RESEARCH IN THE SUNKLANDS

SUMMARIES OF STUDIES UNDERTAKEN

BY BUSSELTON RESEARCH STATION

1970-1983

CONTENTS

Summary: Research update: Growing Pine in the Donnybrook Sunkland.

Part 1: Bibliography of published research.

Part 2: Abstracts of unpublished research prepared by the Busselton Research Section.

H.W. Chevis

Busselton, August 1983

Research Update - growing pine in the Donnybrook Sunkland

1. What Species grows best?
2. What nutrients are limiting?
3. Nutrition strategies.
4. Fertilizer to establish *P. radiata*
   - phosphorus
   - nitrogen
   - zinc and copper
5. Refertilizing *P. radiata*
   - phosphorus
   - nitrogen
   - zinc and copper
6. (a) Fertilizer to establish and maintain *P. taeda*
   (b) Fertilizer to establish and maintain *P. pinaster*
   (c) Fertilizer to establish and maintain *P. elliottii*
7. Clover establishment and growth.
8. Site preparation.
9. Control of competition.
   (a) annuals
   (b) scrub
   (c) coppice
10. Pruning.
11. Thinning
12. Wind stability
13. Epicormic shoots
14. Impact of *Phytophthora* spp. on *P. radiata*.
15. Hydrological impact of planting pine.

RESEARCH UPDATE

Growing pine in the Donnybrook Sunkland

What species grows best?

Of the species which have been grown in the Sunkland, *P. radiata* performs the best (244.1), but only if it is fertilized regularly (McGrath, 1978b). All the pine species which have been tested require fertilizer applications for successful establishment (244.1). *P. pinaster*, *P. taeda* and probably *P. elliottii* and *P. serotina* do not, however, have the same requirements for continuous high inputs as does *P. radiata* (244.52, 244.53). As well, the ability of *P. taeda* and *P. elliottii* to tolerate wet conditions, and *P. pinaster* - dry conditions, means these species have some applications in the Sunkland.

What nutrients are limiting?

Phosphorus, copper and zinc are imperative for the establishment and growth of *P. radiata* (244.1, 244.6). Additional growth benefits have been gained by applications of inorganic nitrogen (244.14). Low soil levels of phosphorus, nitrogen and zinc (McGrath, 1978a, 268.1) substantiate the need to apply these nutrients. The native phosphorus levels are 1/10, and the nitrogen levels ½, the levels considered necessary to successfully grow *P. radiata*.

Manganese was once thought necessary, but this is now known not to be the case (244.50). No growth responses have been obtained from applications of sulphur (244.47) and lime (244.18).

Nutrition Strategies

The development of a nutrition strategy has been based on the premise that the soil levels of the essential elements for pine growth need to be permanently improved.

Responses to repeated applications of phosphorus and nitrogen have been obtained in the Sunkland (244.49). Operationally the first nutrition strategy involved the use of an NP fertilizer ("Agras") and zinc and copper-sulphate sprays. Initial growth was good, but was difficult to sustain.

Early in the life of the Sunkland project, several 'agroforestry' plots were established. Here, P. radiata was established into a clover sward which was fertilized regularly with 'Super'. The better growth and health of these 5-year-old trees, compared to those receiving 'Agras' (244.55) prompted the adoption of this regime on an operational scale in 1979.

The soil levels of nitrogen and phosphorus have not been improved above native levels with the 'Agras' regime (268.1). The nitrogen in 'Agras' is rapidly leached and the small amount of phosphorus would contribute little to the total fertility of the site. The 'Super and Clover' regime has resulted in markedly improved soil levels of nitrogen to a level which should sustain P. radiata. There has also been a 400% increase in the level of total phosphorus, although not to a level generally considered optimal for pine growth.

The 'Super and Clover' regime results in higher levels of phosphorus, copper and zinc in the foliage compared to those achieved with the 'Agras' regime (264.4). The foliar levels of nitrogen are inconclusive, being apparently marginal in both cases. Foliar analysis is not, however a reliable indicator of the nitrogen status of a tree.

Applications of nitrogen, phosphorus, copper and zinc are required to establish P. radiata regardless of whether clover is present or not (244.5). Once established P. radiata can make use of the nitrogen fixed by the clover and applications of phosphorus only are required (242.1?). Two distinct phases can therefore be identified:

- establishemnt
- maintenance (re-fertilizing)

Fertilizer to establish P. radiata

Phosphorus

The optimum rate of phosphorus varies with soil type, and appears to be related to the phosphate adsorption capacity of the soil (244.9). At least 225 g/plant of "Super" should be applied on all soil types. While the optimum rate of application is higher on the loams than the lighter soils, growth is also greater. The optimum is 450 g/plant on loamy soils (244.9).

Phosphorus is best applied as "Super" or Triple 'Super' (244.19) rather than biosuper or rock phosphate (244.16,) and as a spot application (244.2). Mound (244.15), line or broadcast (244.4) applications are inferior methods.

Nitrogen

Even when P. radiata is established with clover, it is of advantage to apply an inorganic nitrogen fertilizer at establishment (244.5). Nitrogen should only be applied with phosphorus (244.17) as it can otherwise depress growth. Ammonium and nitrate give better growth and survival than urea (244.14, 244.19). Slow release fertilizers such as "Osmocote" are not an economic option (244.51) in providing either nitrogen or phosphorus.

The optimum ratio for the Sunkland of N:P is 1:2 (244.46, .21). Given that at least 20 g/plant of phosphorus (225g 'Super') is optimum, approximately 10 g/plant of nitrogen should be applied. 235 g/plant of a 3:1 mix of "Super CuZn'A'":'Agras No.1' gives this amount in the correct ratio. This should be buried 10-15cm from the pine (244.21).

Zinc and copper

Where no nitrogen is applied at establishment, adequate zinc and copper are available to the pine from the early applications of Super CuZn (spot and broadcast) (244.24). Super CuZn'A' has higher levels of zinc and copper and gives better levels than Super CuZn'B'. The increased growth resulting from the proposed application of nitrogen may induce zinc and copper deficiencies. The health of the trees needs to be monitored and any deficiencies corrected with zinc and copper sulphate sprays.

Re-fertilizing P. radiata (maintenance)

Phosphorus

Super is better than rock sulphate (244.9, 244.36, 244.37) for re-fertilizing P. radiata and should be applied every two years at a rate of at least 200 kg/ha (244.9). Applications should continue until canopy closure occurs, and after thinning. It may even be necessary to fertilize in the years prior to thinning given the low levels of soil phosphorus which have been achieved (268.1).

Nitrogen

At least to age 4 years there is no growth response (242.1) to the nitrogen fixed by the clover (80 kg/ha/year to age 5 years) (268.1). However, needle length and colour is improved (242.1) and so improved growth in the long term could be expected. The lack of response in the short term may be due to competition between the pine and the clover and also nitrogen in organic form may not be immediately available to the pine. The application of inorganic nitrogen will sustain the pine for 2-3 years (244.14). By this time the pine will be making use of the nitrogen fixed by the clover. With weed control the loss of growth from competition between the pine and the clover could be minimized (232.7).

Zinc and copper

Where "Super CuZn" is applied at establishment, re-applications of copper and zinc are not required for at least 3 years (244.24). With an application of nitrogen at establishment this will need to be monitored especially on the grey sands where applied zinc and copper are not as readily available as on other soil types (244.28).

