THE FERTILIZER FACTOR IN PINUS PINASTER AIT PLANTATIONS ON SANDY SOILS OF THE SWAN COASTAL PLAIN, WESTERN AUSTRALIA.

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Summary:

In order to meet future timber requirements in Western Australia it has been necessary to consider establishing softwood plantations on infertile, unexploited areas of the Swan Coastal Plain. *Pinus pinaster* is the only species that has proved satisfactory under plantation conditions on the soils available for planting.

Phosphatic applications are necessary at time of planting to ensure satisfactory plantation establishment. Basal applications are essential at this stage to ensure the optimum P_2O_5 concentration is available to the restricted root system before leaching removes the nutrient out of the effective root range.

The effect of this fertilizer treatment fades on certain sites after an initial period of satisfactory growth. The resultant degraded stands can be returned to vigour by second fertilizer applications.

Broadcast treatments are essential to obtain economical, subsequent stand responses. Phosphate, nitrogen and zinc have been found to be deficient nutrients on degraded sites and growth improvement resulting from treatment with amendments containing these materials, is maintained at a high level for at least seven years.

Nitrogenous fertilizers in conjunction with superphosphate have the most consistent and pronounced effect over the range of degraded stands experienced. The addition of 2 cwt. of ammonium sulphate to 5 cwt. of superphosphate per acre provides an economical method of improving the growth response beyond that obtained with 20 cwt. of superphosphate per acre.

Zinc may be a deficient element on all sandplain sites. In the soils with a limestone influence it is a deficiency factor at time of planting. In the more eastern, grey sand plantations, zinc has only been identified as a deficiency element in degraded stands following early satisfactory development as a result of superphosphate treatment.

THE FERTILIZER FACTOR IN PINUS PINASTER AIT. PLANTATIONS OF THE SWAN COASTAL PLAIN, WESTERN AUSTRALIA.

The current pine working plan for Western Australia aims to establish up to 200,000 acres of pine plantation (3). Of this area, less than 50,000 acres of suitable soil is available for planting the desirable, fast growing *Pinus radiata*. The remaining 150,000 acres of the estimate largely covers sandy areas which are suitable only to the more tolerant but slower growing *Pinus pinaster*.

To date 17,000 acres of this species have been established under plantation conditions, mainly in the Wanneroo Division at Gnangara, some 20 miles north-east of Perth. The oldest typical stands in this Division are 30 years of age. Present management information indicates that the rotation period for these plantations will be 60 years.

The Site

Sites proposed for future *Pinus pinaster* establishment in Western Australia are confined mainly to the Swan Coastal Plain in a zone ranging from the Moore River in the north to Busselton in the south. Over this area a reliable, reasonably uniform rainfall of 25 - 35 inches falls; mainly during the four months of May to August. Summers are hot and dry.

The soils are sandy in nature and represent the remaining infertile portions of the Plain, which have not been cleared and utilised for agricultural purposes.

Plantation sites are located within two distinct geomorphic systems.

A. The Spearwood Dunes System (6) - this system is separated from the coast by a narrow undeveloped littoral zone and constitutes the western extent of plantation establishment. In its western margin the system consists of the Cottesloe soil association (1) with shallow yellow and brown neutral sands overlying aeolinite. In many places limestone is exposed at the surface. The eastern portion of the system, the Karrakatta association (1), is a series of sandy dunes reaching elevations of some 200 feet with soils consisting of leached, yellow and brown sands overlying limestone at depth.

Portions of Somerville, Stirling, Pinjar and Myalup plantations are sited on soils of the Karrakatta and Cottesloe associations.

B. The Bassendean Dunes System (6) - The older Bassendean Dunes lie immediately to the east of the Spearwood Dunes. They occupy a far greater land area and often the two systems are separated by a narrow line of drainage depressions. The Bassendean System consists of deep grey sands in the form of dunes with maximum elevations over 200 feet. Dune soils are mainly humus podsols consisting of 3 to 12 feet of leached grey sands overlying an organic or iron hard pan. These soils are highly leached and poor in plant nutrients. (1).

Gnangara, Collier, Coolilup and parts of Myalup and Somerville plantations are sited within the Bassendean Dunes System on the Bassendean soil association (1).

The sands of both systems have an exceptionally low fertility status from the viewpoints of cation exchange capacity and percentages of the major plant nutrients.

The better pine stands have been established on the semi-flat areas between the dunes. Pine quality falls off noticeably proceeding upwards onto the high dunes.

