NURSERY PROPAGATION OF KAURI AT WAIPOUA FOREST*

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Summary

Techniques in the handling of kauri, as developed or in course of development at the Waipoua Forest Nursery, are described under the following heads—seed collection and seed trees, seed bed preparation and seed sowing, cultivation and weeding, nursery injuries and their control, lining out, preparation of trees for planting, nursery trials and experiments. It is considered that successful techniques have been evolved, though there is still room for improvement, particularly in relation to the hardening off of stock prior to planting. A trial of the Dunemann system has shown particular promise.

INTRODUCTION

The kauri forests of northern New Zealand were once two to three million acres in extent, but today all that remains is some 25,000 acres, the remnant stands being those of Warawara, Herekino, Waipoua, Great Barrier Island, the Coromandel Peninsula, and the Waitakere Ranges. Elsewhere not even seed trees remain. Re-establishment of a kauri forest estate is therefore dependent upon development of satisfactory nursery techniques. This paper outlines the progress made in these respects over the past two decades and, more particularly, progress made at Waipoua nursery since this was established in 1945.

A DESCRIPTION OF THE NURSERY

The nursery is sited on a low river terrace between the Waipoua River and the Waikohatu Stream. The easily worked, fertile soil has been derived from parent material of andesitic origin. The altitude is 200 feet above sea level and the well distributed rainfall totals 65 inches with a tendency for the heaviest falls to occur in the winter months. Frosts are very light and are recorded on an average of 15 days each year.

SEED COLLECTION AND SEED TREES

As kauri cones break up on the tree, it is essential to pick them when slightly unripe. Frequent inspections of the seed trees are made from the last week in February, and cone collection commences when the first cone scales are observed on the ground. Usually a clear fortnight elapses before the disintegration of the cones is completed.

The past practice of obtaining seed from mature and over-mature

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trees in the 4-6 ft diameter class has been replaced by the collection of seed from immature, vigorous trees of good form in the 18-30 in diameter class.

Equipped with hand hooks, a 200 foot rope and climbing boots fitted with a toe spike, an expert climber is able to ascend large-sized kauri trees as though climbing a ladder—the descent is made by means of a rope. The smaller trees are climbed by means of an aluminium ladder.

The number of sound seeds per cone ranges from 42 to 94, the average being 70. Nine to ten cones weigh one pound.

The cones are spread out indoors and usually break up without heat within seven days. For some time it was the practice to open the cones by solar heat, but this method did not increase efficiency and was obviously more troublesome. When a period of hot dry weather caused the cones to exude an abnormal amount of gum, it was found that solar heat often impeded disintegration by sealing the cone scales together. Those few cones remaining unopened at the end of the seven day period are discarded.

There is great variation between the unit weight of seed produced by individual seed trees growing on the same site. As can be seen from Table 1, Tree No. 856 has produced 18,000 seeds to the pound, and Tree No. 846 the large number of 45,980 seeds to the pound. Not only are there differences between trees, but there are often marked variations in the amount of seed produced by the same tree from year to year. In 1951, Tree No. 854 produced 29,000 seeds to the pound, 37,000 in 1952, and 14,100 in 1953.

There are also marked variations in the germination percentages (laboratory) of seeds from the different seed trees. The germination percentage generally varies for the same tree from year to year, though some trees have consistently high germination results. In 1951, the germination percentage of seed from Tree No. 843 was 100%, in 1952 the result was 96%, in 1953 92%. Tree No. 846 has shown considerable variation with a germination of 100% in 1951, 33% in 1952, and 16% in 1953.

The seed from the individual trees has been sown separately in the nursery for several years. Resulting trees will be planted so that their nursery identity can be maintained in order to ascertain if any seed tree has produced stock of superior vigour and form.

Even without the support of a statistical analysis, it is evident that Tree No. 843 has produced the most vigorous stock from exceptionally heavy seed, 10,000 to the pound in 1952 and 1953. Germination has taken place consistently two to three days before that of other trees. From the earliest stages of nursery growth, it has been evident that the leaves of the seedlings were outstandingly large for juvenile kauri.

