USE OF INORGANIC FERTILIZERS AND COVER CROPS IN EXOTIC PINE NURSERIES OF SOUTHERN QUEENSLAND, AUSTRALIA

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Abstract. Maintenance of long term productivity in two nurseries producing four to five million slash and Honduras Caribbean pine seedlings annually is based on the judicious use of inorganic fertilizer and grass cover crops. Inorganic fertilizers are applied to replace estimated nutrient losses. Legume cover crops were tested and were found less suitable than Gatton Panic. Effectiveness of the nursery system is monitored by regular sampling and chemical analysis of each pine crop. Long term trends in soil fertility are monitored by periodic soil sampling and analysis.

Additional Keywords: legumes, monitoring nutrient status, nursery fertility, *Pinus elliottii* var *elliottii*, *P. caribaea* var *hondurensis*.

INTRODUCTION

All exotic pine planting stock raised by the Queensland Department of Forestry for outplanting in the south east of the state is produced in two large centralised nurseries. These permanent nurseries are managed with the aim of maintaining productivity in the long term by the judicious use of inorganic fertilizers and rotational cropping.

Four to five million seedlings of slash pine (*Pinus elliottii* Engelm var *elliottii*, Little and Dorman) and Honduras Caribbean pine (*Pinus caribaea* Mor var *hondurensis*, Barrett and Golfari) are produced annually. (Anon 1984) Slash pine was the major species raised prior to 1978. With the availability of improved quality seed and the development of suitable open root nursery techniques (Bacon and Hawkins 1977), Honduras Caribbean pine now comprises approximately 70% of the nursery output.

The large mechanized nurseries, located at Beerburrum (4 ha) and Toolara (21 ha), latitudes 27° 00' and 26° 00' south, were established in 1968 and 1972 to replace four small nurseries established between the late 1920's and the 1950's. The new nurseries are close to the coast and less than 55 metres above sea level. Annual rainfall is 1 600 and 1 400mm, essentially of summer incidence (Hawkins and Muir 1968). The soils have been derived from Mesozoic sandstone and are coarse textured and of low inherent fertility (Coaldrake 1961). The profiles are deep well drained yellowish to red brown loamy sands to sandy loams overlying at depth a mottled red/yellow sandy clay. Internal drainage is good and the soils have good moisture holding characteristics. Soils belong to the Oxic Paleustalf Soil Taxonomy Subgroup. (Soil Survey Staff 1975).

The nursery techniques employed aim at producing ten month old open root seedlings for early winter (May-June) planting. Seed is sown in drills at a rate designed to produce 176 seedlings per square metre of slash pine or 136 seedlings per square metre of Honduras Caribbean pine.

Chemical control of weeds is practiced and height development is controlled by the regulation of irrigation, fertilizer applications and root wrenching. Hardened stock 30 to 40 cms tall with well developed root systems are considered ideal for out planting. After the pine crop is lifted a cover crop of the grass Gatton Panic (Panicum maxumum cv Gatton) is broadcast sown. A mixed fertilizer is applied before sowing and periodic dressings of nitrogenous fertilizer are applied to help maintain the health and vigour of the grass crop. After approximately eighteen months the cover crop is ploughed in during the February prior to sowing of the pine crop.

This paper outlines the development of the fertilizer regimes currently used for the exotic pines and describes the methods used to monitor the nutrient quality of the nursery stock and long term changes in soil fertility. The use of cover crops in the nursery is discussed and a trial to assess the potential of a range of alternative summer growing legumes is reported.

USE OF INORGANIC FERTILIZERS

In the old nurseries, soil fertility was maintained by applying farmyard manure at a rate of 50 tonnes per hectare between crops. From a series of long term trials which tested additions of various quantities of farmyard manure or filter press, a by product of the cane industry, Bevege (1973) establishment critical soil nutrient levels for the major nutrients by relating soil analysis to the production of cull free stock. These levels were set at .07 - .08% for nitrogen, 436 - 480 ppm for total phosphorus and 0.012% for exchangeable potassium. Monitoring of soil nutrient levels prior to bed preparation provided a basis for estimating nutrient inputs for each crop. Inorganic fertilizers were used in the late 1960's to supplement the nutrient additions in the farmyard manure.

