THE REHABILITATION OF INDUCED PAKIHI SITES IN WESTLAND

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SYNOPSIS

Approximately 19% of the land area in north Westland may be classified as high terrace—that is, the highest of a series of terraced glacial deposits. Most such sites were formerly forested but have by now been logged and repeatedly burnt, and reversion to an induced pakihi (Maori: "open grass country, barren land") community has resulted. Soils are podzolic, and the site is impoverished in such instances. Limited success has been achieved with farming these soils, and, equally, forestry did not appear an attractive proposition until trials were established from 1953 onwards in Paparoa State Forest with a number of exotic coniferous species. These trials involved more than twenty species and it was demonstrated that with improved drainage and some mineral fertilizers satisfactory tree growth could be sustained. In 1965 a further trial was established, based on results from the earlier work, and has to date demonstrated good growth with three Pinus *species. Current agricultural trials on similar sites by the Departments of Agriculture and Lands and Survey have many problems, and it now appears that exotic afforestation may prove the most suitable land use on the high terrace pakihi sites.*

INTRODUCTION

Of the total land area of north Westland (that part of the Westland Land District lying north of the Taramakau River), nearly 44,500 hectares, or 19%, may be classified as high terrace—a term derived from the fact that these landforms are the highest and hence oldest of a series of terraced deposits left by late Pleistocene glaciations. Up to the present, most of the high terrace country had been logged of its former forest cover then repeatedly burnt in an effort to encourage the growth of pasture grasses. As a consequence, the site has been degraded and has reverted from forest of rimu, silver pine, pink pine, mountain toatoa and mountain beech to ground ferns, rushes, coarse grasses—the familiar induced pakihi (a word now in common usage taken from the Maori, meaning "open grass country, barren land") of Westland. Extensive pakihi areas are now found in the north of the Westland Land District and the south-west Nelson Land District; Will (1972) considers these pakihis result from land-use mistakes.

Soils are mature podzolics of the Okarito group, which have developed under rainfalls of 3050 mm and more, with con-

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sequent severe leaching. They are today impoverished and intractable.

Limited success has been achieved with farming these soils, and initially forestry did not appear to be any more of an attractive proposition. Promise shown by random plantings of 1953 led to greater attention being paid to pakihi sites than previously, and in 1956 an establishment trial was laid out in Paparoa State Forest. More than twenty exotic species were tried in the early years, but only a few emerged as being particularly suited to the unusual conditions. As a result of this early trial work, which demonstrated that land preparation and fertilizer were prerequisites to satisfactory tree growth, a second experimental area was established in 1965 in which only four major coniferous species were used.

FEATURES OF THE SITE

Both planting trials, 1956 and 1965, are in Paparoa State Forest on a large terraced deposit of approximately 7280 ha in extent, known locally as the Craigieburn Pakihi; this area demonstrates all the features and properties of a typical pakihi site. The Craigieburn Pakihi is located on the inland flanks of the Paparoa Range where heavy rainfall is experienced (between 3050 and 3810 mm per annum), and this has had a profound influence on the soil genesis. The climate is generally warm and humid, with a mean annual temperature of 12.5° C. The terrace ranges in altitude from 183 m to 335 m above mean sea level over a distance of 4 km; the slope is therefore gentle. The surface terrain is uniform, with a slight southerly aspect. A number of low ridges which parallel the direction of fall create distinct watersheds, all of which drain south-eastwards into the Grey River.

Geology and Soils

The Craigieburn high terrace consists of three to four minor terraces resulting from recessional phases during the late Pleistocene glaciations. Piedmont glaciation of *circa* 200,000 years ago (Suggate, 1965) extended throughout the Grey Valley and in receding left thick deposits now known as the Cockeye Formation which now underlies at depth the whole of the Craigieburn Pakihi and adjacent areas. The Formation is a poorly stratified outwash gravel of granitic origin, rounded and ill-sorted with boulders rarely exceeding 30 cm in diameter, in a weathered sandy brown matrix. During each of several later interglacial periods, loess was deposited on the terraces left by the glaciers—the deposits being thickest on the upper older terraces of the Cockeye Formation. This loessic deposit now forms the typical compact and almost impervious subsoil of the mature podzolic Okarito fine sandy loam soil complex. There is every reason to believe that a good deal of the older terrace country was formed under tundra conditions and, if this was so, it is to be expected that, before forest vegetation ever colonized the areas, a great deal of leaching and washing had already taken place.

