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BOX PRUNING TRIALS AND FIELD RESULTS

G.J. Brunsden *

The Concept

Tree toppling is common in plantations, especially of radiata pine and other fast-growing species, not only in New Zealand but in a number of other countries also, overseas. The main line of development to obviate root distortion has been container-seedling production. However, as bare-root methods have been well-developed

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for radiata pine in New Zealand, it was considered that an attempt should be made to see whether bare-rooted seedlings could be 'tailored' in order to produce a root system which would not be readily distorted during planting.

Susceptibility to tree toppling can be increased by a number of factors (Chavasse 1969); poor planting methods, high soil fertility causing an abundance of stem growth, heavy wet soil conditions, excessive weed competition and in particular poor root systems can all increase the severity of the problem. Seedlings need to produce a well balanced root system in the form of an even distribution of laterals and a strong sturdy taproot for future stability. Naturally regenerated trees usually produce root systems that have such characteristics whereas mechanically conditioned or wrenched planting stock frequently do not. Large numbers of long fibrous laterals and a soft flexible taproot can result from the process of wrenching, sometimes there is no distinctive taproot at all. Seedlings with these root types are very prone to further root distortion during packaging and transporting to the planting site but are especially liable to be poorly planted, (Fig. 1A). Such badly malformed root systems are unlikely to develop into a well balanced anchoring system.

Investigations in the early 1970s into the various types and frequencies of mechanical conditioning demonstrated that a seedling root system that planters would, it seemed, have difficulty to 'screw up' in the planting hole could be produced by a combination of four-sided lateral pruning and undercutting. This conditioning type became known as box pruning. The question arose as to what the nature of later survivals, growth and root development would be for such 'structurally sound' planting stock, particularly when compared to that raised by conventional methods.

A. History of Development in the North Island

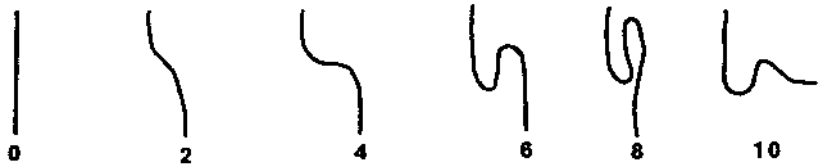
In 1971 and 1972 trials were established at FRI, Whaka and Kaingaroa to study the effects of various nursery conditioning methods on survivals, growth and root development of 1j/0 radiata pine after planting out. A comprehensive range of treatments involving combinations of lateral pruning with and without wrenching and box pruning with and without topping were tested.

Assessment of these trials, and all those to follow, involved recording survivals and general tree health, incremental height and diameter growth and root excavations to assess rooting configuration. When trees were excavated, usually after at least two years growth, their root systems were scored on a demerit points system devised by Menzies in 1973, (Table 1).

TABLE 1: POINTS SYSTEM FOR EVALUATING ROOT SYSTEMS

1. Taproot (Maximum = 10)
Well developed, straight = 0
Stunted but definite = 1
Does not come below horizontal = 10
Laterals now vertical as sinker roots = 1/sinker (subtracted from the 10 for not taproot).

Deformation.



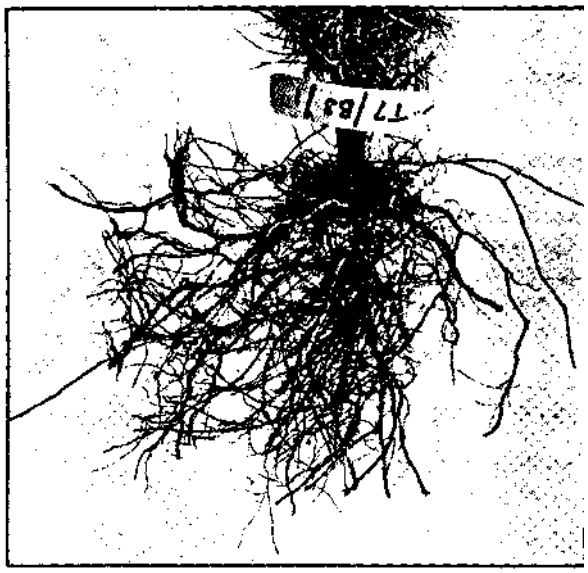


FIG. 1A : THE BUSHY, STRAGGLY ROOTS OF MANY WRENCHED SEEDLINGS ARE EASILY DAMAGED AND SCREWED UP BEFORE AND WITH PLANTING