With the change in 1968 to a new nursery at Beerburrum, established on a virgin site, it was found that unacceptably high rates of inorganic fertilizer would be required to attain the critical soil levels established for the old nurseries. An alternative approach to the long term maintenance of nursery productivity was sought. The use of farmyard manure was undesirable under the new nursery regimes which incorporated rotational cropping and high levels of sanitation.

The more recent approach to maintenance of productivity is based on replacing nutrient loss by additions of inorganic fertilizer and maintaining soil physical and biological properties by rotational cropping and the use of cover crops. The current fertilizer schedule is based on replacing the nutrients removed in the seedling crop plus an allowance for leaching, or fixation in the soil and to allow for a gradual build up of soil fertility. Various estimates of the nutrient content of seedling crops of exotic pines have been made and there is generally good agreements between the estimates with differences being largely accounted for by differences in dry matter production between crops. Simpson (1978) estimated nutrient removals in slash pine seedling crops as:-

Nitrogen	119 - 158 kg ha^{-1}
Phosphorus	14 - 19 kg ha^{-1}
Potassium	89 - 95 kg ha^{-1}
Calcium	29 - 37 kg ha^{-1}
Magnesium	13 - 22 kg ha^{-1}

The recommended fertilizer regime is to supply to each crop a total of:

Nitrogen	215 kg ha^{-1}
Phosphorus	36 kg ha^{-1}
Potassium	123 kg ha^{-1}

Fertilizer efficiencies of approximately 75% have been used to calculate rates for the mobile elements nitrogen and potassium. The effectiveness of nitrogen fertilizing is improved by incorporating a slow release form (ureaformaldehyde) into the soil prior to sowing. Half the total dressing is applied in advance of sowing and the remainder applied in solution during the life of the crop. Potassium is similarly applied as a split dressing. Nitrogen and potassium post sowing dressings are scheduled to coincide with periods of active growth of the crop.

It has been the practice to apply these elements in solution as six to eight foliage sprays. A five percent mixture of ammonium nitrate and potassium sulphate (7:3) was applied at 1 000 litres per hectare but occasionally some burning of the foliage has resulted. Solution strength was subsequently reduced and the fertilizers applied separately but the burning problem was not eliminated. The recently introduced practice is to dribble a concentrated solutions on to the soil surface between the drills at the time of lateral root pruning.

Phosphorus, the major limiting nutrient of exotic pines on the coastal lowlands, is applied before sowing as a single broadcast dressing of superphosphate at a rate double the estimated removals. This rate is designed to accommodate the loss of available phosphorus in the soil fixation complex and to place the nursery on a rising plane of phosphorus nutrition.

The effectiveness of fertilizer additions in providing a balanced supply of nutrients to the crop and in maintaining soil chemical properties is monitored by regular sampling. Flinn et al (1980) have identified monitoring of soil and foliar nutrient levels as an objective means of determining appropriate fertilizer regimes for three nurseries in southern Australia.

USE OF COVER CROPS

With the opening of the mechanised nurseries operating on a three year rotation it was necessary to establish a cover crop on the fallow areas to minimize erosion and weed invasion and to maintain or improve the soil physical, chemical and biological properties. The desire to minimize disease problems in the new nurseries by rigorous attention to sanitation (Brown 1985), restricted the importation of materials into the nurseries. This meant that the use of farmyard manure, or other introduced organic amendments, to maintain soil organic matter levels could not be continued.

Gatton panic was selected in 1968 for use as a cover crop. It is a relatively vigorous perennial grass which tolerates the levels of frost experienced. It has proved to be relatively easy to establish and manage.

