some years ago by the private owner of a small *P. radiata* plantation which lies immediately adjacent to the State forest on its southern edge. This stand, established about 1928 on clay country similar to that in the forest area, was unhealthy and showed die-back of the leading shoots when the property was purchased in 1945. Bulk lime was spread in 1946 (i.e., at age about 18 years) through some 7 acres of the plantation at the rate of 20 cwt. per acre. No response was apparently seen, although it was watched for. In increment borings taken from a number of trees in 1955 there was certainly no evidence of a response, the width of the annual rings decreasing progressively from the pith outwards. At the present time this stand is very poor, although some trees have moderately dense crowns.

Lime has apparently been used extensively in Australian pine nutrition trials without significant results (Kessell and Stoate, 1936; Stoate, 1950).

Developments since 1954:

The encouraging responses to phosphate in the establishment trials of 1951, and particularly in the 1952 trials in unthrifty old stands, have led to further empirical trials of phosphate and other treatments. Work has been carried into areas representative of the large acreage of intermediate-quality *P. radiata,* and into unthrifty stands of other species.

In December 1954, for example, forest staff laid down a small trial of superphosphate at 4 cwt. per acre in a well-stocked radiata pine area which showed severe symptoms approaching those of "thin crown" and "yellowing." A foliage response was reported 8 months after treatment and the stand has since continued to improve.

The 1955 Research Institute trials include superphosphate, zinc sulphate and ammonium sulphate at several rates of application, singly and in combination, in intermediate and poor quality *P. radiata.* These studies are being supplemented by analyses of soil and foliage samples from the plots.

Finally, on the basis of the results of empirical trials, the Forest Service recently decided to experiment with the large-scale distribution

of superphosphate by aerial top-dressing. Test areas representative of upper- and mid-slope *P. radiata* stands were demarcated on the ground, and a total of about 150 acres at Riverhead were treated from the air in November 1955.

General conclusions:

The problem at Riverhead is seen to be a local one involving a considerable area of unthrifty but for the most part well-stocked plantations. The most difficult sites are probably incapable of supporting healthy stands of radiata pine even with the aid of fertilisers. However, there appear to be possibilities in the use of phosphate on a practical scale (i) to improve vigour in the poorest of the existing stands, with a view ultimately to their salvage and the conversion of the site to more suitable species, and (ii) to stimulate volume production on medium quality sites.

So far, fertiliser trials have been sited according to the appearance of the unthrifty stands. In the next phase, quantitative work, the soils and their characteristics will require more intensive study in order to place trial plots on representative sites and to apply the results significantly. A general soil survey, which will of course also be basic to forest management, is therefore planned.

The results of chemical analyses have deliberately been omitted from the present account, since only a limited number are available and their interpretation in such a complex area is extremely difficult without considering a host of other variable site factors. In addition, direct comparison with the published results of Australian work is not possible owing to the different chemical test methods which are standard there.

Acknowledgements:

The programme of studies begun at Riverhead in 1950 was planned and carried out until 1952 by Mr. F. L. Miller and Mr. J. M. Mitchell. Much of the work since 1952 has resulted from recommendations made by Dr. T. N. Stoate of Western Australia during visits to New Zealand in 1952 and 1954.

The co-operation of forest and district staff, who have assisted with the establishment and maintenance of the various trials, and provided data, is gratefully acknowledged.

Use has been made in this article of some descriptive material drawn from the Preliminary Working Plan Report for Riverhead (Anon., 1954).

References:

Anon. 1954: Preliminary Working Plan Report, Riverhead State Forest No. 131, Auckland Conservancy. Unpubl. Report, N.Z. Forest Service.

Bartrum, J. A. 1924: The geology of the Riverhead-Kaukapakapa

district, Waitemata County, Auckland. Trans. N.Z. Inst. 55 (139-153).

Boomsma, C. D. 1949: Phosphate for top-dressing as a normal plantation operation. Australian Forestry 13 (2) (108-112).

Garnier, B. J. 1950: The climates of New Zealand, according to Thornthwaite's classification. *In* N.Z. Weather and Climate. N.Z. Geogr. Soc., Misc. Ser. No. 1 (84-104).

Kessell, S. L. and Stoate, T. N. 1936: Plant nutrients and pine growth. Australian Forestry 1 (1) (4-13).

Stoate, T. N. 1938: Pine nutrition. Bull. No. 50, Forests Dept., Western Australia.

—— 1950: Nutrition of the pine. Bull. No. 30, For. and Timber Bureau, Canberra.

Photo. W. J. Wilson.