NEG. 29799

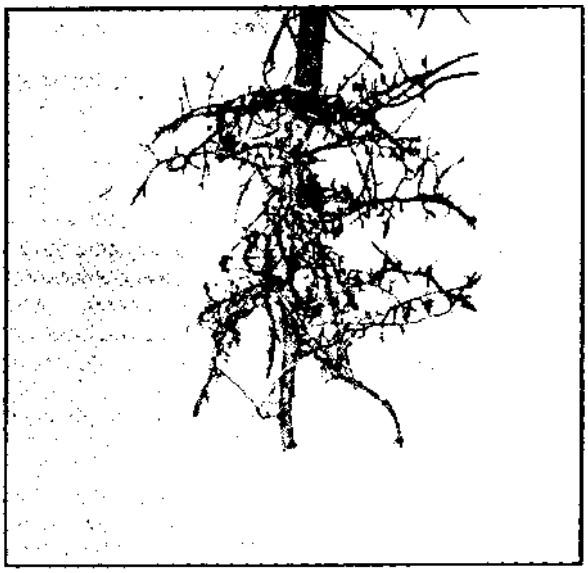
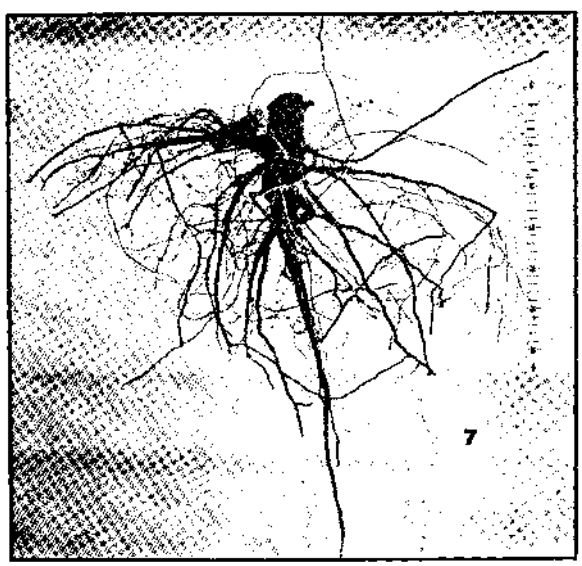


FIG. 1 B : A COMPACT MASS OF SHORT LATERALS AND A STRONG, STRAIGHT TAPROOT ARE CHARACTERISTIC FEATURES OF BOX PRUNED ROOTS

NEG. 33629



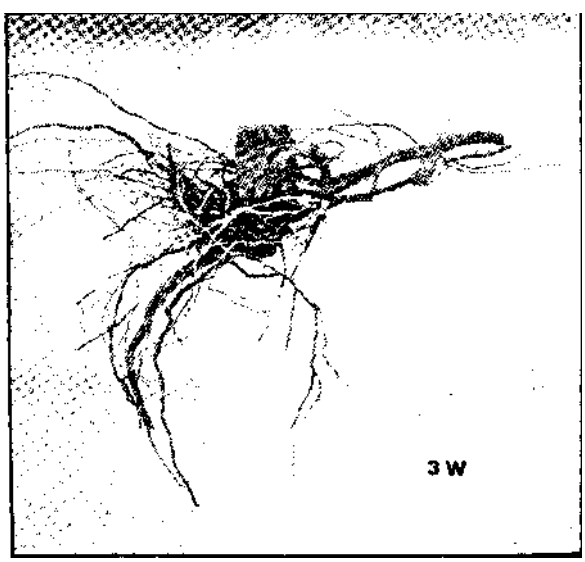


FIG. 2 : BETTER OVERALL ROOT FORM WAS ALWAYS EVIDENT FOR BOX PRUNED TREES (LEFT) COMPARED WITH WRENCHED (RIGHT) FOR THE LATTER DEPTH OF PENETRATION WAS USUALLY BY SINKER ROOTS AND LATERALS WERE OFTEN TWISTED. MULTIPLE TAPROOT REGENERATION ON BOX PRUNED STOCK WAS COMMON.

