BARE-ROOT EXOTIC PINE NURSERY PRACTICE ON THE COASTAL LOWLANDS OF QUEENSLAND: A HISTORICAL PERSPECTIVE

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Abstract. In Queensland, five nurseries annually produce four and one half million bare-root seedlings of Pinus species. Current nursery practices are outlined and their development discussed. Topics include aspects of seed quality, sowing, nutrition, stock conditioning, grading and lifting. Some of the more recent developments have been the use of rotational cropping and strict hygiene measures for disease prevention in the new nurseries and the refinement of stock conditioning methods which has allowed Honduras Caribbean pine to be successfully planted as bare-root stock.

Additional keywords: Cover cropping, pathogen control, Pinus caribaea var. hondurensis, Pinus elliottii var. elliottii, root dipping, seed quality, sowing, stock conditioning, stock grading, weed control.

INTRODUCTION

One of the objectives of the Queensland Department of Forestry is to establish 200 000 hectares of coniferous plantation by the year 2000 (Hawkins and Muir 1968). It is anticipated that 60 000 hectares will be planted with native conifers, principally hoop pine (Araucaria cunninghamii Ait. ex D. Don), on former rainforest sites, and the remaining 140 000 ha will comprise exotic pine plantations established mostly on the infertile coarse-textured soils of the coastal lowlands. The principal species of exotic pines are Honduras Caribbean pine (Pinus caribaea Mor. var. hondurensis Barr. et Golf.) and slash pine (Pinus elliottii Engelm. var. elliottii).

Trial plantings of exotics were commenced prior to 1930 but total annual plantings were less than 1000 hectares until the 1950's. Since then there has been a major expansion in planting with a peak of 7 800 hectares being established in 1979-80. The current annual planting rate is slightly in excess of 4000 hectares. The total plantation estate is 150 000 hectares of which two thirds is comprised of exotic pine. Prior to 1978 slash pine was the major species planted but now Honduras Caribbean pine comprises 70% of southern pine nursery output.

The major southern pine plantations are located in a discountinous belt on the coastal lowlands from 50 to 250 kilometers north of Brisbane, i.e., between latitudes 25° 20'S and 27° 00'. Two large mechanised nurseries supply between four and five million bare-root stock per annum for the planting programmes in this area. Small planting fronts are operated in northern coastal centres of Rockhampton, Ingham and on the Atherton Tablelands. Stock for these programmes is produced in small local nurseries. Details of planting stock production by nurseries are given in Table 1, while Figure 1 shows the locations of the coastal exotic pine plantations with their supplying nurseries.

TABLE 1. Production of bare-root exotic pine stock by nurseries in 1984/85

Nursery	Latitude	Nursery production (x 1000)			Total
		Honduras Caribbean Pine	Slash Pine	Hybrid (Caribbean pine x slash pine)	
Beerburrum	27° 00'	235	31	34	300
Toolara	26° 00'	3581	300	43	3294
Byfield	22° 40'	34			34
Ingham	18° 30'	350			350
Danbulla	17° 20'	50			50
		4250	331	77	4658

This paper will provide a brief review of the nursery research work carried out by the Queensland Department of Forestry and discuss major developments in the production of bare-root southern pine nursery stock.

NURSERY PRACTICE

All bare-root southern pine nurseries are unshaded. Generally the sites are flat to gently sloping and the soils are of coarse texture and well drained but infertile by agricultural standards. Rotational cropping is practiced in the three larger nurseries with the grass Gatton panic (Panicum maximum Jacq. cv. Gatton) being sown for the ley years in the Beerburrum and Toolara nurseries and Highworth lablab (Lablab purpureus cv. Highworth) being favoured in the Ingham nursery.

Modern nursery practice is highly mechanised. Nursery beds are therefore long and about one metre wide to permit efficient operation of tractor mounted equipment. After bed preparation, seed is mechanically sown in drills 12.5 cm apart. Weedicides and foliar fertilizers are applied by boom sprays and reciprocating root wrenchers, lateral root pruners and lifting bars are used regularly to improve the root systems and condition the stock. Irrigation is applied as required.

The schedule of nursery operations for raising of bare-root Honduras Caribbean pine is presented in Figure 2 and details covered more fully in later sections of this paper.