After the 1954 seed collection, it is intended that all but two of the eighteen seed trees (Tree No. 843 and Tree No. 700) will be

abandoned temporarily. Additional seed trees will be located and selected until only the best are retained.

Kauri rarely fails to produce adequate quantities of seed. It is not certain if there is any distinct fluctuation in seed production, though some observers of long experience consider that better seed crops occur every third year. Occasionally, a good crop of high viability is collected, such as the 1948 lot which gave a nursery germination of 7,832 seedlings to the pound.

TABLE I

A comparison of weight of seed (in seeds per pound) from selected seed trees for period 1951-1953.

Tree No.	1951	1952	1953
700	—	—	15,690
843	13,720	9,930	9,700
844	35,660	—	14,470
845	15,180	16,350	20,900
846	45,980	21,750	25,290
847	17,150	—	15,840
848	31,640	30,650	20,170
849	—	43,800	23,000
850	—	19,050	17,380
851	21,760	31,000	27,240
852	20,300	23,620	15,520
853	33,870	33,300	13,660
854	29,000	37,700	14,090
855	27,700	24,800	25,780
856	17,930	25,550	17,680
857	23,700	22,600	21,510
858	26,950	—	16,480
859	28,000	22,500	26,080

SEED-BED PREPARATION AND SEED SOWING

The past system of preparing six foot wide seed beds with four bands, each eight inches wide, made weeding difficult and efficient wrenching impossible. Under present practice, the seed beds are four feet wide with three six inch wide bands.

The beds are built up four inches above the general level of the nursery, thoroughly cultivated by digging, and rolled after being raked down to a fine tilth. Seed is sown by hand according to predetermined germination tests and the desired density of approximately twenty seedlings to the square foot. The seed is lightly covered with well

sieved soil, as past trials have shown that lower germination results from heavy covering. A 1944 trial resulted in the germination of 1,920 seedlings to the pound from a light covering while only 527 seedlings to the pound resulted from a heavier covering.

One trial lot of kauri seed was treated with red lead and kerosene as a protection against birds, rats, and mice. The kauri seed and wing is fused, and as some difficulty was experienced in coating the seed efficiently, the wings were removed. This appears to have damaged the seed, allowing the kerosene to penetrate the testae. The sowing was a complete failure, while untreated seed produced 3,000 seedlings to the pound. The procedure has not been repeated and will never be included in standard kauri nursery practice.

Kauri seed is sown at the first opportunity after extraction and herein lies the key to successful kauri nursery practice. Past experience has shown that kauri seed quickly loses its viability under ordinary storage conditions. A test lot of seed was sown in the autumn of 1936 immediately after extraction and gave a germination of 52%. The same seed lot sown under identical cover conditions six months later gave a germination of only 21%. A spring sowing in 1937 resulted in the low germination of 655 seedlings to the pound, and seed sown in October 1938 produced 495 seedlings to the pound. A sample of seed sown in January 1943, collected in March 1942, resulted in complete failure.

It has been shown that kauri seed will retain, and even increase, its viability under certain storage conditions which could not be attained at a forest station unequipped with special apparatus. By storing seed at 4 degrees centigrade for 43 days, an initial average germination was increased from 52% to 79%. After 107 days the germination was further increased to 82%. The germination of a portion of the same lot stored at ordinary air temperatures was found to be 13% after 43 days and 0% after 107 days. A distinct correlation has been found between moisture content and germination, and 35% to 40% appears to be the critical level of humidity for storage and retention of viability. This information could be extremely useful for the storage of seed collected during an abnormally good seed year.

Spring sowing continued to be the normal practice until 1946, when a May sowing produced 2,056 seedlings to the pound. An April sowing in 1947 resulted in 2,970 seedlings to the pound and in 1948, a March sowing resulted in the extraordinary germination of 7,832 seedlings to the pound. At the first stock-taking after the latter sowing, it was found that the Waipoua Nursery contained some 215,000 kauri seedlings, a record production for this species.

