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NURSERY SOIL FERTILITY STUDIES WITH *PINUS RADIATA* - D. DON

HAMEL NURSERY - WESTERN AUSTRALIA

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A. B. HATCH

FORESTS DEPARTMENT
PERTH
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This Bulletin is a preliminary report on certain aspects of Forest Nursery Nutrition, and deals specifically with Hamel Nursery.

The opinions expressed are those of the author, and do not necessarily reflect current Departmental policy.

A. C. HARRIS,
Conservator of Forests.

NURSERY SOIL FERTILITY STUDIES WITH *PINUS RADIATA* - D. DON.

SUMMARY.

THE oven dry weight production of Pinus radiata *seedlings at Hamel Nursery varies between 4,580 and 9,190 lb. per acre. The variation is caused by both seasonal effects and the fertility status of the nursery bed.*

Chemical analysis of the young pines indicates that the highest concentration of minerals is generally found in the pine needles, with nitrogen and potassium present in the greatest amounts.

The average annual uptake of nutrients from the nursery by the pines over a period of three years amounted to 84 lb. of nitrogen, 8 lb. of phosphorus, 94 lb. of potassium, 22 lb. of calcium and 14 lb. of magnesium per acre.

Continued nursery cropping has resulted in marked soil fertility changes, the chief of which are decreases in (1) organic carbon and nitrogen, amounting to 37,240 lb. and 1,796 lb. per acre 4 in. respectively; and (2) exchangeable and readily soluble calcium, magnesium and potassium, with magnesium showing the most pronounced change.

The effect of pine cropping on the soils is briefly discussed and suggestions are made for improved nursery soil management.

INTRODUCTION.

The production of good quality nursery stock is of primary importance to any afforestation programme. In Western Australia this work is becoming increasingly important, in view of the Department's expanding pine planting programme, which aims at a total of 200,000 acres of coniferous plantations.

In the management of forest nurseries for the production of pines, one of the most important aspects is the maintenance of a satisfactory level of soil fertility, as the growing of nursery seedlings causes a very big drain on soil nutrients. This is due to several factors, the chief of which are—

(1) the dense stocking of the seedlings (300,000 per acre);

(2) the rapid uptake of nutrients by young tree seedings; and

(3) the whole plant crop (needles, stems and roots) is removed from the site.

For several years, research has been carried out on soil fertility problems in forest nurseries of Western Australia, and it has been shown that the maintenance of the soil organic matter level is of major importance in nursery management.

The work described in this paper was carried out at Hamel Nursery with the object of—

(1) gaining basic information on the inorganic composition of one year old *P. radiata* seedlings;

(2) determining the amounts of major inorganic nutrients removed from the nursery by a crop of pines; and

(3) investigating the effects of long term nursery cropping on soil fertility.

HAMEL NURSERY.

Hamel Nursery, 71 miles south of Perth, is the oldest nursery used by the Forests Department and has been cropped since 1898. The soils are derived from alluvial deposits, and generally consist of about 6 in. of a very dark brown loam, or sandy loam overlying an olive brown clay or silty clay subsoil.

The mechanical analysis of the surface soil showed the following values:—

Coarse sand	22.2%
Fine sand	32.9%
Silt	25.3%
Clay	19.6%

The fertility of these soils is high, and analysis of virgin soil adjacent to the existing nursery gave the following values: nitrogen 0.317 per cent., phosphorus and potassium soluble in boiling hydrochloric acid 0.032 and 0.076 per cent., respectively.

The cropping of the pine nursery has not been on a regular rotation since its establishment, and no record of the exact history of the old nursery beds is available. It appears that the nursery beds were put down under pines for about three years out of every five. For the remaining two years treatment varied and the beds were frequently sown with oats or rye, with an occasional fallow year. Since 1935 legumes (usually field peas) have been included in the cropping system and these now alternate with the cereal crop.

Fertiliser treatment of the nursery has been irregular, but in most years superphosphate at the rate of 1 cwt. per acre, has been applied to the section of the nursery sown to a green crop. In addition, the green crops have been ploughed back into the soil to provide a source of inorganic nutrients and organic matter.

As far as can be ascertained, fertiliser was only applied to the pine crop during the period 1932-1934, when an NPK mixture consisting of 2 cwt. of blood and bone, 2 cwt. of superphosphate and ¾ cwt. of potassium sulphate was added to the pine beds.