In south east Queensland sowing is carried out in August to produce ten-month-old stock for early winter outplanting (May-July) under mild temperature conditions when seedling growth is less active. In central and northern Queensland the summer planting is preferred. Nursery sowing times are adjusted accordingly. At Byfield sowing is undertaken in April

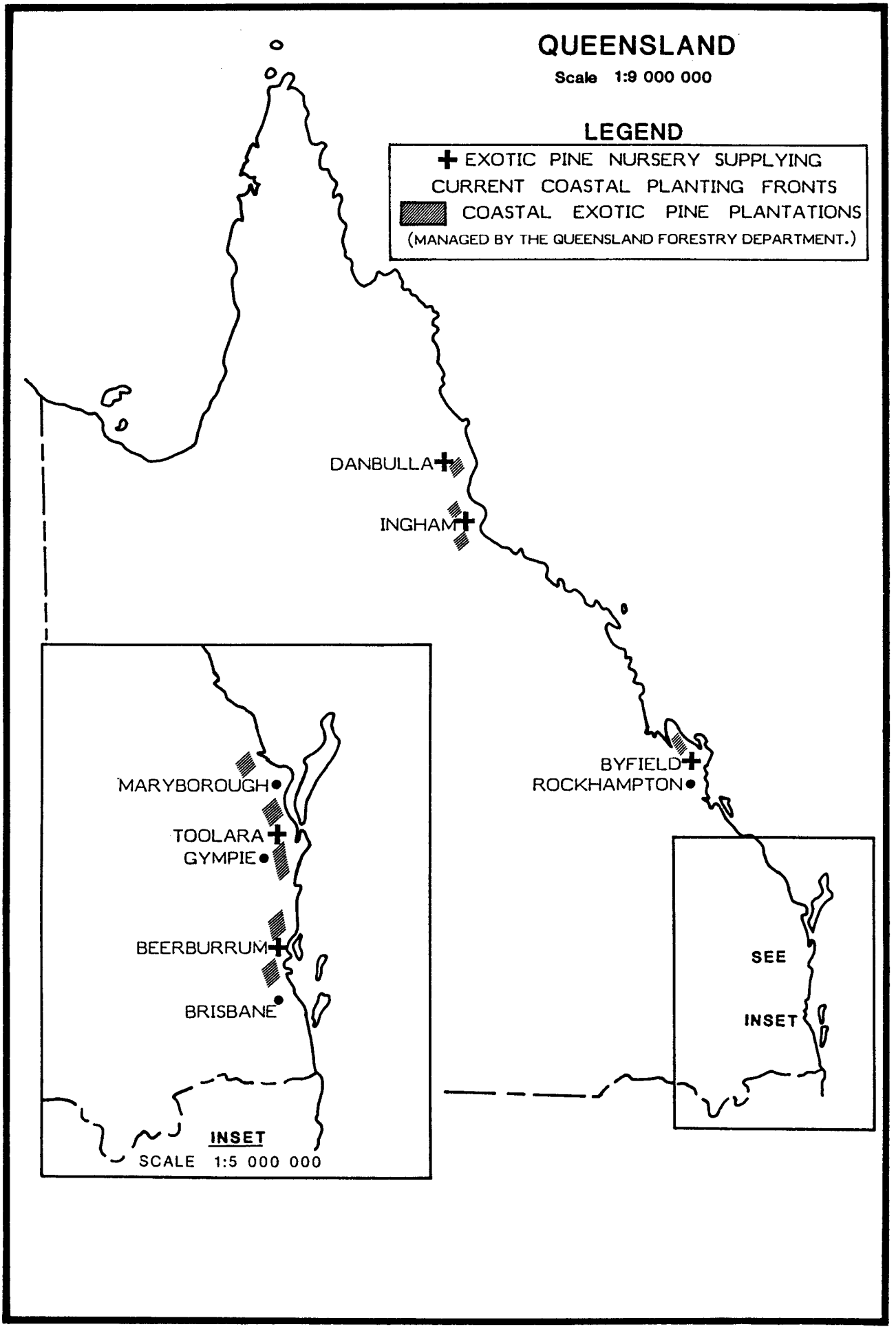

Figure 1. Map of Queensland showing coastal exotic pine plantations managed by the Queensland Forestry Department and exotic pine nurseries which supply current coastal planting fronts.