Structure of the soil type after the forest vegetative cover has been removed and the site repeatedly burnt, consists of:

7.5- 9.0 cm	Peaty matted black humus, sodden most of the year but becoming tinder dry in droughty summer months;
2.5- 7.5 cm	The A horizon, of structureless dark grey wet silt, which dries to a friable loam;
9.0-60.0 cm	A structureless pale bluish-grey impervious fine silt, loessic in origin, which may contain mottled orange granules or small pebbles. This horizon is commonly gleyed;

A thin, but firmly cemented, iron pan;
An infinite depth of granitic or granodioritic/gneissic gravels.

In every respect, these soils are poor. Downward drainage is completely impeded by the gley horizon and the iron pan; lateral drainage is severely imperfect or impeded because of compact structureless silty soils. Analysis of the best type shows only a trace of phosphorus, limited supplies of calcium, magnesium, and potassium, a high carbon : nitrogen ratio, and a general pH of less than 5.0; from the agriculturalists' point of view, the soils are also deficient in copper, cobalt, and molybdenum (Walton, 1971).

Vegetation

The original cover in pre-European times on high terrace lands consisted of dense stands of medium-sized rimu (*Dacrydium cupressinum)*, with silver pine (*D. colensoi*) either pure or in admixture with rimu, and other species such as pink pine (*D. biforme*), mountain toatoa (*Phyllocladus alpinus*), mountain beech (*Nothofagus solandri* var. *cliffortioides*), and kaikawaka (*Libocedrus bidwillii*) occupying swampy hollows and small depressions. Early fellings concentrated on these high terrace stands because of the high standing volume per hectare, easy access, and the proximity of the forests to the markets. Once logged, fire was used to try to induce the growth of pasture plants; however, the method failed. The burning signalled the start of intense degradation, namely:

Removal of the forest cover led to surface water conditions which suppressed regeneration of the high-forest species;

Regenerating seedlings were exposed to full light by the clearfelling practice and did not survive;

This was followed by the complete destruction of the deep spongy duff and humus layers on which so much depended, with consequent loss of nitrogen.

These factors led to a complete change in vegetative cover from forest to non-forest species. With repeated burning, the slow colonization occurred of manuka (*Leptospermum scoparium*), swamp umbrella fern (*Gleichenia circinata*), rushes (*Juncus* spp.), gahnia (*Gahnia setifolia*), wire-rush (*Calorophus minor*), with bracken (*Pteridium aquilinum* var.

esculentum), ring fern (*Paesia scaberula*), and other minor ground ferns on drier mounds. In consequence was left the abandoned and familiar induced pakihi of Westland, with a vegetation which bespoke the poverty of the site (see Fig. 1 in Will, 1972). Scattered pockets of the original forest remain to this day in the deeper streambeds which dissect the terraced block.

Injurious Agencies

Two noxious animals are present on the high terrace country. Opossums occur in low but steady numbers, but they have been known to cause severe damage to trial plantings in the form of bark biting and leader stripping. Periodic control measures enable damage to be kept at minimal levels.

Fallow deer of the Paparoa herd are common on the Craigieburn Pakihi, and, less often, red deer may be encountered. Their contribution to damage is, however, considered relatively insignificant. Private hunters assist in the control of these animals.

Land Use Value

Okarito soils on high terrace sites can be truly described as the foresters' dilemma. These difficult sites have been readily worsened by clearfelling the original stands; indigenous species, though valuable when mature, are characterized by extremely slow growth and are not financially attractive as a cultural crop. Kennedy (1954) summarized the situation when he wrote:

> In New Zealand, with a history of successful exotic forestry, the normal reaction to this problem would be as the indigenous forests on the mature soils are cut out to replace them with faster growing exotics. No species has yet been tried that promises to succeed on the Kumara or Okarito soils, although the range of species so far planted has been restricted to those that have given good results on better soils in other parts of New Zealand. Research to determine possible new species and suitable provenances of species already tried is now proceeding, but conclusive results are likely to be long delayed.

The high terrace site would therefore appear unattractive for afforestation, and Chavasse (1954) concluded that: ". . . this soil type will not, and cannot, make any contribution to the national larder, either practically or economically."