NEG. 41815 NEG. 41783

2. Lateral Roots (maximum = 10)
4-5 well distributed = 0
3 well distributed = 1
Laterals opposite = 4
Laterals at right angles or on one side = 8
No laterals = 10

All root systems were assessed by this subjective method by several persons a number of times.

From the first series of trials Brunsden (1976) concluded:

1. Lateral pruning on two sides only, irrespective of frequency, does not condition seedlings satisfactorily.

2. Seedlings subjected to wrenching regimes which did not include any lateral root pruning showed lower survivals than those which were wrenched at 2-3 week intervals with lateral pruning.

3. The best conditioning method overall in terms of survivial, height growth and root development was a 4-weekly box pruning/topping treatment.

4. A conditioning method of 4-weekly box pruning only, indicated that growth rates of seedlings were comparable to trees treated by conventional conditioning methods.

These first trials demonstrated the advantages of box pruning/late undercutting. At the time of planting it was noted that the small compact mass of fibrous laterals combined with a strong sturdy taproot produced by this technique were subjected to the minimum of distortion and developed into the best root form.

In 1975 a comprehensive investigation on box pruning was started, particularly to see if the regime did produce a tree that would be less topple-prone. By this time 1/0 radiata pine had been selected as a more suitable stock class for treatment, primarily due to its smaller more manageable size. A typical box pruning regime as applied to 1/0 Pinus radiata may be found in Appendix I. Reporting on the results of replications at Mangatu and Tairua Forests Brunsden and Bowles (1979) wrote:

1. Box pruned trees had superior growth to normally wrenched seedlings. A height increment difference of nearly 30 cm was recorded at both forest localities at the end of the third year. Bulk figures, an index derived from $D^2H \times 10^{-}n$, demonstrated that in some instances 100% more growth was recorded for box pruned stock.

2. A root structure of a persistent, unbranched sturdy taproot with an even array of horizontally orientated laterals can be produced by box pruning (Fig. 1B). These trials confirmed from root excavations that less root distortion and better overall form was consistently evident for box pruned trees compared with wrenched, (Fig. 2B).

3. There was no significant difference between the incidence of toppling in the box pruned trees and the normal wrenched, (Table 2). However poor planting markedly affected stability, a poorly planted wrenching treatment having nearly three times the amount of topple as the well planted in some cases.

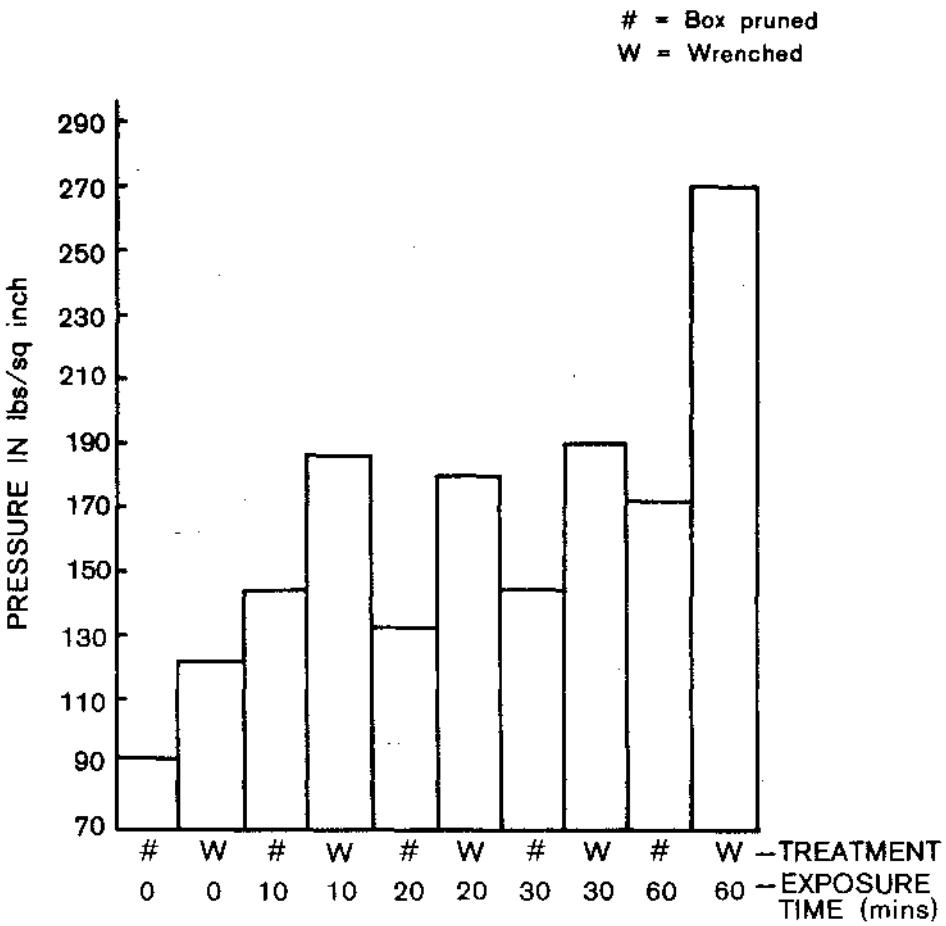
TABLE 2: Percentage of Toppled Trees, Mangatu Forest
After 3 Years Growth