Fertilizer to establish and maintain P. taeda

The optimum rate of phosphorus for establishment is 18.2 g/tree (200g Superphosphate) (244.10). Zinc and copper applied with Super are of benefit, although there is no response to foliar sprays of zinc and copper sulphate (244.26). In contrast to P. radiata the response to "Agras" is less than to Super, suggesting P. taeda does not have the same nitrogen requirement as does P. radiata (244.26). Refertilization is not necessary at least until age three years (244.10). Even then, there is only a slight response to refertilization with "Agras No.1", the optimum rate being 400 kg/ha (244.53).

Fertilizer to establish and maintain P. pinaster

The optimum rate of phosphorus for establishment is 10.3 g/tree (113g Super) on yellow sands (244.11). A larger amount may be optimum on the grey sands on which P. pinaster is being established. There is no response to solid or foliar applications of zinc and copper, even on grey sands (244.25). "Agras" adversely affects the survival of P. pinaster on grey sands (244.25).

P. pinaster responds to broadcast applications of Super (244.25, 244.52) while "Agras" gives only a small response between 200-400 kg/ha and depresses growth at rates above this (244.52).

Fertilizer to establish P. elliottii

There is a greater response to 150g Super than 100g "Agras No.1" and no response to solid or foliar applications of zinc and copper (244.27).

There have been no studies of the refertilization requirements of P. elliottii.

The initial phosphorus requirements of P. taeda and P. pinaster are well defined. The requirements for zinc, copper and nitrogen are less defined as is the case for all nutrients with P. elliottii. It may be prudent to apply the 3:1 Super CuZn'A':Agras No.1 mix to these species, as well as P. elliottii, the rate being in relation to their requirement for phosphorus. The phosphorus requirement of P. elliottii is probably slightly less than that of P. taeda.

In practise, due to the small, and isolated nature of the areas being planted to these species, it may be necessary to apply the same refertilization regime as for P. radiata.

Clover establishment and growth

The cultivars which perform well in the Sunkland are Trikkala, Larissa, (T. yanninicum) Seaton Park and Mount Barker (T. subterraneum). Esperance performs only moderately well (268.2).

There may be potential for perennial clovers on wetter areas, especially if grazing is to occur. All these cultivars are adversely affected by shading, and all to much the same extent (268.3).

500 kg/ha of "Super CuZnMo2" is recommended by the Department of Agriculture for the establishment of clover. An application of 400 kg/ha of "Super" is required in the next year (244.28). Thereafter, the biennial applications of 200 kg/ha "Super" being applied to sustain pine growth are also adequate for the clover.

The clover sward declines after 4-5 years, presumably due to the closing of the pine canopy.

Clover can be established the same year as the pine, or a year later without affecting pine growth or survival (232.5). Planting pine into a one year old sward of clover reduces the growth of the pine by 20% (232.6). This is probably due to weed competition (232.7) which can be avoided.

Site preparation

When establishing pine in the Sunkland it is advantageous to disc plough and mound (232.2, .3, .6, .7). The largest response, in both growth and survival, is to mounding (232.6). The response to mounding is due to a number of factors, including weed control aeration of soil and concentration of nutrients. The timing of clover establishment (one year before, at, or after planting) does not greatly influence the relative response to ploughing and mounding (232.6, .7). Double ploughing may reduce scrub regrowth, especially on the grey sands where root stock species and rushes are common.

Draining is of some benefit on lighter soils, but should be used in combination with mounding, not as an alternative (232.2, .3).

No intensive studies have been made into the effects of ripping.

However, there was no growth response or improvement in stability by ripping through a lateritic layer lying 50cm under loamy sand (232.8). Preparation, using a winged ripper to give a larger shatter zone would cost at least $200/ha.

Control of competition

Pine growth can be restricted by competition from annuals (eg clover) scrub and eucalypt coppice.

Annuals

Pine growth can be improved by 20% by applying a 'Vorox' spray along the mound when planting into established clover (232.7). 4 l/ha is adequate, but should be increased to 6 l/ha where rye grass is present. When clover is established with the pine, or one year later, there is no response to an application of 'Vorox' at planting (232.5). This may, however be a reflection of the poor vigour of the clover sward and weed control may be warranted where a vigorous sward has been established. It may also be worth while to spray along the mound one year after the pine is planted to control the re-colonisation by clover.

Scrub

Controlling scrub by a broadcast spray of 'Velpar' has resulted in an increase in pine growth of 25% after two years (243.3). Many methods of controlling scrub have been tested and the integration of several techniques is probably necessary.

(i) Grazing of a heavy clover sward

Scrub does not appear to persist when a heavy clover sward is established. Scrub can be further reduced by grazing and this is the major advantage of clovering prior to planting the pine.

(ii) Ploughing

Intensive site preparation may control scrub prior to planting pine. Double ploughing, especially of grey sands where root stock species are prevailent, has been successful. After the pine is established, interrow cultivation can be used to treat affected areas. Blade ploughing (Horwood Bagshaw with coulter) is a more versatile method than disc ploughing (243). The machine is cheap and manoeverable being on the 3 point linkage. Further the clover sward is probably not disturbed to the same extent.

Slashing does not seem to be a very successful method of control (232.6).

(iii) Herbicides

Scrub could be controlled by a broadcast application of a herbicide. "Roundup" could be applied as a broadcast spray in the summer prior to the pine being planted. Once the pine is planted the risk of damage to pine, or clover, precludes the use of the herbicides which have been tested (243.8).

Eucalypt coppice

Alternatives to the use of 2,4,5-T for <u>Eucalyptus</u> coppice control have been sought. This has lead to the extensive screening of other herbicides and techniques of application. The most effective technique developed so far is the 'Roundup' foliar spray. Application of a 1:15 solution of 'Roundup':water to the foliage of 6 month old coppice results in a 95% kill. Jarrah is slightly more tolerant than marri. For older coppice a cut stump application of 1:10 "Roundup":water solution gives acceptable levels of control.

Formulations of triclopyr with picloram applied in similar ways to 'Roundup' are as equally cost effective (243.9). As yet they are not commercially available.

Pruning

The objectives of pruning are to remove branches while they are still less than 3.5cm diameter and the stem diameter at the whorl is 10-12cm diameter.

Pruning does result in a reduction in the growth of the tree as a result of removal of the green crown ( ). Growth of the pruned tree is further reduced if there are unpruned trees surrounding it (Fremlin, 1981. 264.2). In a stand of 1100 stems per hectare where 350 sph were pruned to 2.1 metres, 70% of the pruned trees had lost dominance four years after treatment. When a similar proportion of trees were high pruned, 25% of potential diameter growth was lost one year after treatment (264.2).

Pruning to a certain height results in small trees being overpruned (reduced growth) and large trees being underpruned (large knots and knotty core). Pruning to a certain diameter up the stem would give a regular sized knotty core for all trees and should maintain the competitive advantage between trees.

To reduce the growth losses resulting from selective pruning it would be necessary to either prune the whole stand (Fremlin, 1981) or remove the non-crop trees and hence reduce the competition with the pruned crop trees.

Thinning

The current thinning schedule which has been proposed for the Sunkland involves thinning the stand from approximately 1100 sph to 250-350 sph at age 12 years. Two 5.4metre lengths would be removed per tree. For an operation to be economically viable it is considered necessary to harvest 60-80 m3/ha. This volume will be achieved from those areas of the plantation which have received the 'Super and Clover' regime (264.2) and the best of the areas fertilized with 'Agras' (251.1).