In 1960 the Department of Lands and Survey completed a land utilization report on the West Coast which stated that the pakihi lands were quite unsuitable for immediate development, but strongly recommended that experimental and demonstration units be developed. The experimental areas have since been set up and are located at Cape Foulwind and at Bald Hill in the Buller District near Westport. Both units are controlled by Lands and Survey. Their progress with pakihi development is discussed later in this paper. Generally speaking, these sites are currently considered unfarmable, and the

Department of Lands and Survey will not take on land for farm development where Okarito soils are present in any quantity (A. C. R. Elcock, Senior Field Officer, Lands and Survey, Hokitika, pers. comm.).

ESTABLISHMENT TRIALS WITH EXOTIC TREE SPECIES

First Observations

The first records of any planting on high terrace soils in north Westland were those of (then) Forest Ranger K. W. Lindsay, who noted in February 1956 that: ". . . on Craigieburn Pakihi, about 20 two-year old *Eucalyptus delegatensis* planted in 1953 alongside the tram have grown vigorously to a height of about 5 feet."

Interest in the potential of the site quickened, and further investigations resulted in the establishment of a species trial in the winter of 1956, in which drainage and fertilizer work were incorporated. This trial, subsequently to grow to cover 22.5 ha in area, was belatedly accorded sample plot status in 1968 as Permanent Sample Plot (PSP) WD.* 72.

Sample Plot WD. 72

In planning the trial layout, it was realized at an early age that some measure of improved drainage and artificial fertilizing would probably be necessary on this site. Accordingly within PSP WD. 72 there were three subtrials, differing in the land preparation methods employed. Of these three methods, only one—windrowing topsoil with machinery—has been significantly successful.

(a) *Turf Planting*

A small area of 0.9 ha was planted in 1960 and 1961 with four spruces—*Picea mariana, P. omorika, P. rubens,* and *P. sitchensis*. The planting sites had been prepared a year previously when small blocks of turf were dug up at 1.8 × 1.8 m intervals and placed upside down on the ground. Trees were planted in the middle of the small mound so formed. Three fertilizers, supplying N, P, and K, were applied in varying mixtures at the rate of 376 kg/ha soon after planting. No further treatment was given after the initial application.

Turf planting was not successful. After breakdown of the turf there appeared to be little difference between this and direct planting into the topsoil. Few of the remaining *Picea* spp. could be located in 1969, and this trial must—for *Picea* species at least—be regarded as a failure. It was unfortunate that only one genus was tested in this way. However, supplementary evidence exists from other work to support the conclusion that turf planting was not effective as a land preparation method.

*WD = Westland.

(b) *Direct Planting into the Topsoil*

Proposals to experiment with direct planting into the topsoil with no prior preparation were expedited between 1959 and 1962 on an 8 ha block. Once again only a relatively few species were involved—*Alnus rubra, Pinus contorta, P. mugo,* and *Tsuga heterophylla.* Fertilizer treatment was given to the *P. contorta* only, soon after planting.

Growth has been far from spectacular, and animal damage has been severe to all species in this block. As yet, no height increment data have been collected because of excessive malformation; it was unfortunate that the species selected proved so susceptible to animal damage. Direct planting is now no longer considered a suitable method of establishment on the pakihi sites.

(c) *Windrowing Topsoil with Machinery*

Land preparation for the 13.7 ha of the main trial area consisted of peeling away topsoil in 3 m wide strips with the blade of a TD14 bulldozer; the blade was so angled and tilted as to form alternate heaped windrows, and scrapes where the subsoil was exposed. This operation was carried out a year prior to planting, at an estimated cost of $86.50 per ha; this proved to be considerably higher than the cost of preparation with a Cuthbertson plough on similar country in PSP WD. 109 (discussed later in this paper).

Plantings, which commenced in 1956, were largely from a clearing of tree stocks from Granville Nursery at nearby Totara Flat. Attempts were made to space trees at about 2.8 m × 1.8 m; the cost of this operation was $59 per hectare. Trees were planted either on the exposed subsoil (centre rows) or variously placed on the heaped topsoil (side rows); generally there were two rows along each mound. At the time of planting, selected rows were treated with one of three fertilizers—Nauru phosphate, basic slag, or lime; approximately 29 g was spread around each tree.