EXPERIMENTAL.

Samples of one year old *P. radiata* seedlings were collected for analysis. Sampling was carried out during the last week of July of each year to avoid any variation in chemical composition due to seasonal effects. The method employed was to lift small random groups of pines from the nursery beds, using standard nursery lifting techniques, until a total of approximately 400 plants had been collected. All plants lifted were retained in the sample.

One hundred plants were selected at random from the bulked sample, and separated into needles, stems and roots, the latter being carefully washed to remove any adhering soil. Moisture content was determined for all samples, and the dried samples ground for analysis in a Christy and Norris Junior Grinder.

Composite soil samples (0-4 in.) were collected from the nursery beds, using a constant volume soil sampler. For purposes of comparison similar samples were collected from uncultivated grassland soil adjacent to the nursery. All samples were air dried in the laboratory and passed through a 2 mm. sieve prior to analysis.

Standard methods of analysis, as used by Piper (1944) and the C.S.I.R.O. Division of Soils were adopted for the chemical analyses, except that the readily soluble nutrients were extracted with half normal acetic acid (Williams & Stewart, 1941).

For all results calculated on a per acre basis, the figure of 300,000 nursery plants per acre has been used.

ANALYTICAL DATA.

1.—NURSERY SEEDLING STUDIES.

(a) Production of Dry Matter.

The oven dry weight of pines produced is shown in Table 1 and indicates that in new beds, growing their first crop, the amount of plant material varies from 6,960 lb. to 9,190 lb. per acre. The greater weight of seedlings produced in 1957 is attributed to the favourable growing season which was experienced during the spring and early summer of 1956, when 9.05 in. of rain were recorded during the period October to December.

Rainfall for the same period in 1957 and 1958 was considerably less, being 3.70 in. and 4.72 in., respectively.

In the old nursery beds, which have been cropped for a period of at least 50 years, there is a marked decline in the total weight of the seedlings, being only 66 per cent. of the weight produced in the new beds. This decrease in the production of plant material is accompanied by a decrease in the size and vigour of the nursery stock, which is a serious problem in nursery management.

TABLE 1.

HAMEL NURSERY.

P. RADIATA.

PRODUCTION OF NURSERY SEEDLINGS.

Oven Dry Weight—Pounds Per Acre.

Year.	Nursery Beds.	lb./acre and %			Total.
		Needles	Stems.	Roots.	
1957	New	4,440*	2,300	2,450	9,190
		48**	25	27	100
1958	New	4,110	1,930	1,110	7,150
		57	27	16	100
1959	New	3,570	2,090	1,290	6,950
		51	30	19	100
1959	Old	2,120	1,300	1,160	4,580
		46	29	25	100

All calculations based on 300,000 seedlings per acre.

*Oven dry weight—pounds per acre.

**Percentage of total oven dry weight.

The only comparable figures for *P. radiata* appear to be those of Youngberg (1958). In a paper on the uptake of nutrients by nursery conifers this author showed that a one year old crop of *P. radiata* seedlings produced 5,310 lb. per acre of dry matter, which is less than the average annual production at Hamel.

With regard to the composition of the nursery stock, pine needles form the dominant part of the seedling, comprising half of the dry matter produced. The stem and root production is very much less, averaging 28 and 22 per cent. of the total oven dry weight.

Askew (1937) showed that one year old *P. radiata* seedlings in New Zealand were of the same order of composition. On a green weight basis, the needles, stems and roots comprised 65, 24 and 11 per cent. respectively of the total weight produced by the crop.

As the plants from the old nursery beds have approximately the same proportion of needles, stems and roots, it is evident that the decline in plant size is not restricted to a particular part of the plant.

(b) Chemical Composition of Seedlings.

The chemical composition of the nursery seedlings is tabulated in Table 2 and again the seedlings have been subdivided into the three components: needles, stems and roots.

It is evident from the data that the young pine needles are almost invariably higher in inorganic constituents. This is particularly the case with nitrogen and potassium, and to a lesser extent, phosphorus. The alkaline earth metals, calcium and magnesium, do not always attain their maximum concentrations in the needles. In 1957 and 1959 calcium concentration was highest in the pine roots, and in 1957 and 1958 the magnesium concentration was greatest in the roots.

TABLE 2.

HAMEL NURSERY.