Good germination results were obtained in May 1952 when seeds were sown on the soil surface and lightly covered. It was considered that germination at this time of the year would have been retarded by the collection of moisture had normal sowing bands been prepared by the roller.

Seed sowing immediately after extraction has been adopted as the standard nursery practice and will not be changed unless special storage conditions are available.

SEED-BED COVER

Early records show that seed frames with wire-netting and light manuka brush were used to cover the beds after sowing. The manuka brush was replaced by hessian when trials showed that the latter type of cover gave more even germination results, though the brush gave comparable results under optimum weather conditions.

Germination usually commences 7-14 days after sowing but varies according to seed origin and the prevailing weather conditions. When germination is complete after approximately three weeks, the hessian is removed, replaced with light manuka brush, and the frames raised a few inches to allow aeration of the seedlings. The frames are then raised at intervals as the seedling height increases. If the hessian is left on too long, "damping-off" will probably occur and may cause considerable damage among the recently germinated kauri. The manuka brush may appear to be a crude type of cover, but it is considered that the filtered light admitted to the seedlings simulates natural conditions to some extent, and is an improvement in this respect on the lath type of cover generally used in most forest nurseries. However, there is an advantage in the use of the lath cover as the light admitted to the seedlings can be measured. It is probable that trials with this type of cover will be carried out in the near future.

Records show that another type of seed-bed cover consisted of frames made with manuka sticks which were leaned over the centre of the bed from the sides in the form of a tent. This method was not a success as the frames were heavy and awkward to replace once they had been removed for weeding and cultural operations.

CULTIVATION AND WEEDING

Kauri is characteristically a tap-rooting species and requires periodical wrenching after the first year in the nursery beds. This operation not only promotes the growth of fibrous roots, but also retards height growth and results in a tree of improved root/shoot ratio.

Weed growth is troublesome in spring and summer and mainly comprises crab-grass (*Digitaria sanguinalis*), mallow (*Malva* spp.), sheep sorrell (*Rumex acetosella*), cat's ear (*Hypochaeris radicata*), and scarlet pimpernel (*Anagallis arvensis*). Yarr (*Spergula arvensis*) has been recorded but is not important. Hand weeding is carried out as the size of the nursery does not warrant the purchase and use of mechanical equipment.

NURSERY INJURIES AND THEIR CONTROL

Frosts are few and generally light so that frost heaving of soil is unknown. As the seedlings are protected by cover at all stages under

present practice, damage to tissues by frost has never been experienced.

Heavy rains have partially covered young seedlings with splashed soil on occasions without causing permanent damage.

The nursery area is so well sheltered by the close proximity of the forest proper that wind damage to young trees is unknown.

For the first time on record it was necessary to water kauri nursery stock when drought conditions prevailed throughout the Northland province during December 1953, and January and February 1954. The rainfall for this period was 3.52 inches or 9.33 inches below normal. In the past, the moisture-holding capacity of the soil, though often severely tested, has been sufficient to prevent wilting. No provision has been made for an irrigation scheme under current practice, nor is it considered necessary at Waipoua Forest providing there is no decrease in soil fertility.

After the 1950 sowing in the autumn, sparrows entered the seed-beds for the first time, and caused considerable damage by scratching up and eating the seed, until the bed ends were closed with hessian.

Rats and mice seriously damaged germinating seedlings in 1953 in spite of the numerous poison baits laid in the seed-beds. In future, it is intended to lay the poison near the bush edge prior to seed sowing and at the same time block off the bed ends with fine wire-netting.

Insects are not serious pests in the Waipoua Nursery and only two have caused some minor damage. The larvae of a Tortricid moth (*Epichorista persecta*) tie a few kauri leaves together and eat the inside of the "tent". This insect shows no signs of increasing, and to date it has not been necessary to carry out eradication measures. The black Australian cricket (*Gryllus servillei*) occasionally appears in large numbers in the nursery beds and will eat germinating seedlings unless checked with poison baits, a mixture of 50% D.D.T. ,1/5 lb), bran (24 lb), and molasses (4 lb).