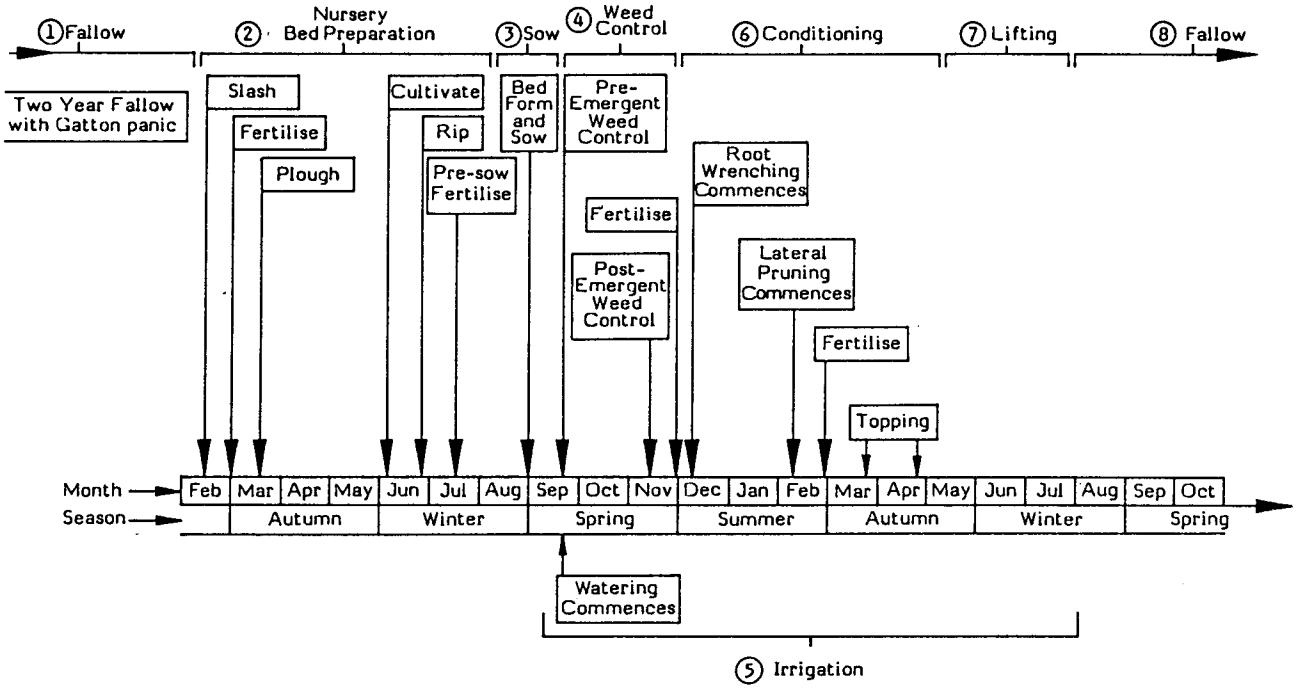

Figure 2: Schedule for the production of open root Caribbean pine at Toolara nursery.

Notes:

1. During fallow years, nursery beds are sown to the cover crop, Gatton panic.

2. The cover crop is slashed initially; Nitram (275 kg per ha) is added to aid in decomposition. The site is then ploughed, cultivated with spiked rotor and crumble roller. Ripping removes any 'plough layer'. Pre-sow fertiliser consists of superphosphate (500 kg per ha), muriate of potash (120 kg per ha) and urea formaldehyde (200 kg per ha).

3. Beds are formed and sown with the precision sower.

4. Weed control is by boom spray application of 22.4 kg per ha chlorthal plus 1.1 kg per ha propazine. Two applications are necessary, the first immediately after sowing and the next up to twelve weeks later.

5. Watering commences immediately after the pre-emergent weed control. Watering is judiciously withheld during conditioning.

6. Root wrenching commences when stock is 15-20 cm tall and repeated thereafter at monthly intervals. Initial wrenching depth is to 10-12 cm, and subsequent wrenching is to a maximum of 15 cm. Lateral pruning commences after the second wrenching and is repeated at six weekly intervals. Foliar fertilising with nitrogen and potassium is done as required. Topping to 30 cm is done if shoot growth is excessive.

7. Stock is manually lifted, dipped and placed in trailers to be taken to the field.

8. Cover crop is re-established for a two year fallow period.

and at Ingham and Danbulla sowing is completed in late May. Essentially the sequence of operations in the northern nurseries parallels that in the southern nurseries.

DEVELOPMENT OF NURSERY PRACTICE

Prior to 1950 bare-root nursery practice was labour intensive. The expanded planting programme, the introduction of mechanisation and increased attention to the quality of nursery stock and costs of production prompted many changes. These changes are reviewed below with particular reference to Honduras Caribbean pine nursery practice.

Seed Quality and Nursery Sowing

A successful tree breeding programme has seen the establishment of clonal seed-orchards, now producing genetically improved high viability seed. The slash pine orchards are located in southern Queensland close to the cone drying and seed extraction facilities. The Honduras Caribbean pine orchards have been located in north Queensland where the best seed yields are obtained. Cones are transported to southern Queensland for seed extraction.