Plantings continued in 1957 at a spacing of 1.8 m × 1.8 m and were on land similarly prepared; similar fertilizer treatments were given except that superphosphate replaced Nauru phosphate. In 1958 and again in 1963 the rates of fertilizer application were varied between 29 g and 454 g per tree. No further treatment has been given this trial since 1963.

Species planted in this part of the trial have included *Abies concolor, A. grandis, A. nobilis, Alnus incana, A. glutinosa, Betula pendula, Eucalyptus aggregata, E. fastigata, E. muellerana, E. obliqua, E. regnans, E. viminalis, Pinus contorta, P. muricata, P. radiata, P. sylvestris, Pseudotsuga menziesii,* and *Thuja plicata.*

TREE GROWTH RESPONSE TO DRAINAGE AND FERTILIZERS

Assessments of the growing stock in PSP WD. 72 have been carried out periodically since 1958, with the most recent being conducted in 1969. Tree growth responses to the effects of

TABLE 1: TREE GROWTH RESPONSE TO ARTIFICIAL DRAINAGE: PSP WD. 72

Mean tree heights in metres (± standard error of the mean at the 95% confidence level)

Species and Year	*Treatment (kg/ha where applicable)*	*Drained Row (D) or Undrained Row (U)*	*Mean Height 1969*
Pinus contorta 1956	Control	D	4.126 (±0.17)*
Pinus contorta 1956	Control	U	2.793 (±0.12)*
Pinus contorta 1956	125.5 kg/ha	D	4.413 (±0.14)*
Pinus contorta 1956	Lime	U	2.332 (±0.12)*
Pinus contorta 1957	Control	D	3.570 (±0.20)*
Pinus contorta 1957	Control	U	1.317 (±0.12)*
Pinus contorta 1957	125.5 kg/ha	D	3.796 (±0.16)*
Pinus contorta 1957	Lime	U	2.325 (±0.17)*
Pinus muricata 1957	Control	D	4.158 (±0.22)*
Pinus muricata 1957	Control	U	2.839 (±0.16)*
Thuja plicata 1956	Control	D	1.384 (±0.07)*
Thuja plicata 1956	Control	U	1.024 (±0.06)*
Thuja plicata 1956	125.5 kg/ha	D	2.336 (±0.13)*
Thuja plicata 1956	Superphosphate	U	1.704 (±0.10)*

Notes: (1) *Differences of statistical significance established between these pairs; Level of probability: $P < 0.01$.

(2) *Pinus radiata* and *Betula pendula* were planted on drained rows only, and therefore it was not possible to apply the above tests to these species.

drainage and fertilizer are therefore well documented. The availability of tree stocks from the nursery clearance governed the distribution of the species (by area, the figures are: *Thuja plicata* 11%; *Pinus contorta* and *P. muricata* 59%; *P radiata* 4%; and other conifers plus broadleaved species and eucalypts 26%), and because of this imbalance it was not possible to test all species with the same range of treatments. However, it has been possible to select the more optimal conditions under which improved tree growth performances were recorded.

Drainage

Blading the soil into heaps was effective in giving adequate drainage for one or two rows of mound-planted trees, but between these windrowed mounds only the structureless subsoil remained: because of this, considerable ponding of surface water occurred, rendering centre row growing conditions more inhospitable than a similar site where the surface drainage was adequate. This preparation served well to demonstrate the necessity of removing water surplus to the needs of the trees from the soil.

Statistically significant differences, which are visibly appreciable in the field, exist between the growth of trees located on side rows and the undrained centre rows; and similar patterns were apparent for those rows which had been given fertilizer treatments. Table 1 lists growth data for several species and compares growth on drained and undrained sites for both control and fertilizer-assisted trees.

Artificial Fertilizers

Where tree growth on pakihi sites is concerned, significant advantages are to be gained by the application of artificial fertilizers. The extent of this advantage was found to vary with the type of fertilizer used and the rate of application of each.

With the four fertilizers used, a graded response series was revealed: commencing with control rows there was a progression through the use of lime, blood and bone, and basic slag, to superphosphate which promoted the maximum response. There appeared to be little advantage gained from the application of lime; in a few cases it actually appeared to reduce relative growth. Basic slag and superphosphate were difficult to separate on merit. However, the former is now no longer available as a general purpose fertilizer.