Treatments	B.P.	B.P.	W	B.P. & P.P.	W & P.P.
Medium	5	4	6	3	11
Bad	4	4	2	8	11
Total	9	8	8	11	22

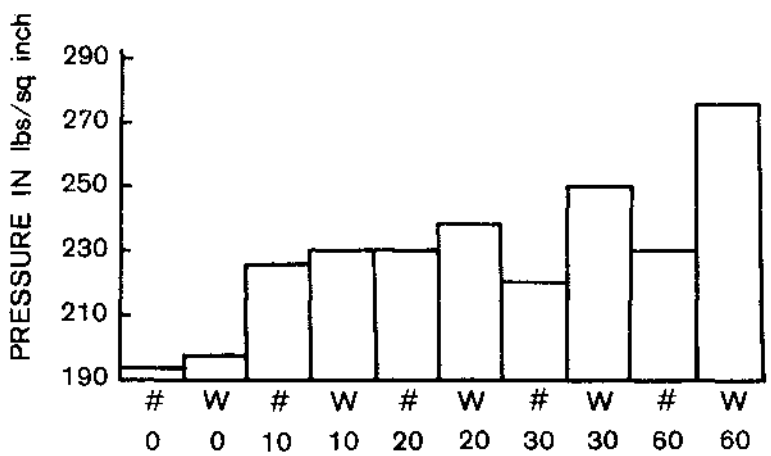
Key: B.P. = Box Pruned, W = Wrenched, P.P. = Poorly Planted

FIG. 3 RESULTS OF PRESSURE CHAMBER TESTS TO DETERMINE PLANT WATER STATUS.

A. AT EXPOSURE TIME : SEPTEMBER.
HIGHER THE READING = GREATER THE WATER STRESS.



B. ONE WEEK AFTER SEPTEMBER PLANTING



In 1975 an even more complex trial, 30 treatments with 200 trees/treatment, was established in Kaingaroa forest. Both 1/0 and 1½/0 Pinus radiata were tested. General trends that have shown up after 5 years include;

- the growth of 1/0 box pruned stock ex FRI, significantly smaller at planting, was comparable to 1½/0 FRI wrenched trees and significantly better than 1/0 wrenched.

- root excavations and stem form/stability assessments showed no differences between tree treatments to be evident after this period.

Superior growth rates of box pruned seedlings compared with wrenched became evident after one year's growth at a number of trial sites during this period. However these early trials had not accounted for the importance of spacing in the seedbed, a factor alone that proved to be of upmost importance to seedling quality and subsequent growth. This was well borne out, (Chavasse, Bowles 1975). Was this improved growth factor due then to the nature of conditioning, seedling density or both factors combined?

Bearing this in mind all trials from 1976 on eliminated this variable testing box pruned with wrenched plants when sown at the same densities.

Physiological Studies

Mechanical conditioning of tree seedlings as a means of preparing a plant to withstand serious forms of stress was a point well debated at FRI Symposium No. 9 (1969). To determine whether stock conditioned by box pruning could tolerate the same degree of stress to which wrenched trees can sometimes be subjected prior to outplanting a trial was established in 1976. Box pruned and wrenched 1/0 radiata seedlings were subjected to varying periods of root exposure at 20 ^{0}C and 50% relative humidity in a controlled environmental cabinet. Identical procedures were carried out in May, July, and September. Results were reported by Brunsden (1977);

- box pruned stock can withstand root exposure better than wrenched. This was apparent from physiological analyses (Fig. 3) and especially in terms of subsequent growth after one year (Fig. 4).