There are disadvantages with this regime. Growth of the crop trees is reduced in dense stands (242.2) and potential growth is further reduced by selective pruning (264.2). Non-commercial thinning holds a great deal of promise for improving the economics of growing pine in the Sunkland. For example, by culling to the sawlog crop at age 6 years the volume of the crop trees can be increased by 25% over a stand of 1150 sph (242.2). There was an increase in branch size. Results of the New Zealand Radiata Pine Task Force showed improvements of this magnitude in the growth of crop trees produced a greater economic return than could be achieved by thinnings. It was also shown that while early thinning lead to greater branch growth, this was compensated for by the increased log size.

Given the current committment to provide particle-board from a first commercial thinning it, unfortunately doesn't appear feasible to adopt a sawlog regime. However, it is possible to reduce the competition on the crop trees by N.C.T. and earlier commercial thinning. A thinning, in which one 5.4 metre length per tree were extracted would yield approximately 50 m3/ha at age 10 years (264.2). By extracting 2.7 metre lengths, thinning could be carried out a further two years earlier than this (264.2). The practise of a non-commercial thinning to 750 sph at the time of low pruning should also be re-adopted.

One of the Task Force findings was that sawlog stockings of 100-150 stems per hectare gave the best economic return. This suggests we should thin to sawlog stockings much lower than at present.

Separate regimes

Wind Stability

Wind damage to pine in the Sunkland has been observed following thinning (251.1, 251.2). Damage is greater with older trees, and stands of P. pinaster are more susceptible than P. radiata (251.2).

The limiting factor to vertical root development in the Sunkland is not waterlogging but compact soil layers (443.2). Shattering these layers may allow root penetration and reduce the chances of windthrow occurring. However, ripping through a lateritic layer lying 50cm under loamy sand gave no improvement in growth or stability (232.8). Preparation using a winged ripper, would give a larger shatter zone but would cost over $200/ha.

The best means of reducing the potential for windthrow is to thin early and allow the trees to become windfirm at an early age. Alternatively, regular and light thinnings could be carried out but this would reduce the growth of the crop trees.

Epicormic shoots

Following early pruning of rapidly growing P. radiata, vigorous epicormic shoot development can occur on the pruned section of the stem. The purpose of pruning is to limit the size of knots to 35mm and to produce clear wood. Growth of epicormic shoots, if they persist for any length of time, can negate the purpose of pruning.

Epicormic growth is greater if pruning is carried out in summer, and on trees on a northerly aspect (249.3). Often the epicormics are more vigorous on the northern side of the trunk. It appears epicormics are stimulated by heating of the stem, especially of thin-barked trees. Pruning in late autumn to winter will reduce their prevalence.

In dense stands these epicormics generally die off after the canopy closes. On open grown trees they persist. Here they can be removed mechanically by chainsaws or shears or by a herbicide spray. "Reglone" and "Gramoxone" at 3 ml/l and amitrol at 100 ml/l have been successful in killing newly developed epicormics (249.2). Some chlorosis of the pine occurrs with the latter treatment.

The impact of Phytophthora spp. on P. radiata

Some P. radiata have died due to infection by Phytophthora species. Deaths cease by age 8 years. However, non-lethal infections of pine do occur and may result in the loss of crop trees at some later date.

Deaths are greatest on areas of leached grey sands and silty loams which have previously been affected by 'jarrah dieback' (443.6). To reduce the potential impact of disease on these sites, families of *P. radiata* tolerant to infection, or *P. pinaster*, could be planted and the plantation could be maintained at a dense stocking, making the soil conditions less favourable for the spread of inoculum.

Hydrological impact of planting pine

The salt content of the soils in the Sunkland are quite low, although pockets of higher salinity do occur (Stirling, 1979). Streams arising in the Sunkland have very low levels of TDS (McKinnell, 1976) and the levels are not affected greatly by clearing and pine planting (Richmond, 1980). There are increases in the ground water table (116.1) and streamflow (Richmond, 1980) immediately after clearing. The ground water table began to recede four years after the pines were established. Increases in the level of TDS in the groundwater have occurred in those isolated localities where there were high levels of stored salt.

Perched water tables are a feature of many sites in the Sunkland. They don't prevent vertical root development (443.2) but possibly cause some instability and reduced growth.

PART 1: PUBLISHED RESEARCH

Listed in alphabetic order of authors. All publications listed are available as papers or reprints from Publications Section Forests Department Como.

Chevis, H.W. and Stukely, M.J. (1983). Mortalities of young established radiata pine associated with Phytophthora spp in the Donnybrook Sunkland plantations in W.A. Aust. For. Vol. 45(3): 183-200.

Fremlin, R.R.A. (1981). Selective low pruning in initially wide spaced Pinus radiata in W.A. F.D. Research Paper No. 69.

McGrath, J.F. (1978). Phosphate and zinc nutrition of young Pinus radiata in the Donnybrook Sunklands. F.D. Research Paper No. 34.

McGrath J.F. (1978). Response to phosphorus fertilization of Pinus radiata grown on the Donnybrook Sunkland. F.D. Research Paper 47.

McGrath J.F. (1979). Initial fertilizer requirements of exotic eucalypts on the Donnybrook Sunkland. F.D. Research Paper 53.

McKinnell, F.H. (1974). Control of weeds in Radiata pine plantations by sheep grazing. Aust. For. Research 6(4): 1-4.

" ——— (1976). Water quality in the Donnybrook Sunkland (Blackwood Plateau). F.D. Research Paper No. 24.

" ——— (1976). Sawlog silviculture in W.A. pine plantations. Proceedings IUFRO Project group 202.

" ——— (1979). Silviculture of Pinus radiata in an agroforestry management system. F.D. Research Paper 51.

Moore, R. (1981). The short lived response to nitrogen and phosphorus by young P. radiata on a sandy soil. F.D. Research Paper 68.

" ——— (1982). Poor response to a slow release fertilizer by young P. radiata on a sandy soil. F.D. Research Paper 71.

Richmond, I.C. (1980). Streamflow and water quality following pine establishment in the Donnybrook Sunklands. F.D. Research Paper 58.

Stirling P.D. (1979). Subsurface sampling in a small subcatchment in the Donnybrook Sunkland. F.D. Research Paper 52.

PART 2: ABSTRACTS OF UNPUBLISHED RESEARCH

Individual studies have been classified according to the Oxford system. Titles are listed below, and abstracts follow in the same order.

Hydrology (116)

1. The effect of conversion of native forest to pine plantation on the ground water table (WP 13/75).

Site Preparation and Establishment (232)

1. Sunkland site preparation trials (232.2 & 232.3)
2. The response of pines to clover and various site preparations and fertilizer requirements (WP 16/79). (232.5)
3. Site preparation methods with clover (WP 12/79) (232.6)
4. Site preparation methods with one year old clover. (232.7)
5. Ripping on a Sunkland Phase 3 site. (232.8)
6. Spacing of *P. radiata*. (232.9)
7. Eucalypt spacing trial (WP 9/75). (232.10)
8. Wetting agents for establishing *P. radiata* on Bassendean sands (WP 5/83). (232.11)

Scrub Control (243)

1. Spot application of Velpar as a means of controlling *E. calophylla* regrowth in Sunklands pine plantations (WP 1/80). (243.2)
2. The use of Velpar L and Velpar 20G to control scrub in recently planted *P. radiata* (WP 25/80). (243.3)
3. The control of Eucalypt regrowth by stem injection with Roundup (WP 2/82). (243.6)
4. Operational evaluation of Roundup and Banvel to control eucalypt regrowth by stem injection (WP 3/82). (243.5)
5. Optimum concentration of Roundup and Tordon 5-15G to control Eucalypt regrowth by foliar spray (WP 46/82). (243.9)
6. Scrub control in a *P. radiata* plantation. (243.11)
7. The tolerance of *P. radiata* and various eucalypts to pre-plant herbicides (WP 19/79). (243.23)