Establishment practice for panic is to sow the seed at a rate of 11 kg ha^{-1} in spring after the pine crop has been removed and some seed bed preparation carried out. A mixed pre sowing fertilizer containing nitrogen (112 kg ha^{-1}), phosphorus (30 kg ha^{-1}), and potassium (94 kg ha^{-1}) is applied. Frequent light irrigation following sowing can be necessary during dry weather to ensure satisfactory germination and establishment. The crop develops rapidly and limits the incursion of weed species. Dressings of nitrogenous fertilizer (up to a total of 500 kg ha^{-1}) are applied during the life of the crop to maintain vigour. Periodic slashing is undertaken to increase production and to limit seeding. The crop is maintained for approximately eighteen months and in February prior to sowing of the exotic pine crop it is rotary hoed at shallow depth to kill the grass. A dressing of 90 kg ha^{-1} nitrogen is applied to aid the decomposition of the crop and the area ploughed to a depth of 20cm. Light cultivation is undertaken as necessary prior to final seed bed formation to remove weeds.

Minor problems associated with the use of Gatton Panic have been associated with the slow breakdown of the crown and roots. Build up of pasture beetles have occurred occasionally and upon removal of the grass sward have attacked the roots of the subsequent pine crop. The need was seen to identify a cover crop species more productive than Gatton Panic to improve soil organic matter levels. If a suitable legume was available there would be a reduced need to apply inorganic nitrogen.

COVER CROP TRIAL

A comprehensive trial was initiated in the Toolara nursery in 1978 to compare Gatton panic with a selection of legume species. Biomass production, nutrient immobilisation and the effects of the cover crops on the soil chemical properties and on the subsequent pine crop were recorded. The crops tested were:-

Gatton Panic	(*Panicum maxumum* cv Gatton)
Dalrymple Vigna	(*Vigna luteola* cv Dalrymple)
Eureka Cowpea	(*Vigna unguiculata* spp *unguiculata*)
Red Caloona Cowpea	(*Vigna unguiculata* spp *unguiculata*)
Rongai Lablab	(*Lablab purpureus* cv Rongai)
Highworth Lablab	(*Lablab purpureus* cv Highworth)

Four replications of each crop were established in September 1978. Plots were 100 m^2 and located in a section of the nursery which had been under grass fallow for four years and had produced one crop of pine immediately prior to the establishment of this trial. Legumes were innoculated with *Rhizobium*. A basal phosphorus, potassium and trace element mix was added prior to sowing. Nitrogen totalling 200 kg ha^{-1} was applied broadcast as four split dressing to the Gatton panic crop.

Above ground biomass was sampled periodically and at final harvest an estimate of root biomass was obtained. Some partitioning of the biomass into grass, weed and legume components was undertaken. Chemical analysis of the various fractions enabled nutrient pools to be calculated at various stages of development.

The legumes were slow to develop but by six months all species covered the site. Total biomass was between 6.1 and 8.5 t ha^{-1} with weeds or grasses forming between 17 and 59% of the biomass on the legume plots. Further estimates of biomass were made in late winter when the crops had reached their best development and prior to the occurrence of frost. Lablabs were the most productive taxa yielding 13 to 16 t ha^{-1} above ground biomass compared with 8.3 to 9.8 t ha^{-1} for the other crops.

One of the most important considerations in selecting a cover crop is its ability to regenerate in the second season. Gatton Panic was relatively unaffected by late frosts and grew well in the following spring. Regeneration and development of the legumes in the second season was poor. Dalrymple Vigna was the best of the legumes in the second season but produced a sward which contained a lot of grass. Above ground living biomass material was 2 t ha^{-1} of legume and 5 t ha^{-1} of grass.

At the final harvest there was no significant difference between treatments in total biomass. Including roots and dead material, production ranged from 7 to 11 t ha^{-1}. This compares unfavourably with rates of organic amendment applied in the old nurseries (50 t ha^{-1}) and may be responsible for the gradual decline in organic carbon levels detected by monitoring soil properties.