The Need for Fertilizers

Successful pinaster plantation establishment on the sands of the Swan Coastal Plain cannot be accomplished without the use of nutrition amendments at time of planting (10).

Following this initial treatment, stand development is generally sound. In certain areas, however, stand decline or degrade (11, 7) has been found to develop between the ages of 10 and 30 years.

Degrade is a result of soil nutrient deficiencies and recent work has shown that phosphate, nitrogen and zinc treatments are necessary to restore degraded stands to vigour.

One and, in some cases, two fertilizer treatments are therefore necessary to manage Pinus pinaster plantations successfully up to the age of 30 years, the mid-point of the estimated rotation.

Fertilizer Requirements

(a) Phosphate Fertilizers - Phosphate treatments are necessary at time of planting to ensure satisfactory pine establishment on the grey sands of the Bassendean association. Basal applications within a 12 inch radius of the transplant provide the optimum effect (10) and concentrations of 2 oz. of either superphosphate or ground rock phosphate per tree, are most satisfactory for general use.

In certain areas of the yellow and brown limestone stands of the western Cottesloe and Karrakatta associations, phosphate is not required at time of planting. Here zinc or original high soil P_2O_5 are the operating factors.

On restricted areas within established plantations the effect of the time of planting fertilizing has been found to fade after a period of early satisfactory growth. Second applications of superphosphate, broadcast, on the resultant degraded stands, produce marked growth responses.

Optimum superphosphate concentrations, to rehabilitate degrade, appear to be between 4 and 8 cwt. per acre, broadcast. After 4 cwt. the law of diminishing returns, operates to excess. Average basal area responses, over the control, for applications of 4, 8, and 20 cwt. of superphosphate per acre tested, were found to be 2.6%, 3.4% and 4.2% respectively (Table 1). This represents a 0.7%, 0.4% and 0.2% increase per unit cwt. of superphosphate added.

Supering at concentrations greater than 4 - 8 cwt. per acre is not warranted, as at this level superphosphate in mixture with nitrogen or minor elements will produce far greater and more consistent responses than with the continued use of phosphate alone (Tables I and II).

To date it appears that 5 cwt. of superphosphate is a satisfactory value to employ in fertilizer mixtures.

Rock phosphate has only recently been proved a substitute for superphosphate at time of planting and further trials are required before it can be considered for general prescription. Rock phosphate has apparent advantages over superphosphate of comparative cost, higher contained P_2O_5 values and greater stability under leaching conditions. It is used in Queensland plantation practice (8). There is a trend in Britain, however, after years of trials with mineral phosphate in heathland plantations, away from these materials to the favour of superphosphate (5).

TABLE I

AVERAGE MAGNITUDE OF BASAL AREA RESPONSE TO STANDARD NUTRITION TREATMENTS TESTED OVER A RANGE OF DEGRADED STANDS AT GNANGARA.

TREATMENT		Number of Sites Tested	C.A.I. Percent on 1953 Basal Area.	
No.	Description		1953-54	1953-5
1.	2½% zinc sulphate spray	7	5.0	4.9
2.	3¼% zinc sulphate spray	7	6.3	7.0
3.	5% zinc sulphate spray	7	6.9	7.5
4.	1 cwt. zinc sulphate solid per acre	7	5.6	6.8
5.	2 cwt. zinc sulphate solid per acre	7	5.1	5.3
6.	4 cwt. superphosphate per acre	7	5.9	7.2
7.	8 cwt. superphosphate per acre	7	7.2	8.0
8.	20 cwt. superphosphate per acre	7	7.6	8.8
9.	9 elements combined	7	5.3	6.4
10.	Control - untreated	7	5.3	4.6
11.	2 cwt. ammonium sulphate + 5 cwt. superphosphate per acre	7	9.6	9.6
12.	4 cwt. blood and bone per acre	7	5.9	7.4
13.	4 cwt. pyrites slag + 5 cwt. superphosphate per acre	7	7.4	9.2