8. Velpar and Banvel as a means to control marri regrowth in the Sunklands (WP 8/81). (243.8)

9. Inter row cultivation trial. (243.8)

10. The tolerance of <u>P. radiata</u> to various herbicides (WP 31/82). (243.8)

<u>Nutrition</u> (244)

1. 1969 Establishment and fertilizer plots (244.1)

2. Fertilizer placement trial. (244.4)

3. Initial fertilizer pilot trial - Telerah. (244.6)

4. Minor element screening trial (WP 18/71). (244.8)

5. Optimum rates of superphosphate for <u>P. taeda</u>. (244.10)

6. Optimum rates for superphosphate on <u>P. pinaster</u> in the Donnybrook Sunkland. (244.11)

7. Nursery zinc trial (WP 11/78). (244.12)

8. Nutrient requirements of <u>P. radiata</u> seedlings in the Nannup nursery. (244.12)

9. NP Initial fertilizer trial. (244.14)

10. Internal mound application of the initial fertilizer for <u>P. radiata</u> in the Donnybrook Sunkland (WP 10/77). (244.15)

11. Bio super evaluation experiment. (244.16)

12. Aspects of the P and N nutrition of <u>P. radiata</u> (WP 6/77). (244.17

13. Effect of liming on the establishment and growth of <u>P. radiata</u> (WP 9/77). (244.18)

14. Methods of initial nitrogen applications for <u>P. radiata</u>. (244.19)

15. N and P planting. P72 Cundinup 1. (244.20)

16. Initial nitrogen and phosphate fertilizer requirements in relation to mechanical placement methods (WP 15/79). (244.21)

17. Single spot initial N-P fertilizer trial (WP 10/80). (244.23)

18. Zinc and copper requirements for <u>P. radiata</u> grown with Super and clover. (244.24)

19. Initial fertilizer to establish <u>P. pinaster</u>. (244.25)

20. Initial fertilizer requirements for <u>P. taeda</u>. (244.26)

21. " " " " <u>P. elliottii</u>. (244.27)

22. Solid applications of zinc and copper on Sunkland *P. radiata* (WP 18/82). (244.28)

23. Inter-row refertilizing. (244.30)

24. Native levels of nitrogen and phosphorus (WP 19/82). (244.33)

25. Superphosphate and rock phosphate (WP 25/74). (244.36)

26. Rock phosphate and superphosphate (WP 3/75). (244.37)

27. Evaluation of compound NP fertilizers for the establishment of *P. radiata* (WP 7/77). (244.46)

28. Effect of Sulphur on establishment and growth of *P. radiata* (WP 8/77). (244.47)

29. Atrazine application trial. (244.48)

30. Thinning and fertilizing 4 year old *P. radiata*. (244.49)

31. Alleviation of a manganese deficiency in the Sunkland. (244.50)

32. Refertilization of three year old *P. pinaster* in the Donnybrook Sunkland (WP 18/79). (244.52)

33. Refertilization of 3 year old *P. taeda* in the Donnybrook Sunkland (WP 17/79). (244.53)

34. The 1979 Ludlow pot trials (WP 15/77, 16/77, 17/77). (244.54)

35. Growth rates of *P. radiata* under different fertilizer regimes. (244.55)

Epicormics (249)

1. Chemical control of epicormics in *P. radiata*. (249.1)

2. Chemical control of epicormic shoots on 4 year old *P. radiata* (WP 39/82). (249.2)

3. 1980 epicormic study in the Central Region. (249.3)

Thinning (242 & 251)

1. Non-commercial thinning of *P. radiata* on clover. (242.1)

2. Sunkland thinning trial (WP 21/78). (242.2)

3. Thinning/wind stability study (WP 6/83). (251.1)

4. Wind damage in the Donnybrook Sunkland (WP 1/81). (251.2)

Pines and Pasture (264)

1. Establishment of pine with pasture. (264.1)

2. First thinning of pine stands grown with super and clover (WP 7/83). (264.2)

3. Chemical thinning - an alternative in agroforestry? (264.3)

4. Foliar nutrient levels with two fertilizer strategies in the Donnybrook Sunkland. (264.4)

(268)

1. Legume trials in W.A. pine plantations (WP 17/80). (268.1)

2. Clover cultivar trial (WP 13/79). (268.2)

3. Clover shade tolerance (WP 6/79). (268.3)

Inimical agencies (443)

1. The effect of a perched water table on *P. radiata* root form (WP 6/80). (443.2)

2. Inoculation trials (WP 11/80). (443.3)

3. Soil moisture/temperature experiment (WP 13/75). (443.5)

4. The occurrence of pine deaths, associated with *Phytophthora* spp., on soils in the Donnybrook Sunkland. (443.6)

The affect of clearing native forest for pine plantation on the ground water table.

W.P. 13/75 File No. 116.5

This project was to investigate whether clearing native forest in the Sunkland for pine plantation would affect the ground water table. A number of piezometers were established in an area of native forest at Jarrahwood due to be cleared for pine plantation 10 piezometers were established in 1975, and another 10 in 1976. They were located over a range of topographic positions. Two were on ridge tops in native forest which was not to be cleared. Depth to the water table (ground water potentiometric head) was measured every month and a water sample taken to determine any changes in the quality of the water. The native forest was cleared in 1978 and P. radiata planted at 800 sph.

There were seasonal fluctuations in the depth to the water fable, being greatest in autumn and least in spring. Following clearing of the native forest the water table rose. The maximum depth to the water table (in a year) decreased by over a meter in some cases. The depth to the water table in the two piezometers under the native forest increased in the year the other forest was cleared. This was an opposite trend to that observed in the cleared areas.

The water table began to decline once the pine had reached four to five years of age while remaining fairly constant under the native forest on the ridge tops.

The level of bore water salinity was high where higher levels of total salt storage were recorded. However, the level of bore water salinity only increased in a small number of piezometers following clearing, and appeared to be related to the occurrence of a pronounced salt bulge at the site of these piezometers (Stirling, 1979).