P. RADIATA.

CHEMICAL COMPOSITION OF NURSERY SEEDLINGS.

1957-1959.

Year.	Nursery Beds.	Element.	% Composition.		
			Needles.	Stems.	Roots.
1957	New	N	2.020	0.557	0.475
		P	0.151	0.074	0.064
		K	1.433	0.925	0.578
		Ca	0.231	0.130	0.263
		Mg	0.158	0.109	0.396
1958	New	N	1.850	0.767	0.640
		P	0.169	0.127	0.085
		K	1.066	0.818	0.363
		Ca	0.294	0.126	0.113
		Mg	0.082	0.091	0.102
1959	New	N	1.478	0.595	0.676
		P	0.137	0.063	0.070
		K	2.600	1.830	0.016
		Ca	0.429	0.299	0.569
		Mg	0.441	0.151	0.184
1959	Old	N	1.458	0.491	0.534
		P	0.137	0.078	0.064
		K	1.783	1.079	0.669
		Ca	0.597	0.271	0.299
		Mg	0.226	0.188	0.159

Apart from the calcium and magnesium values, plant nutrients in the stems and roots show similar trends to those observed in the needles, but the absolute values present are much lower in these sections of the plant. Nitrogen and potassium are again dominant, with potassium invariably present in higher concentrations in the stems. Nitrogen was present in greater concentration in the stems in 1957 and 1958, but was lower in both sets of samples in 1959. On the other hand, phosphorus values tended to be slightly higher in the stems than in the roots.

Askew (1937) reported that with one year old *P. radiata* seedlings, the needles were relatively rich in nutrients, particularly nitrogen, while all the major elements examined, with the exception of sodium, showed maximum concentrations in the pine needles. The data indicated that in the nursery seedlings the order of abundance of the elements was nitrogen, potassium, calcium, phosphorus and magnesium.

(c) Uptake of Nutrients by Nursery Seedlings.

The nutrients removed from the soil were calculated by combining data from Tables 1 and 2. The results from these calculations is shown in Table 3.

TABLE 3.

HAMEL NURSERY.

P. RADIATA.

NUTRIENTS REMOVED FROM SOIL BY NURSERY SEEDLINGS.

1957-1959.

Year.	Nursery Beds.	Element.	lb./acre.			Total.
			Needles.	Stems.	Roots.	
1957	New	N	89.7	12.8	11.6	114.1
		P	6.7	1.7	1.6	10.0
		K	63.6	21.3	14.2	99.1
		Ca	10.3	3.0	6.4	19.7
		Mg	7.0	2.5	9.7	19.2
1958	New	N	76.0	14.8	7.1	97.9
		P	6.9	2.5	0.9	10.3
		K	43.8	15.8	4.0	63.6
		Ca	12.1	2.4	1.3	15.8
		Mg	3.4	1.8	1.1	6.3
1959	New	N	52.8	12.4	8.7	73.9
		P	4.9	1.3	0.9	7.1
		K	92.8	38.2	13.1	144.1
		Ca	15.3	6.2	7.3	28.8
		Mg	15.7	3.2	2.4	21.3
1959	Old	N	30.9	10.3	6.9	48.1
		P	2.9	1.6	0.8	5.3
		K	37.8	22.6	8.6	69.0
		Ca	12.7	5.7	3.8	22.2
		Mg	4.8	3.9	2.1	10.8

All calculations based on 300,000 seedlings per acre.

These values indicate very clearly the large drain on soil nutrients, particularly nitrogen and potassium, caused by the pine crop. Calcium and magnesium are removed in smaller amounts, and the uptake of phosphorus by the seedlings is much less than that of the other elements.

On the old nursery beds the uptake of nutrients by the pines is markedly reduced and also much smaller plants are produced.

These Hamel figures are very much higher than those quoted by Askew (1937) for *P. radiata* seedlings in New Zealand. This author calculated that the pine seedlings (density, 175,000 seedlings per acre) removed 40.1 lb. of nitrogen, 8.2 lb. of phosphorus, 9.5 lb. of potassium and 11.7 lb. of calcium from an acre of soil. It is of interest to note the very much smaller uptake of potassium by the New Zealand nursery seedlings.