Twelve seedlings from each treatment used in this trial were harvested, divided into foliage, stem, and lateral and tap roots, and immediately frozen in liquid nitrogen. The tissue was freeze dried, ground in a Wiley mill and analysed using the routine g/c procedure for soluble sugars and colorimetric procedure for starch. From this experiment Cranswick (unpubl. data), concluded;

> "Box pruned seedlings have a greater amount of total carbohydrate per seedling, and higher concentrations of soluble assimilate and starch reserves available to them for new growth and general metabolism. Wrenched seedlings appear to have more than adequate reserves for these functions".

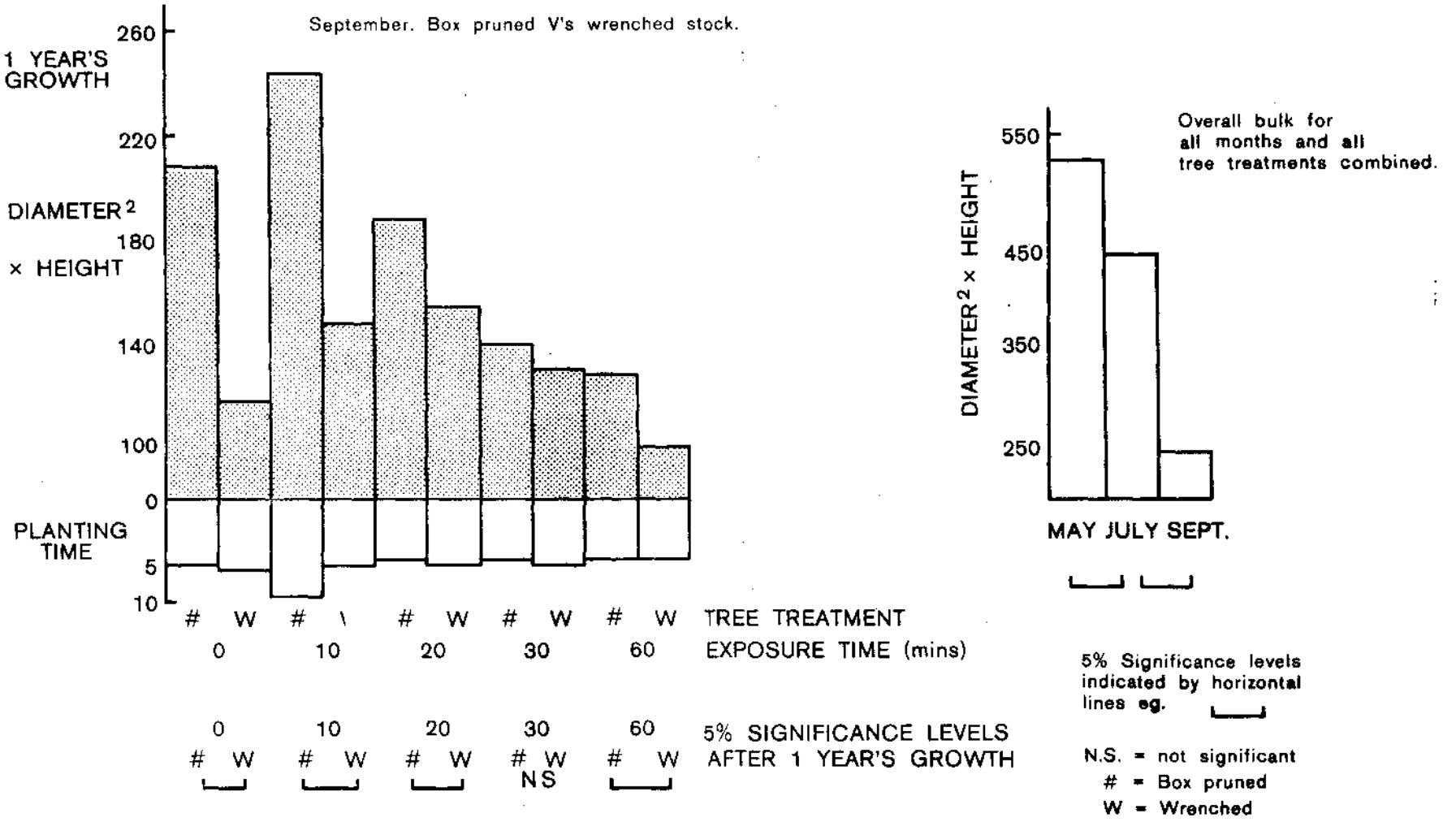
Mechanisation. An Attempt

True box pruning involves the vertical pruning of lateral roots on four sides at a specified distance, usually 5 cm for 1/0 radiata pine. This requires seed beds to be set up so that the distance between drills and seed stations is uniform. Cutting of roots longitudinally or along beds is a viable mechanical operation but cutting across beds between trees is a labourious hand operation using a garden spade. A trial was set up in 1977 at NZ Forest Products Athol nursery to test whether mechanical box pruning with a self-steered lateral pruner, both ways, was a feasible and practical proposition.

From the nursery operations the main points found were;

1. Cross or right angled lateral pruning of seedbeds proved to be an unsatisfactory technique. Land lost through tractor wheel alleyways across beds was 29% of original bed area.

FIG. 4 BULK FIGURES FOR EXPOSURE TRIAL AFTER ONE YEAR'S GROWTH.
BULK = MEAN (ROOT COLLAR DIAMETER)^2 x HEIGHT i.e. HIGHEST POINTS = BEST GROWTH



2. A 30-35% loss of trees from mechanical damage was sustained after three box prunes. Current equipment and bed modules are therefore not suitable for complete mechanised box pruning.

3. An outplanting trial using treated seedlings from the nursery operations demonstrated that the growth and yield was slightly better for hand and mechanised box pruned stock compared with wrenched.

Growth pattern studies of box pruned versus wrenched after conditions of storage, when planted over 8 months on a hard frost flat, and when established on a range of Northland soil types were to follow. There was no evidence to show that box pruned trees survived or grew any better than wrenched in these trials. Nevertheless better rooting depth and configuration was achieved from box pruned trees planted on the more marginal soil types, for example the gleys of Waipoua and the dry clays of Waitangi forests.

B. South Island Trials

Development work here on the technique was summarised (Chavasse and Balneaves 1980).