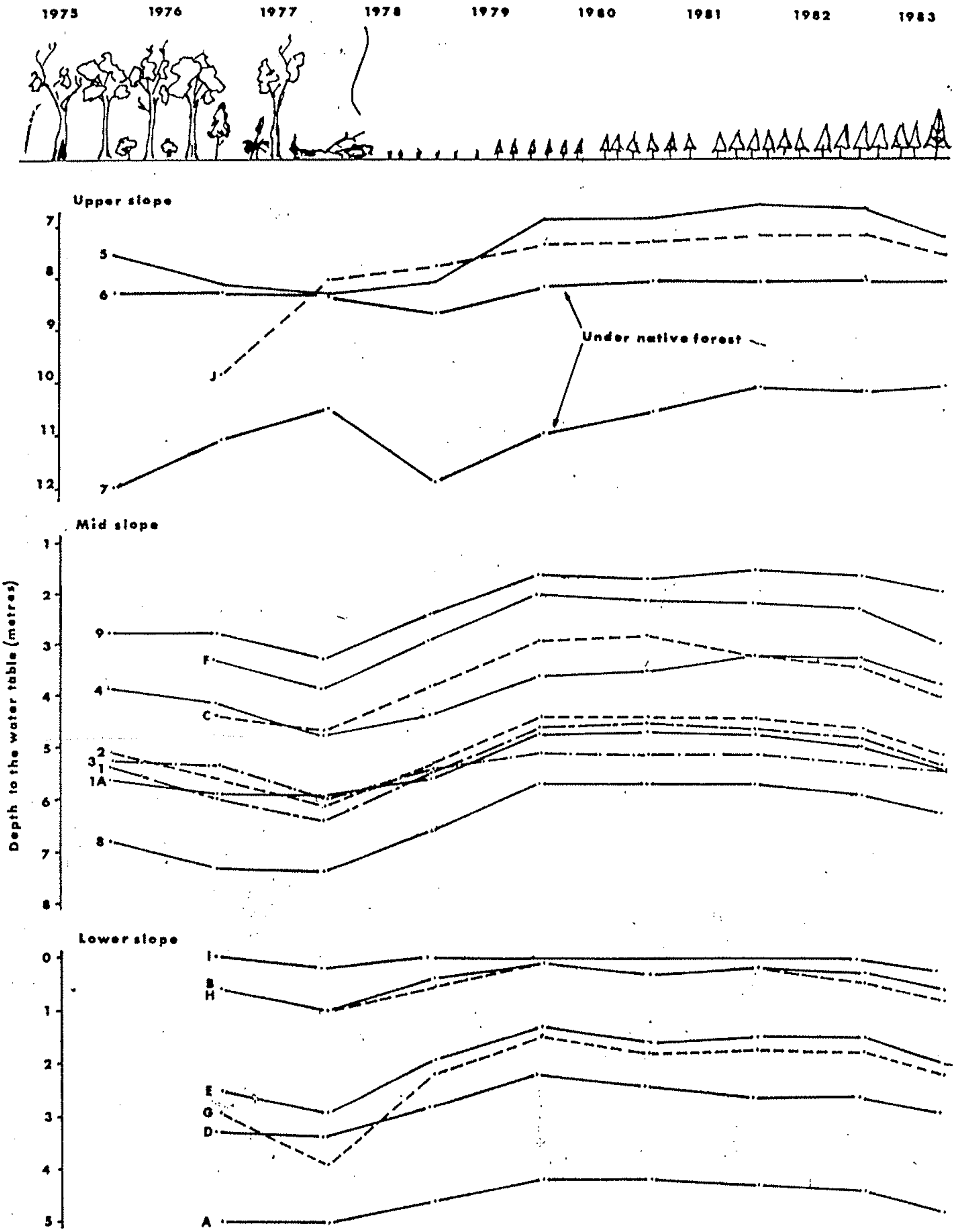
There is an increase in streamflow following clearing of the

.../2

native forest but no increases in salinity of the runoff (Richmond, 1980). While data from these ground water studies suggests that a rising water table following clearing can lead to an increase in the salinity of the ground water, the occurrence is apparently not frequent enought to cause an increase in the salinity of the streamflow. It remains to be seen whether the salinity of the ground water will change as the ground water potentiometric head decreases under the developing pine stand.

The affect of clearing of native forest for pine plantation on the ground water table.

Depths are the maximum in each year.



SUNKLAND SITE PREPARATION TRIALS

File Nº 232.231 and 232

Two seperate trials were established, one in 1974 and the other in 1975. The aims were twofold; firstly to determine the extent to which the initial preparation of the site was necessary to ensure satisfactory establishment of P. radiata and secondly, to compare the effectiveness of these preparations in improving the trees tolerance to wind.

The basic requirement when preparing the site for planting in the Sunkland is to form a mound that will be high and large enough to support a young tree, free from the surface-lying water that is a feature of Sunkland sites. The mound must be firm enough to allow the use of planting machines without the mound being destroyed and they must also be designed to allow drainage from the site to occur without any errosive effect.

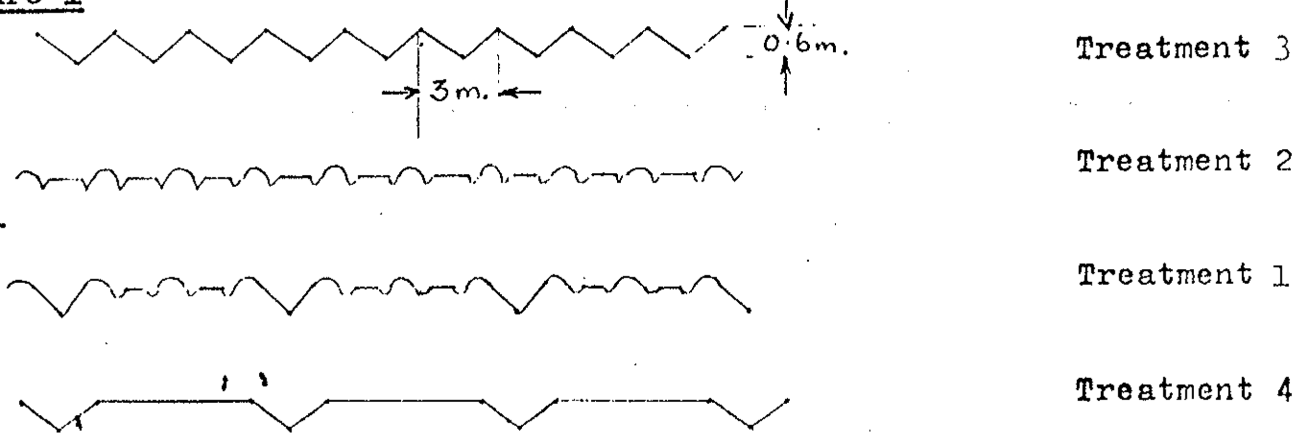
The 1974 trial was established to compare five methods of site preparation viz:

1) mound at 3-metre spacing and drain at 9-metre spacing
2) mound at 3-metre spacing only
3) drain at 3-metre spacing only
4) drain at 9-metre spacing only
5) control - no treatment

All treatments were double ploughed prior to final preparation.

Profiles of treatments were approximately as shown in figure 1. Mounding was accomplished by using the standard Forests Department two-disc mound plough, whilst drains were formed using a D4 bulldozer.

Figure 1



Three replicates of each treatment were established on soils described by G.S. McCutcheon (see figure 2.)

Results

Height measurements were carried out in 1975, 1976 and 1977. A summary of data are shown below.

Treatment		Height (cms)			Inc. (cms)		Survival %
		6/75	2/76	6/77	75/76	76/77	
1 Mound (3m) and Drain (9m)	2	42.1	91.9	192.7	49.8	100.8	99
	9	43.9	83.8	185.7	39.9	101.9	99
	14	46.1	98.8	196.6	52.7	97.8	95
MEAN		44.0	91.5	191.7	47.5	100.2	
2 Mound only (3m)	3	39.6	69.1	154.5	29.5	85.4	96
	10	48.5	102.5	259.8	54.0	157.3	99
	15	41.6	76.1	162.5	34.5	86.4	94
MEAN		43.2	82.6	192.3	39.4	109.7	
3 Drain (3m)	4	43.5	91.7	174.9	48.2	83.2	99
	8	42.2	85.0	171.7	42.8	86.7	99
	11	55.8	111.7	223.6	55.9	111.9	99
MEAN		47.2	96.1	190.1	48.9	94.0	
4 Drain (9m)	5	43.1	82.3	165.7	39.2	83.4	96
	7	43.9	85.0	166.2	41.1	81.2	98
	13	52.3	106.0	223.6	53.7	117.6	94
MEAN		46.4	91.1	185.2	44.7	94.1	
5 Control	1	41.2	80.0	176.0	38.8	96.0	97
	6	53.8	97.7	212.4	43.9	114.7	91
	12	44.7	90.8	192.6	46.1	101.8	94
MEAN		46.6	89.5	193.7	42.9	104.2	