Additional data for *P. radiata* is available from the work of Youngberg (1958). In this paper, it was calculated that a one year old nursery crop of *P. radiata* seedlings removed the following nutrients from the soil: nitrogen 80 lb., phosphorus 7 lb., potassium 55 lb. and calcium 28 lb. per acre. Again, these figures are lower than those calculated for Hamel Nursery, but the trends in nutrient uptake are rather similar.

With regard to nursery crops of other species, Cossit, Rindt and Gunning (1949) calculated that a two year old untransplanted crop of white pine seedlings (density 4,356,000 plants per acre) removed 94.6 lb. of nitrogen, 13.8 lb. of phosphorus and 34.5 lb. of potassium per acre. In some nursery soil fertility experiments with loblolly pine seedlings (density 1,742,000 plants per acre) Switzer and Nelson (1956) showed that the following nutrients per acre were removed by the crop: nitrogen 102 lb., phosphorus 20 lb. and potassium 64 lb.

The feature common to all the data is the high nitrogen uptake by young pine seedlings. Maintenance of the soil nitrogen level, therefore, becomes an important aspect of nursery soil management.

2.—NURSERY SOILS.

The composite soil samples were collected from two areas: (1) The old pine beds which have been cropped for at least fifty years, and (2) uncultivated soil adjacent to the nursery. The only treatment that this soil had received was the initial clearing of the area, and the subsequent development of a sward of volunteer pasture, consisting mainly of various grasses. The analytical data for the two groups of soils is shown in Table 4.

(a) Soil Reaction.

Both groups of soils are acid in reaction with a mean pH value of 5.5. This soil property has not been affected by the nursery cropping.

(b) Soluble Salts.

There are moderate amounts of soluble salts present in the soils, and the long term cropping has resulted in a 24 per cent. reduction in these in the old nursery beds (from 0.058 per cent. down to 0.044 per cent.). Water soluble chlorides, expressed as NaCl, are extremely low, being 0.001 per cent. in both samples.

(c) Organic Matter.

Organic matter, as measured by organic carbon and nitrogen, is high in both soils, even after long term cropping, but there is a marked decrease in soil organic matter as a result of the nursery cropping. Organic carbon values have decreased from 5.93 per cent. in the virgin soil to 3.13 per cent. in the old beds. Similarly nitrogen values have declined from 0.317 per cent. to 0.182 per cent. in the old beds and accompanying these changes, there has been a slight decrease in the C/N ratio from 19 to 17.

TABLE 4.

HAMEL NURSERY.

MECHANICAL AND CHEMICAL ANALYSIS OF SOILS.

	Old Nursery Beds.	Virgin Soil (Pasture).
Depth (inches)	0-4	0-4
Physical Analysis:		
Gravel %	—	—
Coarse sand %	21.5	25.3
Fine sand %	33.4	27.1
Silt %	25.4	23.8
Clay %	19.7	23.8
Chemical Analysis:		
pH %	5.4	5.6
Total soluble salts %	0.044	0.058
Chloride (NaCl) %	0.001	0.001
Loss on ignition %	13.5	16.1
Air dry moisture %	4.8	5.6
Organic carbon %	3.13	5.93
Nitrogen %	0.182	0.317
C/N ratio	17	19
Phosphorus % (a)	0.056	0.032
Potassium % (a)	0.062	0.076
Exchangeable Cations:		
Calcium m.e.% and %	4.0 65	4.5 50
Magnesium m.e.% and %	1.4 23	3.6 39
Potassium m.e.% and %	0.48 8	0.54 9
Sodium m.e.% and %	0.27 4	0.22 2
Hydrogen m.e.%	30.8	35.7
Cation exchange capacity m.e.%	37.0	44.8
Saturation %	17	21
Readily Soluble Nutrients: (b)		
Calcium m.e.%	4.3	4.8
Magnesium m.e.%	3.6	8.3
Potassium m.e.%	0.16	0.35
Sodium m.e.%	0.39	0.28
Phosphorus p.p.m.	18	19

(a) Soluble in boiling hydrochloric acid.

(b) Soluble in N/2 acetic acid.

In the calculation of these losses on a per acre basis, the factor 1 acre 4 in. of soil weighs 1.33 x 10^6 lb., has been used. On this basis the loss of carbon and nitrogen from the old nursery beds amounted to 37,240 and 1,796 lb. respectively.

It is extremely fortunate that the nursery has such a big reserve of organic matter, otherwise this depletion would have exhausted the nursery soil many years previously.