> "Results of this work are encouraging. The short 'bottle brush' root system, produced by box pruning facilitated planting with little root deformation. The development of taproots and laterals in terms of distribution is superior on box pruned trees when compared with conventional planting stock. Survival of both series was identical while box pruned stock exhibited greater shoot extension and basal diameter growth (both significant at the 5% level), over a two year period following planting at Balmoral Forest. However on heavy soils as experienced at Rangiora (FRI) nursery the operation of re-undercutting prior to lifting was extremely difficult and in essence can really be called a wrenching."

In the course of experimentation with the technique at Rangiora Balneaves (unpubl. data) observed;

> 'Some figures were collected for lifting box pruned stock and conventionally root pruned stock from the nursery beds. It was noted that the former treatment required a lifting force between 0.5 and 2.0 kg whilst the latter varied from 1.5 to 6 kg. Root damage in the box pruned series was nil, they did not need root trimming and could be packed with confidence on the beds. Conventional stock had many damaged roots, needed root trimming and some culling was needed because of root damage at lifting.

C. Other species

Attention was drawn to the fact that box pruning may be more suitable for inducing a fibrous root system on species which do not normally produce one (e.g., eucalypts) and also for confining the growth of species which produce a highly fibrous root system, such as Sequoia sempivirens. A pilot investigation studying the technique on Eucalyptus saligna seedlings at FRI nursery demonstrated;

> 'It was obvious at planting that the box pruned trees had root systems of a more fibrous nature with laterals of even thickness whereas wrenched trees were variable. A more even line of trees was evident in the box pruned treatment however with regard to later growth no significant trends were evident (Bowles, unpubl. data).

Recently the box pruning technique has been applied to Californian redwood, Sequoia sempivirens and again Bowles (unpubl. data) reports that initial indications are most favourable. Repeated wrenchings in warm zone nurseries can distort taproots into a permanent sweep and tend to strengthen lateral roots running in the direction of the row. Box pruning appears to be the most suitable conditioning method here as laterals are trimmed to a compact fibrous mass and the taproot is left without distortion. Survival and growth of box pruned redwoods in the field to date has been comparable to conventionally conditioned plants.