During long distance transport of cones heating can occur. These condition are favourable for invasion of the cones and seed by the fungus Botryodiplodia theobromae Pat. Recent studies have shown that immature seed is less resistant to invasion than is mature seed. Careful monitoring of seed ripening on the trees ensures that only mature seed is collected. Thereafter, attention is paid to the handling and transport of the cones.

All cleaning and storage of seed is carried out at a central depot in Brisbane using modern equipment. A mechanical seed dewinger, air screen cleaner and a gravity table are now used to clean and grade seed.

Standard laboratory testing procedures provide a reliable estimation of seed germinability prior to sowing. For Honduras Caribbean pine seed laboratory germination is generally above 85%. Calculation of the sowing rate takes into account the lower germination that occurs in the less than optimum conditions that exist in the nursery beds. Long term monitoring of nursery bed germination has indicated that a 'reduction factor' of 0.80 should be used.

In 1983 a precision sower (vacuum drum type) was purchased for use in the major nurseries. Precise seed placement in terms of spacing and depth is obtained but successful operation of this equipment is dependant upon the use of clean seed of high viability.

Pathogen Control

By the mid 1960's pathogen problems had become severe in several nurseries, especially three of the four major southern pine nurseries established in south east Queensland. Beds in these nurseries were heavily cropped, in some cases annually. A build up of soil pathogens, notably Phytophthora cinnamomi Rands, resulted in heavy seedling losses. Routine fumigation of nursery bed soils began in 1963 using methyl bromide and

chloropicrin (Brown 1985). Fumigation provided effective control of pathogens and also of weeds. Undesirable features however were the stimulus it provided for stock height development and adverse effects on stock morphology.

These nurseries were replaced by two large centralised nurseries (Beerburrum and Toolara) which were first sown in 1968 and 1972. Rotational cropping and strict attention to hygiene has virtually eliminated pathogen problems.

Nutrition

Prior to the opening of the new nurseries soil fertility was maintained by additions of farmyard manure (50 tonnes per hectare) or filter press (a sugar processing residue - at 40 tonnes per hectare). Ryan (1973) drew attention to the fact that nutrients were provided in an unbalanced manner, potassium replacements barely equalled removals. Bevege (1973) established critical soil nutrient levels and recommended the addition of inorganic fertilizers to supplement nutrient additions in the organic amendments. These critical soil levels however proved inappropriate for the new nurseries established on virgin sites.

The current approach to maintenance of soil fertility is based on the judicious use of inorganic fertilizers and rotational cropping. Inorganic fertilizers are applied at a rate calculated to replace nutrient removals in the crop plus an allowance for leaching or fixation losses and to place the nursery on a rising plane of nutrition (Simpson 1985). Inorganic fertilizers are applied as a pre-sowing dressing and during the life of the crop. Rotational cropping includes the use of green manure crops to minimize erosion and invasion of weeds but also helps maintain or improve soil physical, chemical and biological properties.

Regular monitoring of the pine crops allows short term changes to fertilizer schedules to be made if necessary and long term monitoring of soil properties allows trends to be identified and necessary corrective action taken (Simpson 1985).

Weed Control

Selective weedicide trials began in the early 1950's as a response to the high cost of hand weeding in nurseries. Weed Problems were compounded by the regular use of farmyard manure. In these trials, best results were obtained with white spirits (Richards 1956).

The search for better weedicides has continued. The current prescription is to apply pre-emergence 22.4 kg per ha chlorthal plus 1.1 kg per ha propazine by boom spray immediately after sowing. This provides up to twenty weeks broad spectrum weed control (Bacon 1979). A repeat application is carried out twelve weeks after the pre-emergence application.

Stock Conditioning

A feature of the southern pine planting programme has been the replacement of slash pine with Honduras Caribbean pine. Introduced in trial

plantings in 1948, Caribbean pine subsequently proved to be a more productive species than slash pine. Expensive nursery procedures requiring the production of containerized stock, together with the species characteristics of poor stem form and inferior wind stability precluded broadscale planting of the species. A successful tree breeding programme initiated in the 1950's was responsible for improvements in the genetic quality of stock available and largely overcame the problems of poor stem form and wind stability while maintaining or improving the species vigour advantage over slash pine (Nikles and Hawkins 1972).