Greatest interest in the interpretation of the nutrient immobilisation data centred on nitrogen. The nitrogen concentration in legume material was twice that of the grass but differences in biomass tends to mask difference in nutrient immobilisation. At the first harvest six months from sowing the legumes had accumulated a greater amount of nitrogen (85 - 140 kg ha^{-1}) than Gatton panic (74 kg ha^{-1}). At the end of the first season the lablabs had accumulated 220 to 280 kg ha^{-1} nitrogen above ground compared with 123 to 143 kg ha^{-1} for the other species. At the final harvest there was little overall difference in nitrogen accumulation.

Chemical analysis of soil samples collected at final harvest did not reveal any differences between treatments in pH, nitrogen, total phosphorus, exchangeable cations or organic carbon.

The identity of the plots was retained and the area sown in normal nursery operations to Honduras Caribbean pine. In order to force treatment differences two of the replications were kept unfertilized and two had routine inorganic fertilizers applications which included 179 kg ha^{-1} nitrogen, 50 kg ha^{-1} phosphorus and 140 kg ha^{-1} potassium. The development of the pine crop was monitored by foliar analysis and an assessment of stock development made at lifting. There was no effect of the cover crop treatments on development of the pine crop. Stock from the unfertilized replicates was not as well developed as stock from the fertilized replicates and tended to be nutritionally inferior (table 1).

Table 1. Effect of fertilizing on the development of Honduras Caribbean Pine seedlings after cover cropping.

(Means of 12 plots, 250 plants per plot - Sown 7.1980, Lifted 5.1981).

Parameter		Unfertilized	Fertilized	LSDp = .05
Mean Height (cms)		33.6	35.1	1.2
Diameter at Ground Level (mm)		5.7	6.3	0.2
Dry Weight/Plant, Roots + Shoots (gms)		84.8	100.8	6.9
Foliar Nutrient Levels:	Nitrogen (%)	1.01	0.99	N.S
	Phosphorus (%)	0.098	0.116	.009
	Potassium (%)	0.37	0.64	.04

The general findings from this trial were that the summer growing legumes tested were not suited for nursery use because of their poor regenerative capacity. Alternative management regimes aimed at utilizing the abundant seed produced to give a satisfactory seedling crop for the second season should be investigated. If this approach is unsuccessful, then a search for productive, easy to eradicate perennial legumes will be necessary. Meanwhile, the continued use of gatton panic as a cover crop and addition of inorganic fertilizer to the pine crop is advocated.

MONITORING OF CROP NUTRIENT STATUS

In order to monitor the short term effectiveness of nursery management systems and fertilizer regimes, regular sampling of the developing pine crop is undertaken. Composite plant samples are collected from between 15 to 25 areas in each nursery at ages three, five and seven months. Chemical analysis of the foliage provides a guide as to the nutrient status of the crop and the need to adjust the post planting fertilizer regimes. Foliar nutrient levels found to be associated with normal healthy stock at the time of lifting are summarized in table 2.

Table 2. Foliar nutrient levels of healthy nursery stock at lifting

	Slash Pine	Honduras Caribbean Pine
Nitrogen (%)	1.0	1.3
Phosphorus (%)	0.15	0.14
Potassium (%)	0.4	0.45

The foliar nutrient levels decline as the nursery stock ages. For slash pine crops from Toolara between 1981 and 1984 nitrogen levels decline from 2.6% to 1.4% phosphorus from 0.22% to 0.13% and potassium from 1.3% to 0.8% over the four month sampling period.

It is not the intention to produce stock of a minimal acceptable nutrient status but rather to ensure that ample nutrients are available in a balanced manner to give the plants the best chance of survival and potential for maximum early growth. Simpson (loc cit) demonstrated that post planting increment was related inter alia to foliar phosphorus levels of the nursery stock, better increment being associated with the higher foliar phosphorus levels.

MONITORING SOIL NUTRIENT STATUS

Soil samples are periodically collected from nursery beds for chemical analysis to provide data on the long term changes in soil nutrient status. Sampling is carried out after the cover crop is ploughed in and prior to the addition of pre sowing fertilizer dressings. While detailed interpretation of soil analysis has been frought with some difficulties the approach has proved useful in determining the long term drift in some paratemeters. Changes in cropping patterns, fertilizer histories and season to season variation must be taken into account. Two summarized examples of nursery records are provided in table 3.