Table 2 contains an analysis of some of the measurements taken during a 1969 assessment and demonstrates the effects of differing application rates of fertilizers on several species. The rectangular spacing achieved during trial establishment of 2.7 m × 1.8 m corresponds to a net stocking of 1990 stems per hectare. Fertilizers were applied by hand at rates varying between 29 g per tree and 454 g per tree, or a range of 63 kg/ha to 940 kg/ha.

For lime, the maximizing effect appeared to be at application rates corresponding to 250 kg/ha, whilst for basic slag, superphosphate, and blood and bone, performances were best at the highest application rates of 500 kg/ha—though all were unreliably tested beyond this point. It is worthy of note that, as the rates of application become heavier, variability of the trees within that treatment category decreases.

The critical time between successive applications when the effects of the fertilizers applied began to wane was not specifically tested. However, analysis of data collected in 1963 and again in 1969 suggests that, initially, 6 years may be too long between successive applications.

THE 1965 TRIALS

PSP WD. 109, Craigieburn Pakihi

Initial trial work from PSP WD. 72 showed that several exotic tree species would grow on the pakihi soils, and that growth of these trees was enhanced by improved artificial drainage and the application of mineral fertilizers (especially those containing phosphate) at rates of up to 500 kg/ha. A similar trial to follow on from the earlier one was planned from 1961. Land preparation commenced in the following year and planting began in 1965; this second trial became PSP WD. 109, and is located within half a kilometre of PSP WD. 72 The Forest Research Institute has advised on layout and design from the earliest stages. The object of the younger trial is to test the effects of drainage and fertilizer application on the growth of each of three selected *Pinus* species.

A number of natural water channels inadequately drained the trial block of 25 ha prior to 1962. Drainage was improved in four stages, variously involving the use of a TD14 tractor and blade, D7 tractor and Cuthbertson single-furrow mouldboard plough, explosives, and manual shovel labour. When completed, the drainage pattern consisted of a herring-bone system of main drains, with lateral drains (ploughed furrows leading into main streams) approximately 45 cm wide by 45 cm deep. The lateral drains followed roughly along the contour and were spaced 5 m apart on the average. The cost of this land preparation was $49.20 per ha.

Three species were selected for this trial, based on performance shown in PSP WD. 72—*Pinus contorta*, *P. muricata*, and *P. radiata*. Small blocks of approximately 0.8 ha were established with these species so as to produce 24 randomly placed replicated subplots; 20 of these were planted in 1965 and a further four *P. muricata* subplots were added in 1967. Proposed espacement was 1.8 m × 1.8 m, and this was generally achieved. In 1965 also, a few smaller subplots of *Picea sitchensis* and a mixture of *Pinus contorta* and *Betula pendula* were included. Tree rows were planted on both sides of the ploughed furrows, either on top of the spoil-mound from the furrow or on the flat ground bordering the furrow and about 30 cm back from the edge of the drain (see Fig. 1); centre

FIG. 1: *Replicate plot 1/4A of* Pinus contorta *in PSP WD. 109 on the Craigieburn Pakihi, Paparoa State Forest. The general nature and the induced flora of a pakihi site is well illustrated in this 1967 photograph, taken two years after establishment. The ploughed furrow lies centre, and to the left is the spoil mound from the furrow. Two rows of trees, one on each side of the furrow, are to be seen. The southern Paparoa Range forms the background skyline.*

N.Z. Forest Service photo by G. M. Will

rows were sometimes added between the two to give regular spacing. Fertilizer treatments applied to the replicates soon after planting were: control plots with no treatment; Christmas Island phosphate at 375 kg/ha; a 1 : 1 superphosphate-blood and bone mixture (to supply nitrogen and phosphorous) at 250 kg/ha; and a 3 : 3 : 1 mixture of superphosphate-blood and bone-muriate of potash (giving supplies or nitrogen, phosphorous, and potassium) at 375 kg/ha. Further applications will be dependent on needs shown up by observation and by foliar analyses. To date, two growth assessments have been carried out; results from the 1971 assessment on the A replicate are given in Table 3. In general terms, species performance can be placed in the descending order of *Pinus radiata*, *P. contorta*, and *P. muricata*. The benefits of site drainage are again apparent (see also Fig. 2), and the N + P fertilizer combination appears to have elicited a better response than any other for two of the three species being tested.