A "damping-off" fungus (*Fusarium*) occasionally has caused heavy damage in the past during humid winter conditions. Provided the attack is detected in the early stages, the application of a very dilute solution of potassium permanganate will destroy the fungus. A heavy attack of *Pestalozzia* followed high humidities and air temperatures in the winter of 1952, causing leaf collapse in kauri nursery stock of all ages. Seedling and sapling kauri in the forest proper were also affected by this fungus. Fortunately, a cold period of weather checked the attack before the trees had been damaged permanently.

LINING-OUT

Indifferent results from the planting of two year seed-bed stock suggested that kauri lined-out for one or more seasons prior to planting would stand a better chance of survival. The two year trees tended to be smothered by strong regrowth of ground vegetation, particularly bracken (*Pteridium aesculentum*), when planted in cut lines through heath country as in present practice.

It was reasonable to anticipate that a larger tree would be able to compete more successfully with the ground vegetation, providing the root system was developed in proportion to the shoot growth. Subsequent trials proved that a superior fibrous root system was developed when kauri seedlings were lined-out for two seasons under overhead shade.

In 1948, a bush-house with open sides and ends, designed to accommodate 20,000 lined-out kauri at 9 x 4 inch espacement, was built of punga and timber uprights and roofed with manuka sticks at a density which excluded approximately 50% of direct light.

Care must be exercised when lifting or lining-out kauri seedlings as the rootlets with their clusters of nodules are prone to damage. It is considered that these nodules are lateral roots with their apical growth checked. The organism occupying the nodules is a non-septate fungus and it is possible that certain nucleated vesicles are degenerate sex organs. It is probable that the fungus is a *Phycomycete* from the size of the hyphae and the absence of septae.

Before lining-out commences, undesirable trees are culled and usually represent 12%-15% of the total. The seedlings are placed against the perpendicular face of a prepared trench with roots well spread, and are firmed in an upright position. It is not considered practicable or advisable to use lining-out boards, as kauri bark in the vicinity of the root collar is very easily damaged.

When the bush-house is fully occupied, seedlings are lined out under raised seed-frames covered with light manuka brush, in the open nursery.

PREPARATION OF TREES FOR PLANTING

Until 1952, the normal practice was the bundling of kauri trees in fives with soil in hessian. This method was designed to incorporate some nursery soil from the bundle in the planting pit with the trees and, to some degree, lessen the sudden change from nursery to field conditions. Although sound in theory, this method had a serious defect as the roots were damaged when the trees in the bundle were separated for planting. It was decided that the method should be discontinued and replaced by bundling singly with soil in hessian. As hessian takes about a year to rot in the soil, it was reasonable to anticipate that no restriction of roots would follow. Later observations showed occasional folding back of the roots in the form of the undesirable "hockey stick." In a further trial, the hessian cover was not folded but merely tied at the end to prevent the soil falling out. Trees prepared by these two methods have been planted at Omahuta Forest. As yet it has not been possible to observe any positive results.

The preparation of single trees for planting is expensive and time consuming, and a further method was tested in trials at Waipoua and Omahuta Forests. The trees were puddled and placed in 50's (5 rows of 10 trees) in wooden boxes (18 x 12 x 6 inches deep) containing soil to pack between the rows and seal the moisture taken up with

the puddling. Forest officers and planting gangs at both forests agreed that the box method is superior, particularly with reference to tree distribution at the planting site. Observations to date show that neither method is superior when survival rate is considered—it is too early to assess results by statistical analysis.

NURSERY TRIALS AND EXPERIMENTS

Shade Trials

As a radical departure from normal practice, a seed-frame with manuka brush cover was removed from a bed of 2/1 stock so that the trees were subjected to full direct light from January 1951 until they were under-planted in heavily thinned *Pinus caribaea* (planted 1935—thinned to 170 stems per acre in March 1952) on 9 September 1952. An equal number of shaded stock were planted on an adjacent area as a control. All trees were planted by the same workman to eliminate the human factor as far as possible. Although the unshaded trees were not as healthy in appearance as the shaded before planting, results of a mortality survey in March 1954 showed that 69% of the former were alive, and that the others were a complete failure. It is highly probable that the survival figures in both cases were affected by the unusually dry summer and the open nature of the *Pinus caribaea* stand, as a 100% loss has not been recorded in any previous trial or planting operation. Under these particular conditions, there is a strong probability that the rigorous hardening-off process prior to planting was a distinct benefit.