It is apparent in these and other data that there is a consistent decline with time in soil pH. This decline is thought to be due at least in part to the regular use of inorganic fertilizers. Although no growth irregularities have been detected at pH below 4.5 it is considered desirable to maintain pH in the range 5 to 6. Periodic additions of lime to nursery soils is advocated to reverse this pH shift. Lime applied at 1 340 kg ha^{-1} to the 1981 sowing area at Beerburrum (pH 5.2) raised soil pH to 5.5 seven months after application.

Table 3. Examples of long term trends in the nutrient status of nursery soils.

Rotation	Sampled	No. of Samples	pH	Nitrogen (%)	Organic Carbon (%)	Phosphorus (Total) (ppm)	Potassium (exchange-able) (%)
			Beerburrum nursery (Bed B1)				
1	1968	8	6.0	0.054	-	38	0.102
2	1971	5	5.7	0.038	1.89	43	0.049
5	1980	7	5.4	0.050	1.13	178	0.276
6	1982	4	4.9	0.044	0.70	168	0.085
			Toolara nursery (Bed 3a)				
1	1974	16	6.2	0.056	1.78	54	0.125
2	1977	16	5.7	0.065	1.41	226	0.145
4	1983	8	5.0	0.060	1.26	219	0.062

Changes in soil nitrogen status are generally difficult to interpret with any degree of confidence. Organic carbon levels show a gradual decline which is of concern and the reason for interest in selecting more productive cover crops. Soil phosphorus status shows an improvement with time. This undoubtly is a reflection of residual benefits of the modest phosphorus fertilizer regime. Soil exchangeable potassium levels have shown wide variation possibly reflecting the mobility of this element in the soil. Flushes of potassium resulting from additions of potassic fertilizer have been traced through the soil profile.

CONCLUSIONS

The general lack of significant nutritional problems to date attests to the suitability of fertilizer regimes. The long term soil monitoring studies however suggest that additional measures are required if long term productivity is to be maintained. More widespread use of lime is forecast and the apparent decline in soil organic matter levels requires a thorough investigation. The identification and testing of perennial legumes which produce high quantities of dry matter is desirable. Monitoring of soil and foliar nutrient levels will be continued.

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REFERENCES

Anon 1984. Annual Report, Department of Forestry, Queensland: 42pp.

Bacon, G.J and Hawkins, P.J. 1977. Studies on the establishment of open root Caribbean pine planting stock in Southern Queensland. Aust. For., 40(3) 173-191.

Bevege, D.I. 1973. The use of organic amendments in southern pine nurseries. Qld. Dept. For. Res. Paper No. 3. 19-33.

Brown, B.N. 1985. Phytophthora cinnamomi root rot in Pinus nurseries: soil fumigation and disease control by hygiene. Paper to be presented at 'International Symposium on Nursery Management Practices for the Southern Pines' Auburn Uni., Alabama.

Coaldrake, J.E. 1961. Ecosystem of the coastal lowlands, Southern Queensland. C.S.I.R.O Aust. Bull. No. 283. 138pp.

Flinn, D.W., Hopmans, P and Craig, F.G. 1980. Survey of the nutrient status of Pinus radiata seedlings and of soil properties in three Victorian nurseries. Aust. For., 43 (1).

Hawkins, P.J. and Muir, J.D. 1968. Aspects of management of plantations in tropical and sub tropical Queensland. Paper presented at the Ninth Commonwealth Forestry Conference. 36pp.

Simpson, J.A. 1978. Nursery nutrition studies with slash pine at Beerburrum. Qld. Dept. For. Res. Paper No.9. 32pp.

Soil Survey Staff 1975. Soil Taxonomy: A basic system of soil classification for making and interpreting soil surveys. U.S Dept. Agri. Handbook, 436. (U.S. Govt. Print Office, Washington, D.C.).