TABLE II – FREQUENCY OF RESPONSE TO STANDARD TREATMENTS FOR SHORT AND MEDIUM PERIODS

Treatment Number	Compartment Response Designated +																				TOTALS	
	18		26		14		27		20 & 21		29		77		2		16		30			
	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1	6	1 year	6 years
1.		+								+			+	+					+	0	2/10	3/9
2.			+	+				+	+	+			+	+	+	+				0	4/10	5/9
3.	+	+			+	+	+	+	+	+		+	+	+	+			+		0	6/10	7/9
4.	+	+	+	+				+					+	+	+	+			+	0	6/10	5/9
5.			+		+		+	+					+	+					+	+	5/10	3/10
6.		+	+	+				+	+	+				+			+	+	+	+	4/10	7/10
7.	+	+	+	+	+	+	+	+		+			+	+	+	+		+	+	0	7/10	8/9
8.	+	+	+	+	+	+			+	+				+	+		+	+	+	+	7/10	7/10
9.				+				+		+		+		+	+		+	+	+	+	3/10	7/10
10.																						
11.	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	10/10	10/10
12.		+	+	+	+	+	+	+		+				+			+	0	+		5/10	6/9
13.	+	+	+	+	+	+	+	+		+	+	+	+	+				0	+		7/10	7/9
Totals:	6/12	9/12	9/12	9/12	7/12	6/12	6/12	10/12	5/12	10/12	2/12	4/12	8/12	12/12	7/12	4/12	5/12	6/10	10/12	5/7	65/120	75/113

(b) Nitrogenous Fertilizers - Prior to 1952 there was no indication that nitrogen was an important deficiency element under local pine plantation conditions. Mixed fertilizer trials carried out between 1933-1950 generally provided no benefit over phosphatic fertilizers used alone (10).

Young, working with Pinus taeda and Pinus elliottii under Queensland conditions, has reported detrimental effects for nitrogen either used alone as ammonium sulphate or in mixture with phosphatic fertilizers (13). American and British workers report favourable effects of nitrogenous fertilizers in pine nutrition.

On sandy soils in Western Australia, nitrogenous materials have a definite place in plantation fertilizing. In conjunction with phosphatic fertilizers, ammonium sulphate gives a degree of improvement, in stands of subsequent degrade, beyond that obtained with phosphate alone and at more favourable treatment costs. Leyton (5) reports similar circumstances in heathland pine plantations in Great Britain. Nitrogen deficiencies only show up later in the rotation following initial phosphate treatments.

Average growth responses obtained for fertilizer trials over seven degraded sites, as set out in Table I, show that a treatment of 2 cwt. of ammonium sulphate plus 5 cwt. of superphosphate produces an average response of 5%. This is superior to all other treatments tested. Table II which records the frequencies of treatment responses over a range of 10 different sites further shows that this N.P. mixture is more consistent in its increment over the general range of sites tested.

It is obvious that N.P. mixtures are superior to straight P. application in subsequent fertilizer work. The few cost analyses available indicate that the N.P. treatment is economical from the viewpoint of improved stumpage values.

(c) Potassium Fertilizers - Potassium has only been tested on a limited scale in Western Australian pine nutrition work. Recent trials incorporated 1 cwt. of potassium sulphate with 1 cwt. of superphosphate and seven other elements (Treatment 9). Results are not very promising and in certain instances needle burning is attributed to this treatment.

Potassium has been found beneficial in America (4,12), while British workers (14) report detrimental effects for this nutrient. Rossiter (9) has shown the necessity of potassium to pasture growth on sands of the Swan Coastal Plain and it is considered that potassium sulphate at the 0.5 and 1.0 cwt. level, in mixture with the standard N.P. treatment, is worthy of future plantation trial.

(d) Zinc Sulphate - Zinc can be a deficient element in pinaster nutrition on all sands of the Swan Coastal Plain tested by plantations or small 0.1 acre sample plots.

On the limestone sands of the coastal Cottesloe and Karrakatta associations, zinc may be deficient at time of planting or within a few years after planting. This deficiency can be corrected by a 2½% zinc sulphate foliage spray.

Certain test areas at Pinjar and Moore River on the Limestone associations indicate that zinc may replace the phosphate effect experienced at time of planting elsewhere. Superphosphate plus zinc spray treatments on these sites have no effect further than zinc spray alone in the initial establishment stage and in certain instances, superphosphate treatments had no advantage over the untreated control. Here zinc was the only necessary addition for establishment.

On the typical grey sands of the Bassendean association, zinc is not a deficiency element in the early years of establishment. In areas of subsequent degrade zinc is a deficiency element, and may be remedied with a 5% zinc sulphate foliage spray.

Of three spray treatments and two soil applications tested in degraded stands at Gnangara (Table I), the 5% zinc sulphate spray has given the maximum average stand response. Table II also shows that the 5% spray is the most consistent of the five zinc treatments tested.

It is of interest that a soil application of 2 cwt. of zinc sulphate solid broadcast per acre appears to have a toxic effect on pine growth.