Two short parallel fences of manuka sticks were set up in the nursery, nine feet in height and eleven feet apart, in a further shade trial. A seed-bed was prepared between the fences, sown at the same time as the normal nursery beds, and covered with a frame and hessian. The frame and cover were removed after germination so that the only shade cast on the seedlings was from the side by the fences set in a north and south direction. The maximum daily period of full direct light on the seedlings in mid-summer was 1½ hours and at no stage were any deleterious effects observed. It is proposed to compare the root/shoot ratio of these side-shaded trees and those raised in the normal way. Further trials will be established in the field to assess any significance in survival rates and height growth.

A Kauri Field Nursery

It is probable that kauri trees will be planted in soils inferior to those of the Waipoua Nursery. Kauri may not be a species that reacts unfavourably to this, but to obtain some information on a more gradual introduction to the planting site, a small kauri field nursery was established in heath country.

Vegetation comprising manuka (*Leptospermum scoparium*) 10-12 feet in height, inaka (*Dracophyllum urvilleanum*) 8-12 feet in height, bracken (*Pteridium aesculentum*), *Lycopodium volubile,* the hard fern

(*Blechnum procerum*) and toi-kiwi (*Gahnia xanthocarpa*), was cleared from a gentle slope of westerly aspect.

One year old kauri seedlings with some nursery soil were lined out under difficult conditions as organic detritus prevented the formation of a good lining-out trench. It was hoped that the standing manuka would cast sufficient shade on the beds. However, it appeared during the following summer that the trial would be ruined by over-exposure, and so artificial shade in the form of manuka brush on a seed-frame was added. The field nursery trees have been compared with bush-house lined-out stock of the same age and seed lot, but no significant differences were observed. Trial plantings of field nursery and bush-house trees will test the benefit or otherwise of this treatment.

Experiments Involving Nursery Treatment Prior to Planting

Experimental areas, established in 1950 and 1952, incorporating certain nursery treatments prior to planting, were laid out in randomized plots so that results could be analysed statistically for significant differences; height growth will be taken as the index of comparison.

Each plot was divided into two sub-plots, one series being planted in 1950, the other in 1952, with the object of eliminating the weather factor as far as possible. As the use of normal 2/2 trees would have meant delaying this experiment by two years owing to stock shortages, two year seed-bed stock was used in all plots.

(a) Seedlings were rolled in veneers (1/16 in. thick and 6 inches long) with nursery soil and lined-out under overhead shade for a year before planting.

(b) Seedlings were rolled in veneers of the same dimensions but were planted immediately after preparation.

(c) Seedlings were rolled with soil in newspaper.

(d) Seedlings were rolled with soil in hessian and planted immediately after preparation.

(e) A few sound seeds were sown in soil-filled, non-waxed cardboard flower-pots (3 inch diameter). All but one of the resulting seedlings were removed and the complete unit was planted.

(f) Control plots were planted with trees taken from bundles of five trees.

Results have not yet been statistically analysed, though it is possible that the trees rolled in veneers and lined out under shade for a year prior to planting are the most vigorous.

A Nursery Fertilizer Experiment

With the primary object of increasing the root/shoot ratio of kauri planting stock, ammonium sulphate, superphosphate, and muriate of potash were applied on two blocks of randomized plots lined out with two year seed-bed kauri. One block was sited in the bush-house and the other was shaded by a series of manuka brush fences in the open nursery. A maximum-minimum thermometer and a rain gauge

was set up in each block to record climatic data. Half the plots in each block received an application of lime.

Two years after application, analysis of results showed that superphosphate plus ammonium sulphate, and superphosphate alone, significantly affected the *total weight* of the kauri trees. The root/shoot ratio, survival rate, and tree height were not affected by any of the fertilizers, either alone or in combination. It appeared that the overhead shade of the bush-house increased the rate of shoot growth.