(d) Phosphorus and Potassium.

The hydrochloric acid soluble phosphorus in the old nursery soil has increased by 75 per cent. due to the application of superphosphate to the cereal crops, but the "available" phosphorus (soluble in N/2 acetic acid) has not increased. The amounts extracted were 18 p.p.m. in the old nursery beds and 19 p.p.m. in the virgin soil.

Soil potassium has declined in the nursery soils, and there has been a loss of 186 lb. of potassium from the first 4 in.

(e) Exchangeable Cation.

Cation exchange capacity declined from 44.8 m.e. to 37.0 m.e. per cent. in the cropped soils, and this decreased exchange capacity is probably related to the decreased organic matter content of the soil.

With regard to the individual metal ions there has been a decrease in exchangeable calcium, magnesium and potassium amounting to 0.5, 2.2 and 0.06 m.e. per cent. respectively. Exchangeable sodium has increased slightly in the nursery soils, but is still only of minor importance, occupying 4 per cent. of the exchangeable metal ions.

(f) Readily Soluble Nutrients.

The nutrients extracted by N/2 acetic acid show similar trends to those shown by the exchangeable cations, i.e., there is a decrease in calcium, magnesium and potassium and an increase in the amount of sodium.

As with the exchangeable cations, the most pronounced feature is the very marked decrease in magnesium, which has fallen from 8.3 m.e. to 3.6 m.e. per cent. in the old nursery soils.

DISCUSSION AND CONCLUSIONS.

It is evident from the data that the nursery cropping causes a marked drain on soil nutrients, and particularly on nitrogen and potassium. Similar results have been obtained from other Departmental nurseries (Hatch, unpublished data), but in all cases the soils were of lower fertility than Hamel, and consequently the uptake of nutrients was much less. Table 5 shows the amounts of nutrients removed by a one year old crop of *P. radiata* from three different nurseries, covering a wide range of soil fertility.

TABLE 5.

HAMEL NURSERY.

P. RADIATA.

NUTRIENTS REMOVED FROM DIFFERENT SOILS BY PINE SEEDLINGS.

Nursery.	Fertility Status.	Nutrients Removed. lb./acre.		
		N	P	K
Hamel	Excellent	84	8	94
Grimwade	Good	85	6	57
Nannup	Fair	34	4	32
Gnangara	Poor	27	8	18

In planning inorganic fertiliser treatments for Hamel Nursery, the figures quoted in Table 3 can be used as the basis for the calculations and it is evident that considerable applications of fertilisers will be necessary to maintain soil fertility. Using the average uptake of nutrients from the nursery during the period 1957-1959, it can be shown that the following are the fertiliser equivalents of the nutrients removed by the pine seedlings. (Table 6.)

TABLE 6.

HAMEL NURSERY.

P. RADIATA.

FERTILISER EQUIVALENTS TO THE NUTRIENTS REMOVED BY PINE CROP.

Element.	Fertiliser.	Amount lb./acre.
N	$(NH_4)_2$ SO_4	394
P	23% superphosphate	81
K	K_2SO_4	209
Ca	$CaCo_3$	54
Mg	$MgSO_4$	71

In addition to the inorganic fertiliser, steps must be taken to build up the level of soil organic matter. This may be attained in two ways:—

(1) By the addition of an enriched compost to the soil. A typical example of this is the compost described by Partos (1954). This method has the advantage of supplying both inorganic and organic nutrients to the soil with a single application of compost.

(2) By enlarging the nursery and cropping the soils with pines less frequently. In connection with this suggestion it must be remembered that nursery cropping is rather similar to agricultural cropping and in this field it has been shown that soil fertility declines rapidly with short term rotations.

Associated with the increased rotation of cropping, it would appear advisable to incorporate a legume (e.g., subterranean clover) in the rotation. This crop with fertilisers could form a clover ley and be ploughed back into the soil to provide a source of both inorganic nutrients and organic matter.

In conclusion, it must be stressed that the data quoted in this paper refers only to Hamel Nursery, which has a high fertility status. However, it is felt that these results provide an important guide to nursery soil management, and the following factors need to be considered:—

(1) Steps need to be taken immediately to restore to the soil nutrients removed by the pine crop; and

(2) Remedial measures are required to prevent the loss of organic matter caused by the short term rotations.

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