TABLE 2: TREE GROWTH RESPONSE TO FERTILIZERS: DRAINED ROWS ONLY (PSP WD. 72)

Mean tree heights in metres (± standard error of the mean at 95% confidence level)

Species and year	Application Rate (kg/ha)	Control Mean Ht.	Control CV %	Lime Mean Ht.	Lime CV %	Blood and Bone Mean Ht.	Blood and Bone CV %	Superphosphate Mean Ht.	Superphosphate CV %	Basic slag Mean Ht.	Basic slag CV %
Betula pendula 1957	125.5	2.472 (±0.16)	43.7	2.821 (±0.21)	33.5	4.646 (±0.16)	28.1	3.405 (±0.17)	21.7	—	
Pinus contorta 1956	125.5	4.126 (±0.17)	31.6	4.413 (±0.14)	29.1	—		5.985 (±0.13)	19.0	6.049 (±0.17)	17.8
Pinus contorta 1957	251.0	3.409 (±0.27)	37.1	4.035 (±0.15)	24.4	5.282 (±0.22)	23.6	4.761 (±0.12)	19.6	4.994 (±0.22)	24.6
Pinus contorta 1956	502.0	—		4.208 (±0.17)	23.4	—		5.985 (±0.13)	19.0	6.049 (±0.17)	17.8
Pinus contorta 1956	941.0	—		4.416 (±0.14)	18.9	—		5.761 (±0.18)	26.6	—	
Pinus muricata 1956	125.5	3.640 (±0.27)	37.9	—		—		6.032 (±0.36)	22.0	7.320 (±0.30)	13.0
Pinus radiata 1957	125.5	5.495 (±0.29)	44.0	4.139 (±0.39)	46.9	7.359 (±0.43)	23.1	6.003 (±0.54)	34.8	4.886 (±0.35)	42.6
Pinus radiata 1957	251.0	—		—		6.814 (±0.46)	18.1	8.292 (±0.28)	17.3	6.810 (±0.35)	27.3
Pinus radiata 1957	502.0	—		—		8.251 (±1.19)	38.3	8.817 (±0.56)	33.9	5.705 (±0.65)	47.5
Thuja plicata 1956	125.5	1.380 (±0.07)	38.9	1.285 (±0.08)	34.4	—		2.336 (±0.13)	37.8	2.724 (±0.19)	41.3

Note: CV = coefficient of variation.

THE AGRICULTURAL POTENTIAL

The Department of Lands and Survey 1960 report on land utilization on the West Coast stated that the pakihi lands were quite unsuitable for immediate development, but strongly recommended that experimental and demonstration areas be developed. The experiments, which have since been conducted by the Department of Lands and Survey at Cape Foulwind and by the Department of Agriculture at Bald Hill (both in the Buller District), have had their measure of success. The present rate of development is about 120 ha per year.

Soils on these demonstration units are mapped as Utopia and Addison podzolics (DSIR, 1968), which respond much more readily to fertilizers and drainage than do the Okarito podzols found on the Craigieburn Pakihi: this fact should be kept in mind during the following discussion. It is therefore perhaps questionable to compare agricultural development and afforestation on these two slightly differing sites.

Walton (1971) gives a brief account of progress in the agricultural rehabilitation of pakihi lands. The basis of large-scale development is oversowing with clover (*Trifolium* spp.) and

FIG. 2: *The same site as in Fig. 1, in 1970 when the* Pinus contorta *was 5 years of age. The drain is obscured in the foreground shadow in the centre. This plot was supplied with N-P-K fertilizers soon after establishment. Height differences and improved vigour between mound-planted trees (left) and those on the flat (right) are apparent.*

N.Z. Forest Service photo by G. M. Will

TABLE 3: TREE GROWTH RESPONSES TO DRAINAGE AND FERTILIZERS: WD. 109, CRAIGIEBURN PAKIHI

Mean tree heights in metres (± standard error of the mean at 95% confidence level) of the A replicate* at age 6 years, after a 1971 assessment