Non-selected trees from all combinations of fertilizer and shade type have been planted in line-cut manuka to test the effect of the fertilizers on future survival and growth. Results have yet to be analysed statistically; visual observations do not indicate any obvious differences.

Lining-out Trials

Cotyledonary seedlings were lined out under frame overhead shade at 9 x 4 inch espacement with the object of promoting root growth by early reduction in competition. When compared with normal seed-bed stock of the same age, no significant differences were observed.

Kauri seedlings were rolled with soil in heavy hessian and lined out under frame shade in the open nursery. No obvious differences were observed when these kauri trees were compared with trees of the same age lined out in the bush-house. The hessian was well rotted after a year but still remained intact, and had not prevented root penetration. Light wrenching had been carried out during the lined out period. Field trials will be established to test the benefit, if any, of this type of nursery preparation.

A Planting Trial Incorporating the Use of Veneers

Cotyledonary seedlings were pricked into soil-filled rolled veneers which were placed on the ground surface in manuka brush covered frame. To prevent tap-root extension beyond the veneers and to encourage the formation of fibrous roots, the veneers were moved periodically after six months. A small percentage of leaf mould had been included in the soil to prevent excessive drying out during the summer months. When compared with seed-bed kauri of the same age it was evident that this treatment had not produced superior stock.

Red Leafed and Green Leafed Kauri

Approximately 50% of all kauri seedlings have green leaves, while the leaves of the remainder are a dull reddish colour. This variation has been observed in kauri natural regeneration up to the sapling stage, but not in any later phases of growth. These kauri types have been planted separately in randomized plots under manuka to determine the comparative survival and growth rates by statistical analysis. Wood anatomy will be investigated at a later stage.

After two years, a visual inspection showed that the green leafed kauris are the more vigorous. If statistical results show any marked

differences, it is highly probable that the inferior type will be rejected at the first opportunity.

Kauri Raised Under the Dunemann System

In April 1953, a seed-bed was prepared at the Waipoua Nursery based on the Dunemann system of nursery practice in Germany. The bed took the form of an open bottomless box (6 x 3 ft.) with sides 12 inches high. Ten inches of *Pinus pinaster* needles were packed into the box, thoroughly soaked with water and covered with a fine layer of taraire (*Beilschmiedia taraire*) leaf mould. On this, two ounces of kauri seed were sown and covered with another fine layer of taraire leaf mould. The seed was sown from two of the selected seed trees on the same day as the same seed lot was sown in the nursery beds. Battens extending above the boards at the end of the box, together with cross battens above these, formed a support for a cover of hessian.

Germination in the Dunemann bed was at least a week ahead of the normal nursery beds. The hessian was removed and replaced with manuka brush cover after germination was complete.

Germination figures were:

Seed Tree No.	*Seed-bed per lb.*	*Dunemann bed per lb.*
847	1,552	5,600
852	1,648	3,280

It should be mentioned that the lower germination figures from the seed-beds were partially caused by depredations of mice and rats.

Compared with seedlings from normal seed-beds after eleven months growth, the Dunemann seedlings showed superior shoot growth possibly due to the liberation of nitrogen from decomposing pine needles, and superior fibrous development due to absence of resistance to root penetration. In Germany, the beds are watered daily to facilitate needle decomposition. At Waipoua Forest, the Dunemann bed was watered once only and still produced vigorous and healthy seedlings after one of the driest summers on record.

These interim results are encouraging as the introduction of the Dunemann system as standard kauri nursery practice would have other advantages. The seed-bed area would be reduced by 75%, weeding would be almost eliminated, and the beds would not be difficult to proof against mice and rats.

CONCLUSIONS

A successful kauri nursery technique has been evolved over the past 20 years after trial and experiment.

There is still room for improvement in certain aspects, and investigations will be continued, particularly concerning a process to harden-off kauri nursery stock prior to planting.

The very satisfactory results from the Dunemann trial and the favourable reaction of kauri to hardening-off could well bring about an adjustment in nursery practice.