Analysis of Variance - Height 1977

Source	S.S.	d.f.	M.S.	F	Sig.
Block	2379.0	2	1189.5	1.04	N.S.
Treatment	129.4	4	32.34	0.03	N.S.
Error	9126.9	8	1140.87		
Total	11635.33	14			

(Treatment) F = 3.84 p = 0.05
7.01 p = 0.01

Survival %

Treatment	Replicate		
	1	2	3
Mound (3m) + Drain (9m)	99	99	95
Mound only	96	99	94
Drain (3m)	99	99	99
Drain (9m)	96	98	94
Control	97	91	94

Analysis of Variance - Survival % 1977

Source	S.S.	d.f.	M.S.	F	Sig.
Block	14.8	2	7.4	1.72	N.S.
Treatment	42.26	4	10.57	2.45	N.S.
Error	34.54	8	4.32		
Total	91.6	14			

(Treatment) F = 3.63 p = 0.05
6.42 p = 0.01

It is noteable that the two treatments, mound only and control had the smallest increment in 75/76 yet are currently growing faster than the others. The control plots had the poorest survival, whereas the high profile drains showed the best survival.

The 1975 trial was established having three different treatments:

1) mound plough at 3 metre spacing

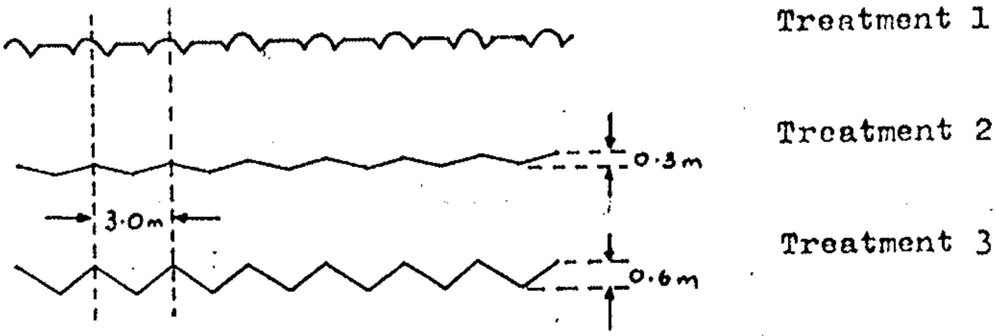
2) low profile drains at 3 metre spacing

3) high profile drains at 3 metre spacing.

Mounds and high profile drains were prepared using the same method as the 1974 trial. The low profile drains were constructed using a grader (Cat. 14E) see fig. 3. Mounds and drains were established in a North/South direction in the first replicate and East/West in the second. The effect of row orientation relative to the prevailing wind will be studied at some future date.

All treatments were double ploughed prior to treatment.

FIG. 3



See figure 4 for soil plan.

Results

Treatment			Height (cms)			Inc. (cms)		Survival % (8/78)
			5/76	1/77	8/78	76/77	77/78	
Mound Plough	P/N 1	1	70.4	151.5	325.0	81.1	173.5	67
		2	52.6	109.4	222.4	56.8	113.0	88
		3	54.4	124.3	266.7	69.9	142.4	94
		4	66.1	144.9	262.7	78.8	117.8	94
	MEAN		60.9	132.5	269.2	71.6	136.7	86
	P/N 5	17	68.6	143.9	284.9	75.3	141.0	88
		18	62.6	130.9	282.4	68.3	151.5	100
		19	67.9	146.3	314.4	78.4	168.1	82
		20	73.5	156.4	337.9	82.9	181.5	94
	MEAN		68.2	144.4	304.9	76.2	160.5	91
Grader Drain	P/N 2	5	63.6	135.7	242.7	72.1	107.0	87
		6	68.2	154.4	285.6	86.2	131.2	94
		7	45.5	102.7	237.0	57.2	134.3	81
		8	44.4	99.6	210.9	55.2	111.3	100
	MEAN		55.4	123.1	244.1	67.7	121.0	91
	P/N 4	13	48.7	99.7	195.3	51.0	95.6	94
		14	54.3	113.2	255.4	58.9	142.2	93
		15	38.4	80.9	154.1	42.5	73.2	100
		16	78.8	166.6	272.8	87.8	106.2	81
	MEAN		55.1	115.1	219.4	60.0	104.3	92
Bulldozer Drain	P/N 3	9	43.1	85.7	176.5	42.6	90.8	94
		10	39.9	84.6	202.9	44.7	118.3	100
		11	46.0	91.4	209.7	45.4	118.3	94
		12	41.3	78.9	174.4	38.5	94.6	100
	MEAN		42.6	85.2	190.9	42.6	105.7	97
	P/N 6	21	68.1	135.3	260.4	67.2	125.1	75
		22	70.7	160.5	326.8	35.8	166.3	94
		23	68.8	146.5	294.3	77.3	148.2	94
		24	65.1	152.1	318.1	87.0	166.0	81
	MEAN		68.2	148.6	299.9	80.4	151.3	86

../5

The limitations in design (2 error d.f.) rule out the possibility of statistical analysis. There is little evidence to support any hypothesis other than the possibility of increased growth on the moister or light textured sites (plots 1, 5 and 6). The soils on which plots 3 and 4 are located, though predominantly type 5, have a higher clay content and are drier than soils further to the west.

Summary

Whereas in the 1974 trial there seemed to be some early response to intensive draining, there is little evidence, in the 1975 trial, of any treatment effect. The trend in the earlier trial, though of no statistical significance is none the less interesting. The higher growth rate from the high profile mounds in the first year and better survival does indicate that waterlogged conditions are detremental to successful establishment. However, the reversal of this trend later, cannot be explained and may be due to a number of factors. Firstly, the larger mounds may dry out quicker and therefore reduce the growing season, whilst the steep sides of these mounds may encourage quick drainage and therefore water penetration is less and loss of fertiliser by leeching is hastened. A further factor that may influence plant behaviour is the certainty that the top-most part of the larger mounds will be predominantly heavy textured sub-soil, whereas the plough mounds are a concentration of surface light textured soil. It is inevitable that large mounds constructed on type 5, 6 or 7 soils will be predominantly heavy textured and though they may have initial benefit, the overall effect may be detremental. However, intensive draining of type 3, 4 and the lighter type 5 soils may improve survival and growth.

THE RESPONSE OF PINES TO CLOVER AND VARIOUS SITE PREPARATIONS AND FERTILISER REQUIREMENTS

W.P. 16/79 File No: 232.233

This trial was to determine the effects of timing of clover establishment, spot spraying with 'Vorox' herbicide and type of initial fertiliser on the growth of *P. radiata*.

Two site preparation methods were applied:-

i) Ploughed, mounded and clover established the same year that the pine was planted.