Fertilizer Treatment	*Replicate*	*Pinus contorta* Mound	*Pinus contorta* Flat	*Pinus radiata* Mound	*Pinus radiata* Flat	*Pinus muricata* Mound	*Pinus muricata* Flat
Control	1A	2.243 (±0.088)	1.805 (±0.089)	2.172 (±0.113)	1.386 (±0.113)	1.826 (±0.083)	1.275 (±0.088)
P	2A	2.106 (±0.087)	1.306 (±0.082)	2.867 (±0.148)	2.188 (±0.122)	2.138 (±0.110)	1.821 (±0.118)
N + P	3A	2.141 (±0.099)	1.827 (±0.107)	3.872 (±0.159)	3.233 (±0.196)	2.554 (±0.109)	2.018 (±0.131)
N + P + K	4A	3.217 (±0.119)	2.990 (±0.315)	3.754 (±0.129)	2.411 (±0.146)	1.693 (±0.087)	1.201 (±0.058)

**Note*: The trial has two replicated series of subplots. Replicate A was wholly established in 1965; replicate B was established partly in 1965 and completed in 1967. The uneven-aged replicate is unsuitable for presentation of results in this form.

TABLE 4: ESTABLISHMENT COST COMPARISONS ON PAKIHI

(All costs in $ per hectare, rounded to the nearest dollar)

Item	*PSP WD. 72 1956 2240 s.p.ha* $	*PSP WD. 109 1965 1990 s.p.ha* $	*Hill Country Conversion (Day, 1969) 2990 s.p.ha* $	*Agriculture (Walton, 1971)* $
Forestry:				
Clearfelling forest cover	—	—	74	—
Slash burning of felled cover	—	—	4	—
Drainage and ploughing	86	49	—	—
Planting (stocking specified)	59	17	79	—
Agriculture:				
Grassing and oversowing	—	—	—	112
Fencing, tracking, drainage	—	—	—	38
Totals	145	66	157	150

introduced pasture grasses. Prior to development the natural cover of pakihi fern and rush is fired. Three sowings are made: in August, 22.5 kg of seed, 3.7 tonnes of lime, and 500 kg of superphosphate are spread over each hectare, followed in February with another 500 kg/ha of potassic superphosphate, and a final dressing of 500 kg/ha of potassic superphosphate is applied in the second spring. Copper, cobalt, and molybdenum are included as trace elements with the superphosphate at each treatment. Once the newly sown pastures have come away, they are mob-stocked at the rate of 490 ewes per hectare; this stock pressure is essential if the fern and rushes are to be kept under control. The Cape Foulwind Farm Settlement is currently carrying 7 to 9 ewe equivalents per hectare, and planning is under way to increase this to 12 to 14 ewe equivalents per hectare.

Drainage is not the problem that was envisaged. High stocking rates with sheep in the initial stages of development pro-

Pinus muricata, *planted in 1956, showing growth up to 1962, on the Craigieburn Pakihi. Paparoa Forest, after draining and fertilizing. This should be compared with Fig. 1 in Will, G. M., Soil science and forestry—past and future.* N.Z. Jl For., 17 (*1*): *15.*

N.Z. Forest Service photo by J. H. G. Johns, A.R.P.S.

mote vigorous growth of the grass sward, which in turn leads to higher transpiration rates and therefore the land dries out relatively rapidly. Those areas which still appear wet after 2 or 3 years are best tackled with light machinery.

The total cost of this development is seldom less than $150 per ha, and may be as high as $360 per ha to bring timbered land into production as pasture. The unimproved value of the land accounts for some $12 per ha of this total. The land requires skilful management, but it is regarded as excellent cattle country. Studies carried out under the auspices of Lincoln College in 1969 showed that the establishment of a farm unit on a 400 ha block was unprofitable from an individual farmer's point of view. The problems associated with this land are as yet far from solved, and the large tracts of pakihi country in Buller and Westland are currently under little pressure from the agricultural fraternity.

DISCUSSION

Most hope for the establishment of a commercially viable exotic forest on high terrace sites of the Craigieburn Pakihi type rests with the three pine species, *Pinus contorta, P. muricata,* and *P. radiata,* with reservations being held for some of the *Eucalyptus* species. Compared with the early growth rates of conifers elsewhere in New Zealand on amenable sites, the rate of the best Craigieburn Pakihi pines is about one-half; it is considered that this can be improved upon as techniques develop, and with the knowledge gained in retrospect from PSP WD. 72. The performance of the above three pine species in the younger PSP WD. 109 is encouraging, and it is hoped to maintain growth on the pakihi trials to achieve site indices between 60 and 100 ft (Lewis, 1954); site indices of 95 to 102 are currently being obtained with *P. radiata* on the better hill country conversion forests elsewhere in Westland Conservancy (G. P. S. Allan, pers comm.).