Several tests carried out with zinc spray in conjunction with phosphate treatments on degraded sites of the Bassendean association have registered responses far above those of similar zinc or phosphate treatments employed alone. Results obtained in the second year after treatment in two areas tested were 3.5% for treatments with 1 cwt. of superphosphate plus a 2½% zinc spray as compared with 0.1%, 2.8%, and 3.6% responses for the 5% zinc spray, 8 cwt. of superphosphate and 5 cwt. of superphosphate plus 2 cwt. of ammonium sulphate treatments respectively. Insufficient plots have been established to confidently state what will be the average trend over all degraded sites for this combined, inexpensive treatment.

Commercial Pyrites Slags

Excellent results have been obtained on degraded sites with a treatment of 5 cwt. of superphosphate and 4 cwts. of pyrites slag. In relative trials with other treatments this combination has given a response second only to the combined N.P. mixture of superphosphate and ammonium sulphate (Tables I and II).

Analysis of the slag reveals several minor elements to which the increased effect could be attributed. Zinc (1.24% as zinc oxide) has already been discussed. Copper (2.05% as copper oxide) has been found necessary for pasture growth on these soils (9) while manganese (0.07% as manganese dioxide) was an early suspect element in Western Australian pine nutrition work (10). Sulphur (1.90% as sulphate and 0.85% as sulphide) is a further constituent which has been found important in pasture establishment in Australia.

Pyrites slag, containing 90% of silica and ferric oxide, is a very unwieldy vehicle for adding minor elements, and controlled pot trials are required to define the important constituents for use in more economical fertilizer mixtures.

Mode of Application of Amendments.

Three separate application methods have been found necessary in pinaster fertilizer practice.

At time of planting, basal applications of superphosphate or ground rock phosphate are necessary to initiate growth. Broadcasting is essential for applications in stands older than 3 years, if fertilizer treatments are to be effective. Zinc is applied most satisfactorily as a foliage spray.

Three separate factors operate on the site to determine the placement of soil fertilizers.

1. The poor nutrient fixing capacity of the surface sands.
2. A climate and soil type which favour rapid leaching.
3. The rate of root development of *Pinus pinaster*.

1. Nutrient fixing capacity - The grey surface soils of the Bassendean association have very little fine fraction; in some instances the coarse sand percentage is as high as 96% (10). Cation exchange capacity of these layers is directly correlated with their organic content, a value which is in the vicinity of 2.0% in the surface 6 inches and as low as 0.3% at a depth of 36 inches.

   With such a restricted ability to fix applied cations, fertilizers added to these soils are wide open to leaching.

2. Leaching - The coarse nature of the soils and prevailing climatic conditions favour rapid leaching down the profile. Ploughing prior to planting, to reduce scrub competition, would also tend to aid leaching.

   Superphosphate applied at time of planting at the rate of 2 oz. per plant, within a 12 inch radius of the transplant stem, may be leached from the surface 6 inch soil layer within 6 months of the date of application, (See Table III) and from the surface 3 foot layer within 12 months of application.

TABLE III

RESIDUAL EFFECT OF A 2 OZ. BASAL APPLICATION OF SUPERPHOSPHATE APPLIED IN SEPTEMBER AT GNANGARA.

P_2O_5 IN SURFACE 6" SOIL LAYER IN PARTS PER MILLION				
Sample	August	September	November	December
1	33.2	110.5	55.8	21.4
2	57.2	75.2	203.8	20.8
3	56.8	128.5	127.8	43.8
4	34.5	132.2	93.8	16.0
5	41.2	91.7	153.0	17.1
6	66.8	100.8	110.0	41.3
7	61.9	268.2	88.8	50.9
8	53.4	257.3	171.3	42.5
9	63.5	164.5	85.3	59.2
10	54.0	146.3	81.8	29.3
11	89.2	162.8	118.8	38.9
12	43.8	287.9	157.8	40.3
MEAN	54.6	160.5	120.6	35.1

TABLE IV - RETENTION OF APPLIED SUPERPHOSPHATE IN THE PROFILE UNDER GNANGARA PLANTATION CONDITIONS

A - FLAT TYPE

Date Applied	Control		1934-41		1933-37		1933-49		1949		1950	
	P_2O_5 Values in Parts per Million											
Replications.	0-6"	36"	0-6"	36"	0-6"	36"	0-6"	36"	0-6"	36"	0-6"	36"
1.	18	8	34	12	17	9	40	11	24	-	38	5
2.	20	10	26	15	22	6	31	20	18	2	42	13
3.	14	6	40	13	17	6	34	32	9	2	43	19
Mean P_2O_5	17.3	8.0	33.3	13.3	18.6	7.0	35.0	21.0	17.0	1.3	41.0	12.6
Total super Applied.	Nil.		12 oz.		6 oz.		16 oz.		2 oz.		2 oz.	
Date Sampled	19/1/51		16/2/52		19/1/51		16/2/52		19/1/51		19/1/51	