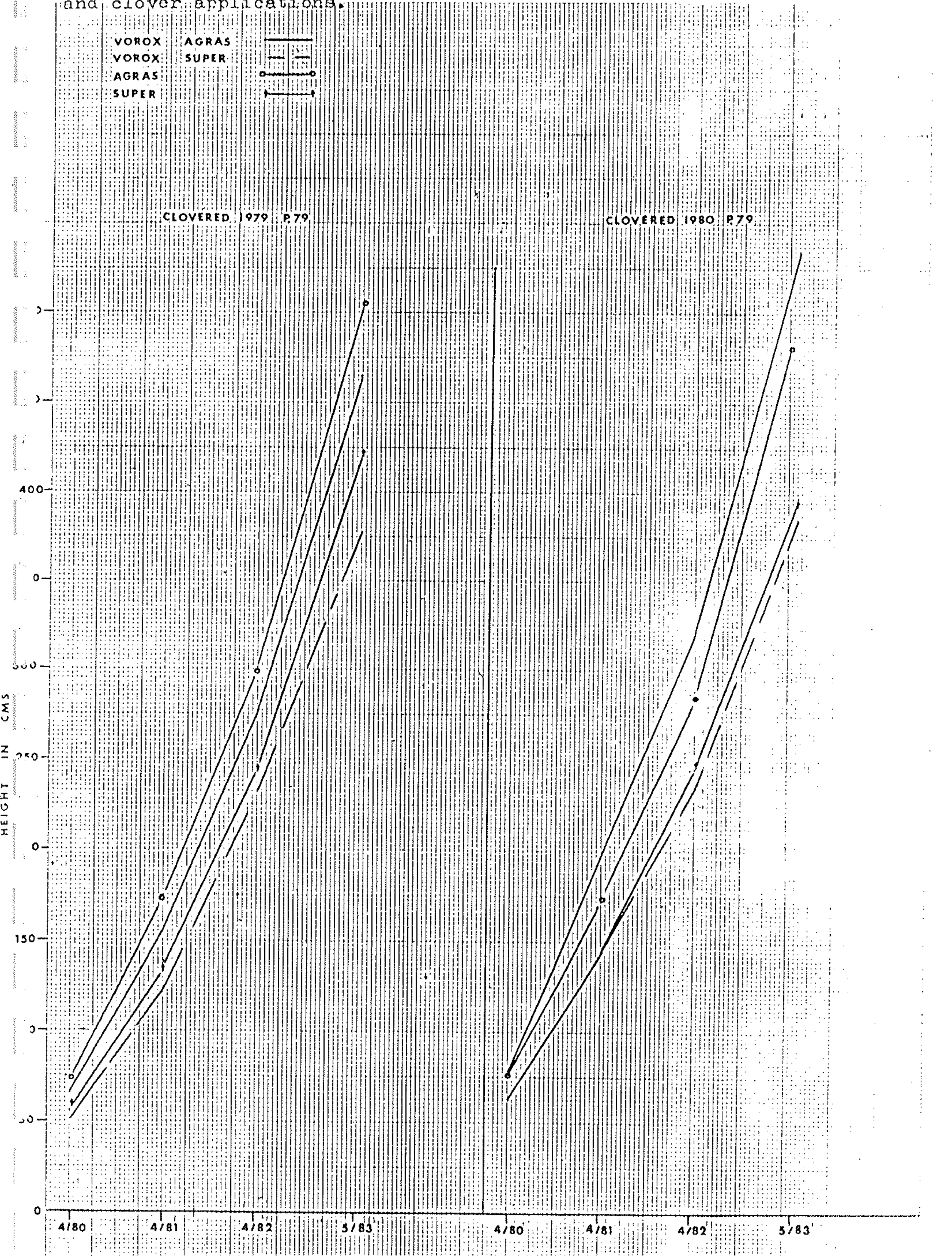
ii) Mounded the year pine was planted, and inter-row cultivated and clover established a year later.

Spot applications of 100gm/tree Agras or 150gm/tree Superphosphate 22% were applied with or without a spot spray of 'Vorox'. The fertiliser was applied in boot heel holes on either side of the plant to simulate machine application. The 'Vorox' was applied as a 64% solution at approximately 25 mls a.i. per plant. The experiment was in a factorial design.

Analysis of the height increment from one to four years after transplanting showed no effect ($p < 0.05$) of the timing of clover establishment. There was also no response in height growth to the 'Vorox' application. The application of Agras, however, resulted in greater ($p < 0.05$) pine growth than in response to Super. (See Figure 1).

From this trial it can be seen that clover does not compete with pine if they are planted at the same time or the clover a year later. The greater response to Agras compared to Super, indicates the necessity of a NP fertiliser application at planting. Nitrogen fixed by the clover would not be available to the pine until the year following clover establishment.

FIGURE 1: Height growth of P. radiata following fertiliser, vorox and clover applications.



SITE PREPARATION METHODS WITH CLOVER

W.P. 12/79 File No.: 232.234

This trial was established to investigate whether ploughing and mounding were necessary when establishing pine with, or into, a clover sward. Slashing was tested as a means of weed control.

The treatments were:-

A. P. radiata planted into a one year old clover sward.
   P. radiata and clover established the same year.

B. Plough and mound
   Mound
   Plough
   Control (no ploughing or mounding)

C. Slashing
   No slashing

The trial was laid down as a 2 x 2 x 4 factorial with 4 replications. Three years after establishment the slashing had not affected the growth of the pine. Ploughing and mounding was the best establishment method with mounding having a greater influence on growth and survival than ploughing. The increased growth and survival in response to ploughing compared to the control may be in response to better scrub control. Establishing clover one year prior to the pine resulted in a 20% loss of height increment. This was probably due to competition between clover and pine on the mound, also the mounds were established one year prior to the pine. In this situation weed control on the mound is essential.

The optimum treatment in this trial was to plough and mound and establish pine and clover in the same year. Controlling weeds on the mound when planting into clover would probably result in similar pine growth to this treatment.

TABLE 1 Growth and survival of *P. radiata* in response to site preparation treatments. Data at age three years (except survival) and is presented as a factorial analysis. Bars denote significance at the 95% level.

Height Increment (cm)

Plough and mound	135
Mound	129
Plough	119
Control	69

Clover established one year before pine	100
Clover established with pine	126

Slashed	114
Unslashed	113

Total Height (cm)

Plough and mound	266
Mound	261
Plough	232
Control	153

Clover established one year before pine	215
Clover established with pine	242

Slashed	229
Unslashed	228

Survival (arcsin %) Age 2 years

Mound	70
Plough and mound	67
Plough	60
Control	49

Clover established one year before pine	59
Clover established with pine	64

Slashed	62
Unslashed	61

SITE PREPARATION METHODS WITH ONE YEAR OLD CLOVER

File 232.235

Establishment of pasture and grazing prior to pine planting is being considered for the Sunkland plantations. Competition between the pasture and the newly established pine is a potential problem. Planting the pine into a mound is of advantage in the Sunkland. However, where pine has been planted into pasture without mounding (No. 7 Road plot) good survival and growth was achieved.

This trial was to investigate whether mounding and grass control around the pine was necessary when planting into established pasture in the Sunkland. The pasture was a mixture of subterranean clover and rye grass and was established one year prior to the pine. The site was not ploughed. There were three treatments; mounding plus weed control, mounding only and weed control only. A 0.5 metre strip spray of 4 $l ha^{-1}$ Vorox plus 2 $l ha^{-1}$ Gesaprim (atrazine) was applied to achieve weed control.

One year after the pine were planted the mounding plus weed control had resulted in a 27% growth response ($p < 0.05$) over the weed control treatment. This could be expected to increase in the future. Weed control improved the survival rate of the pine.

The optimum treatment when planting into established pasture in the Sunkland is to mound and control pasture along the planting line. Weed control should be over a 1 metre width rather than the ½ metre swathe used in this trial.

Fig. Growth and survival for *P. radiata* planted into established pasture in the Sunkland.