Discussion

One of the main objectives of the research into box pruning was to determine whether seedlings prepared by the technique performed as well as those treated by conventional ways. These trials have proved that they do, and comparable performance may be anticipated from seedlings of both treatments on any site. Moreover, under certain conditions of stress as indicated by our physiological work, box pruned plants were significantly superior to wrenched. Because the absence of stress during the lifiting-planting sequence, whether from adverse climatic influences or from poor practices, can not always be guaranteed during commercial operations, a tree conditioned by box pruning may well be a more viable proposition. More work is needed on this aspect.

Planting stock prepared by box pruning characteristically have a root system of sound architectural form that may be packed, transported and most importantly planted with the minimum of damage and distortion. These trials have demonstrated this particularly with regard to later root development trends at the planting site. There was consistently less malformation recorded for box pruned trees compared with wrenched and taproot penetration on some soil types has been superior. The ease with which box pruned plants were lifted from some nursery beds substantiates how beneficial this type of conditioning would be for machine lifting of stock. Other advantages of box pruning include that generally, compared with wrenching, there are a lesser number of operations and it precludes the need for further root trimming, and associated handling.

Considering the benefits outlined in this paper box pruning still remains to be an elite conditioning regime. Any future work should, it is recommended, be designed to study comparative performances between box pruned and wrenched stock when grown, lifted, packaged, transported and finally planted under a normal management scale of operation.

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APPENDIX I

Typical order of Operations for the Box Pruning of Spring Sown 1/0 Pinus Radiata

Operation No.	Operation Type
1.	Either precision sow seeds at 10 x 10 cm (minimum) spacings or thin to this density as soon as practical.
2.	At seedling mean top height 20 cm. Deep undercut at 15-18 cm. A receprocating blade is preferable for this operation.
3.	Four weeks after undercut box prune to a depth of 12-15 cm. Note that trees can show severe stress symptoms from box pruning. If such is the case after lateral pruning two sides, allow 2-3 days before completing the operation.
4.	The frequency of following box pruning treatments depends entirely on the root regeneration of the seedlings, i.e., box prune again when roots have grown abundantly beyond the severance point. Usually in North island Nurseries this is every 4-5 weeks and an overall total of three box prunes is regarded as adequate.
5.	The final operation is a shallow undercut (8-10 cm) two weeks prior to lifting, timed to allow taproot to callus over before removal. This undercut may have to be carried out before the last box prune so as to avoid seedling upheaval.

Note: A sharp garden spade has been the most widely used tool for box pruning. However the recent development of self-steered lateral pruners has meant spades need only be used for the cross cutting of beds. A future approach may require the development of a specialised tool for box pruning.

These notes serve only as a guideline to a box pruning regime. Specific frequencies and timing of operations will vary according to nursery localities.

Discussion of Geoff Brunsden's paper

Bolton : It seems that in the early box pruning trials the best results were from a regime which included four-weekly box pruning, undercutting and topping. Could you comment please.

Brunsden : For very hard sites (the frost flats of Kaingaroa) the evidence was that the combination of box pruning and topping were better for hardening the plants for unseasonal frosts. Box pruned trees, without topping, performed exactly the same as normally conditioned seedlings. A point with box pruning is that it is the only regime we have which produces an ideal seedling in the nursery bed. We can send it out to the forest on the basis that we are giving the planter as much as we can from the nursery point of view. But this is not to say that a well-conducted normal conditioning regime, with proper root trimming at lifting, can't do the same.

Handiside : There's some comment in Jaap's paper on poor taproot development after planting. Box pruning has some bearing on this. I should like some discussion on poor taproot development of wrenched stock after planting.

Chairman : This raises the whole business of the importance of the freshly cut taproot.

van Dorsser: The instance of poor taproot development came to light in a trial which Peter Bowles may be discussing, where we subjected seedlings to different regimes in the nursery, and then used cold storage as a means of stressing the seedlings before planting. No matter whether they were box pruned or traditionally conditioned by weekly, fortnightly or monthly wrenching, wherever we stored seedlings for eight or twelve weeks, we had a reduction in taproot development after planting in the nursery. Only in a similar case could I say that wrenched trees - or unwrenched trees - can have bad taproot regeneration.