Early trials of bare-root planting of Honduras Caribbean pine during winter in south east Queensland resulted in unreliable survival. The general lack of success of bare-root planting was attributed to the fact that the species does not enter a dormant condition as does slash pine. In the mid 1970's reliable stock conditioning procedures based on intensive root wrenching schedules were developed for Caribbean pine (Bacon and Hawkins 1977). This coupled with an increasing supply of genetically-improved seed opened the way to broadscale plantings.

The prescription for the conditioning of bare-root Honduras Caribbean pine involves commencing root wrenching when the stock is 15 to 20 cm tall. Wrenching is carried out at monthly intervals, though the interval may be reduced if growth is rapid. The depth of the initial undercut is 10 to 12 cm with subsequent cuts made progressively deeper up to a maximum depth of 15 cm. Lateral root pruning commences after the second wrenching and is repeated at six weekly intervals.

Judicious watering of the stock complements the conditioning process, water being withheld as long as possible to promote plant stress. However, conditioning takes place primarily during the wet season and the moisture stress imposed is therefore dependant also upon prevailing weather conditions. Evidence suggests that the level of stock conditioning is related more to the number of wrenchings rather than the wrenching interval *per se* (Shea and Armstrong 1978).

Although root wrenching constrains shoot growth to some extent, topping seedlings to 30 cm at least two months prior to lifting may be required to control excessive height growth and to even up stock development in the beds. Current research will determine whether topping promotes a conditioning response.

Grading and Culling

The aim of culling is to remove seedlings of low survival and growth potential, and spindly stock difficult to handle during mechanised planting operations. Culling of slash pine is based on a grading system which predicts field performance by easily measured morphological characteristics of shoot development, root collar diameter and shoot length (Bacon *et al* 1977a). Plantable slash pine is classed as stock with a terminal dormant or flushing bud, root collar diameter at least 4 mm and shoot length 15 to 40 cm.

Field survival of Caribbean pine has been shown to be strongly related to shoot development classes based on stem, bed and needle morpholical characteristics (Bacon and Hawkins 1977). Seedlings at lifting are graded into one of eight possible shoot classes (Appendix 1). Trials have shown that stock with unlignified stems and no secondary folaige (class 1 and 2) have poor survival and early growth potential and should be culled.

Hand sown research trials have indicated that low cull rates of five percent can be achieved at the optimum spacing of 150 to 160 seedlings per square metre. On an operational basis cull rates are generally much higher at ten to thirty per cent. This has been attributed to irregular spacing of seed within the drills leading to over-crowding and uneven development. With the recent introduction of a precision sowing machine lower cull rates are anticipated.

Lifting and Dipping

The long established practice of saturating of puddling of nursery beds before lifting was used prior to the opening of the large mechanised nurseries. Puddling had many disadvantages such as promoting pathogen build up, nutrient leaching, deterioration of soil physical properties and prohibiting the operation of machinery.

Trials reported by Bacon et al (1977b) showed that slash pine could be manually dry-lifted successfully, provided the roots were immediately dipped in a clay slurry made of 0.4 to 0.8 kg of clay per litre of water (depending upon clay type). Subsequent trials have confirmed the value of clay dipping bare-root Honduras Caribbean pine in southern Queensland. Only limited success has been obtained in summer outplanted trials in north and central Queensland and the practice has not been adopted on a routine basis (Shea and Armstrong 1978).

CONCLUSIONS

Bare-root exotic pine stock has been produced in Queensland since the 1920's. The past practices were labour intensive but modern techniques are highly mechanised. Some of the most significant changes that have occurred include:

- widescale introduction of rotational cropping;
- enforcement and strict hygiene measures especially in new nurseries;
- development and stock conditioning technique allowing the production of open root Caribbean pine seedlings;
- a swing away from the use of organic amendments to the judicious use of inorganic fertilizers and monitoring of soil and plant nutrient status;
- the use of clay dipping in lieu of puddling.

Research into all aspects of nursery practice in on-going.

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Appendix 1. Shoot development classes for Honduras Caribbean pine - stem, bud and needle characteristics.

(Source: Bacon and Hawkins 1977)

Class	Characteristics
1	Soft white stem bearing only primary needles.
2	Pliable stem with fascicles developing in primary leaf axils.
3	Secondary needles common, upper stem soft and immature.
4	As for class 3 with shoot top maturing.
5	Mature plant in a resting condition with a hard lignified stem completely clothed in secondary foliage.
6	Seedling previously class 5 now possessing a tuft of glaucous foliage on the shoot tip.
7	The new growth initiated in class 6 has now elongated, and the flush shoot is soft and white stemmed.
8	The flush shoot of Class 7 is now maturing.