B - TOP OF MEDIUM DUNE

Date Applied	Control				1933-37		1933-49		1949		1950	
	P_2O_5 Values in Parts per Million											
Replications.	0-6"	36"	0-6"	36"	0-6"	36"	0-6"	36"	0-6"	36"	0-6"	36"
1.	20	8			27	11	18	8	25	11	57	14
2.	28	10			24	15	24	11	29	10	61	14
3.	18	7			20	19	23	12	26	16	67	11
Mean P_2O_5	22.0	8.3			23.6	15.0	21.6	10.3	26.6	12.3	61.6	13.0
Total super Applied	Nil.				6 oz.		16 oz.		2 oz.		2 oz.	
Date Sampled	16/2/52				16/2/52		16/2/52		16/2/52		16/2/52	

Analyses to determine the residual P_2O_5 values resulting from frequent superphosphate dressings within the plantation have shown that within 12 months of the cessation of fertilization, P_2O_5 values in the surface 36 inches soil layer are almost back to normal. (Table IV).

3. Root Development of *Pinus pinaster* - For the first 6 months after planting, pinaster roots are restricted to a soil cube of approximate maximum edge 12 inches. In a 3 year old plantation at 7 foot spacing, roots may, however, extend over a radius of 21 feet from the parent plant (2).

   Fertilizer employed at time of planting must be applied basally within a radius of 12 inches from the transplant if it is to be effective before leaching removes the soluble P_2O_5 out of range of the restricted root system. 2-oz. of superphosphate per tree (approx. 1 cwt. / acre at 7' x 7" spacing) is optimum under such conditions. (10).

   It is not practical to broadcast superphosphate at time of planting under prevailing conditions. Excessively high concentrations of approximately 20 cwt. per acre are required to give the optimum, transitory, surface P_2O_5 values of 150 parts per million. The majority of this broadcast material would be lost through leaching before root extension could utilize it, and the only effect the applied P_2O_5 between the rows may have is to encourage excessive weed growth.

   In stands older than 3 years, where the feeding roots are fully utilizing the surface soil layers, basal fertilizer applications are only able to feed the limited root area immediately adjacent to the pine stems. Under these conditions, broadcast dressings, at much reduced concentrations, adequately supply the entire surface root area of the site.

This pattern of fertilizing applies to sites where leaching is an excessive factor. In Queensland plantations where the applied nutrients are fixed in the surface soil layers (7) there is possibly no great advantage in utilizing basal treatments. This should also hold true for *Pinus pinaster* and *Pinus radiata* plantations established on the more fertile soils of Western Australia.

With regard to foliage sprays, tests at present under way indicate that neither phosphate nor nitrogenous nutrients can be effectively applied to pines by this method.

Zinc deficiencies can be effectively remedied by foliage sprays, stem injections or soil treatments. The foliage application has proved the most economical and efficient.

Conclusion

Experience to date indicates that fertilizer programmes must play an important part in the management of Pinus pinaster plantations on the Swan Coastal Plain. This has always been realized. It is sufficient to say that research indicates that fertilizer treatments will be practical and economical over large areas of sandplain plantations.

Forest fertilizing must not be considered as a feature restricted to marginal sites or sandplain afforestation. Nutrition should now become as integral a part of all productive forestry as the traditional practices of thinning, pruning and fire protection if sustained yield management is to be achieved. Rennie clearly states the position when commenting on the upset of the natural fertility balance of forests by removing nutrients bound up in log material "...... the only alternative to diminishing timber productivity is the development of silvicultural methods which have, at least, as their basis, the replenishment from extraneous sources of the nutrients removed via timber crops; and although to the forester this may seem a novel, revolutionary and perhaps impossible principle, it must be remembered that it is the one which has been the basis of sound husbandry and all lasting forms of agriculture". (7).

In forestry, thinning practices and the addition of soil fertilizers have the same function. They must be considered in conjunction with each other. There is a limit to the extent to which satisfactory stand growth may be maintained through progressive thinning. There is also a limit to which nutrition amendments can be added to the site to support vigorous growth. The desirable balance between the two practices can only be determined from further investigation into the nutrient requirements, nutrient uptake and nutrient removal in managed forests. Studies into the economics of thinning and fertilizing schedules will determine our future forest practice in accordance with the nutrition findings.

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