Balneaves: This brings us to the point of the cold wet soils of the Southland planting sites. Does any wrenching regime produce a good vigorous root system in a cold wet soil quickly, rather than the seedlings having to sit there in a situation similar to cold storage waiting for the soils to warm up and dry out a bit before they can make any growth? Would box pruning offer any advantages in that situation compared to conventional wrenching?

Brunsden: In our trial experiences on the more marginal or more inhibiting soils, as far as root development is concerned - for example the gleys of Waipoua - there's consistent evidence that there is less incidence of root distortion with box pruned trees than with normally wrenched stock.

Balneaves: But did it encourage the trees to grow a root system to make re-contact with the soil much earlier under adverse conditions?

Menzies: There's plenty of evidence around now that root growth is highly dependent on soil temperature. In Southland conditions there are very cold soil temperatures, sometimes only just above freezing, so new root growth is very limited. There's also quite a bit of evidence from root growth potential studies that when you plant a seedling out with more root initials on it, then you get more new root growth. So a conditioned tree by either box pruning or by wrenching should have plenty of new root growth because it has more root initials than an unconditioned tree.

Rook: You can get root growth at a soil temperature of 3 °C, but for initiation of new roots you need 5°C. It will have nothing to do with box pruning.

Balneaves: Yes. You've got seedlings sitting in what is virtually a cool store situation trying to develop a root system. Jaap has said that trees placed in a cool store don't readily develop tap roots. Is this what is happening on the cold sites in Southland? Do we need to purpose-grow seedlings to cope with particular sites?

van Dorsser: My interpretation of that cold storage trial is that it may simulate planting on a cold site, but the cold site can't be so bad, because the seedlings aren't also in the dark in plastic bags. Or you could equate the amount of stress in the cold store to bad handling effects. In our experience, the effects of eight weeks in a cool store are equivalent to the effects of a series of bad handling practices.

McCracken: The taproot is a major source of nutrients for the tree and these will be utilised during cool storage or for subsequent growth after planting. So if the period of cool storage is too prolonged then these resources become depleted and are no longer available for subsequent growth. If a seedling is sitting in the ground, if there is a little sunlight, it's able to make its own gains in nutrients, so the food resources in the root system will at worst be depleted more slowly than in a cool store. So a seedling should be better off in the ground.

Kemp: Bearing in mind that this technique we're talking about has some potential, how close is it to a practical application?

Brunsden: Lateral pruners along the bed are operational. The cross (or right-angled) cut still has to be made with a spade. This sounds like a laborious job, but two men can treat a precision-sown bed at a rate of 20,000 seedlings in an hour and a half, or less.

van Dorsser: But it's the most terrible job. If it has to be done, you can do it.

Preest: Harold Sanderson took some seedlings and conventionally pruned one lot, box pruned one lot and pruned all the roots off one lot, leaving only the taproot. He planted them in cultivated ground. He's just lifted some of these and he's found that the conventionally conditioned and box-pruned ones have all their roots oriented along the spade cut. The ones from which all the roots were cut didn't grow quite as fast, but did develop a fairly balanced root system. I'm not sure what the implications of this are in the field, but there needs to be some alteration in the planting system if this box pruning is to have any advantages.

Brunsden: Current views are to encourage planters to plant as many trees as they can per day. Last year in the paper there was some character standing up with a tree in his hand having planted 5225 trees in that day. How could they possibly be put in the ground properly? It means that we have to attempt to give planters an idiot-proof tree. Box pruning may not be the only way; a properly applied wrenching regime and careful root trimming at lifting can produce similar results.

van Dorsser: If you look at the mechanics of box pruning, then you have to raise seedlings at 10 cm spacing either way. Otherwise you can't get a spade between them, let alone any mechanical device. The longest lateral roots that you can expect are diagonals - about 7 cm. If you trim seedling roots by folding the roots down after lifting, and then going chop, the longest root is about 10 cm. Is the difference between 7 and 10 cm of any consequence when it comes to planting? I don't think so. Certainly, any planting we have done (admittedly in the FRI nursery) hasn't shown any advantages from box pruning, compared with well trimmed and well planted trees.

Mackintosh: I'm a bit concerned with Jaap's comments that people want box-pruned trees. I'm certainly not going to produce box-pruned trees with a spade unless people are prepared to pay something like $130 per 1000.*

Chairman: We now have Mike Menzies to tell us briefly about puddling.