Although *Pinus contorta* was once favoured for these sites, it has recently lost some face because of its several disadvantages (G P. S. Allan, pers. comm). Its sawn timber potential is doubtful, although it could become a ready source of pulp timber. Nutrient problems may be encountered, but these can be overcome. Susceptibility to opossum damage is a major factor influencing use of the species on a large scale.

Pinus muricata, even the blue strain used in these trials, is encumbered with a dubious reputation for poor form. Greater hopes are currently held for this species for the future. Its usefulness could be in two spheres: when branchiness can be controlled it provides good sawn timber, and with a growth rate and form similar to *P. radiata* it can be mixed with the latter to take full advantage of microsite differences—*P. muricata* has a better threshhold value on wetter sites than does *P. radiata.* Opossum damage may be severe initially unless control measures are taken.

The survival of *Pinus radiata* was initially not good. Nevertheless, it appears to be the most promising species on high terrace sites. Growth has been proven on other Westland soils, and it is currently the major species of the exotic conversion programme on cutover hill country (Day, 1969), constituting more than 80% by area of current planting schedules.

Eucalyptus species have not been tested to the same extent as have the pines. However, with the growth of the best mound trees of *Eucalyptus fastigata* comparing favourably with that of *Pinus radiata* (5 to 6.5 m in the first 8 years), certain species of this genus could be expected to record even faster growth with some fertilizer treatment.

The costs of establishment on pakihi country, when considered with the potential growth possible, are sufficient to make forestry a worthwhile venture. A comparison of costs incurred up to the time of establishment on several site types is given in Table 4. It should be noted that considerable savings are to be made by using the type of land preparation employed for PSP WD. 109; if adopted on an operational scale, it is possible that this establishment cost for pakihi afforestation could be improved upon. When growth rates are taken into consideration, however, it is unlikely that a case can as yet be put for other than further experimental establishment on Okarito soils.

Wind-firmness is an unknown quantity with trees on the high terraces of the Craigieburn Pakihi site, but it is nevertheless an important consideration which should affect any extensive forest establishment on these soils. Evidence of windthrow on both Okarito and Waiuta soils at Mahinapua State Forest near Hokitika counsels some caution. The undisturbed site has, on the average, approximately 20 cm of soil suitable as a rooting medium; even with mounding as was provided artificially in the trials, the maximum rooting depth rarely exceeded 1.2 m. In defence, it may be stated that, although exposed to all winds on the Craigieburn Pakihi site, to date only a relatively few trees have actually been thrown. To what extent wind stability could be improved by some form of deep ripping during site preparation provides only for conjecture at this point.

CONCLUSIONS

Establishment trials with a number of exotic coniferous species on the high terrace site of the Craigieburn Pakihi in Westland demonstrated that satisfactory growth was effected only when: (1) Provision was made for improving the natural drainage by mounding or otherwise building up of the planting microsite; and (2) Application of inorganic mineral fertilizers (especially the phosphates) was made at rates of not less than 500 kg/ha. The critical duration between successive applications of fertilizer was not tested. Three pine species (*Pinus contorta, P. muricata,* and *P. radiata*) appeared to be the most promising species for rehabilitation of induced pakihi by afforestation.

The high terrace site type has generally been regarded as a marginal site for both agriculture and forestry. However, work carried out since 1953 tends to suggest that, for afforestation purposes, the high terrace country has a potential hitherto unrecognized. It is almost certain that afforestation with exotic pines is currently the only land management practice that can fully utilize the pakihi lands; the soils are under no pressure from other land-using interests.

Although currently of low priority for afforestation purposes in Westland (Molloy (1970) records that there are 46,460 ha of land of selected hill country sites suitable for exotic plantings within a 48 km radius of Greymouth), the high terrace sites may receive further consideration if the current interest in the West Coast beech resources materializes to an industry with a concomitant establishment of a supplementary exotic softwood resource.

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Note: All imperial units were converted to metric measure by using the "Table of Precise Conversion Factors" which appears as Appendix 1 to *Metric Guide for Forestry,* published in 1969 by the U.K. Forestry Commission. The metric equivalents have been rounded down to integral form if no decimal point is shown.

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