Treatment	Height Increment (cm)	Survival (%)
Mound + weed control	26.5^{a}	89
Mound	24.7^{ab}	78
Weed Control	20.8^{b}	97

$p < 0.05$

RIPPING ON A SUNKLAND PHASE 3 SITE

File 232.291

The soils south of the Blackwood River in Phase 3 of the Sunkland project are often of heavier texture and shallower than those encountered in Phase 1 and 2. Ripping was seen as a means of ameliorating these site conditions. In 1972 several sections of the Brockman 10 were deep ripped and planted with *P. radiata*. The pine was fertilized with 113g/tree of Super 22% at planting and 200kg/ha in 1974. A foliar spray of 2½% $ZnSO_4$ and $MnSO_4$ was also applied at this time. In 1980 400kg/ha of Agras No. 1 was applied. The 1949 C.S.I.R.O. survey of the area classified the soils on which this plot is situated as Milyeannup and Mowen sands. These soils are characterized by a sand of variable depth over massive laterite or hardpan. In the areas which were ripped laterite was sometimes present on the soil surface. Paired plots were established in the ripped and unripped areas. Height was measured in 1973, 1975 and 1982. Diameter and number of leaning trees were assessed in 1982. This data is presented in Table 1.

	Unripped			Ripped		
	Height (cm)	Diameter (cm)	% leaning stems	Height (cm)	Diameter (cm)	% leaning stems
1973	61.7			69.7		
1975	215.9			228.6		
Inc.	154.2			158.9		
1982	1048	15.34 a	20.7	1059	14.63 b	19.7
73/82 Inc.	986			989		

Table 1: Effect of ripping on *P. radiata* growth.

These results show that ripping has had very little effect on *P. radiata* growth or stability on these soils. The site was not mounded and the ripping resulted in a furrow being formed along the planting line which may be a contributing factor to the lack of response. To justify the expense of ripping there would have to be a large increase in growth. The height of the pine at age 10 years is only 10 metres, which suggests this site is marginal for *P. radiata*. More frequent applications of fertilizer may have resulted in greater pine growth.

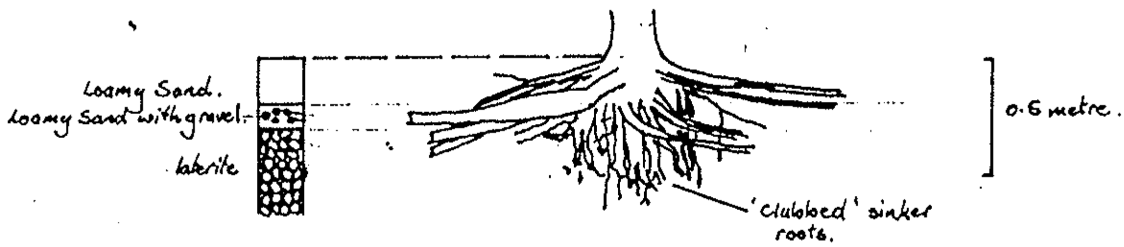
(initials) 9/3

Root Excavations

The roots of six trees were examined. Three of the trees were growing on unripped soil, the others on ripped soil. Two of the trees were leaning. Descriptions were made of the soil profile around each tree.

There was generally a layer of loamy sand of 20 to 40cm depth overlying a laterite layer. The roots of the pine were well developed in the loamy sand but were impeded by the laterite (Figure) Small "club" roots had formed at the surface of the laterite (see photograph). This trial, and other work at Jarrahwood suggest physical impedance is more important than waterlogging in the root development of radiata pine in the Sunkland.

Fig. The structure of the roots of P. radiata growing on a site with a limited depth of soil in the Sunkland.



Spacing of P. radiata - Jarrahwood 1974

File No. 232.423

This unreplicated trial aimed to determine the optimum spacing to commercially harvest *P. radiata* in the Sunkland. Four spacings were tested;

Spacing	Density	Actual density
3x3 m	1111	1038
2x4 m	1250	1114
2x3 m	1667	1421
2x2 m	2500	2175

The pine was planted in 1974 and presumably spot fertilized with 100g/tree of Super. The plots were re-fertilized in 1979 and 1980 with 400kg/ha of Agras and Zn & Cu sprays. The 2x3, 2x4 and 3x3 plots were ploughed, fertilized with 500kg/ha SuCuZnMo No. 2 and sown with 12kg/ha of Esperance clover in 1980.

The wider spacings gave the greater diameter growth for individual trees but lower basal area per hectare. The growth of the trees in all treatments was low compared to other plantations. This reflects the poor fertilizer history of the trial.

The trees at 2x4 m spacing performed better than expected. This is probably due to a site difference within the area of the trial.

The establishment of clover improved the growth of the pine in the three plots compared to the plot which was not treated. The clover sward was very poor so ploughing and the application of Super were probably the main causes of this response.

Fig. Diameter growth of P. radiata with age at various spacings

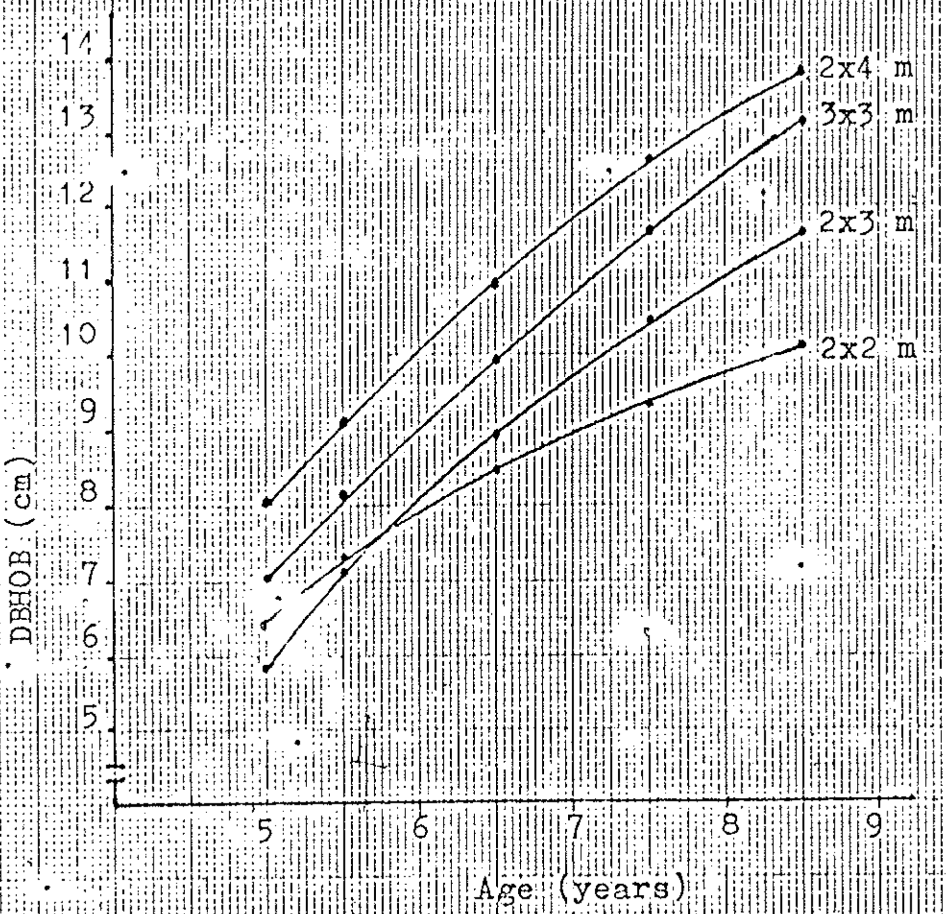
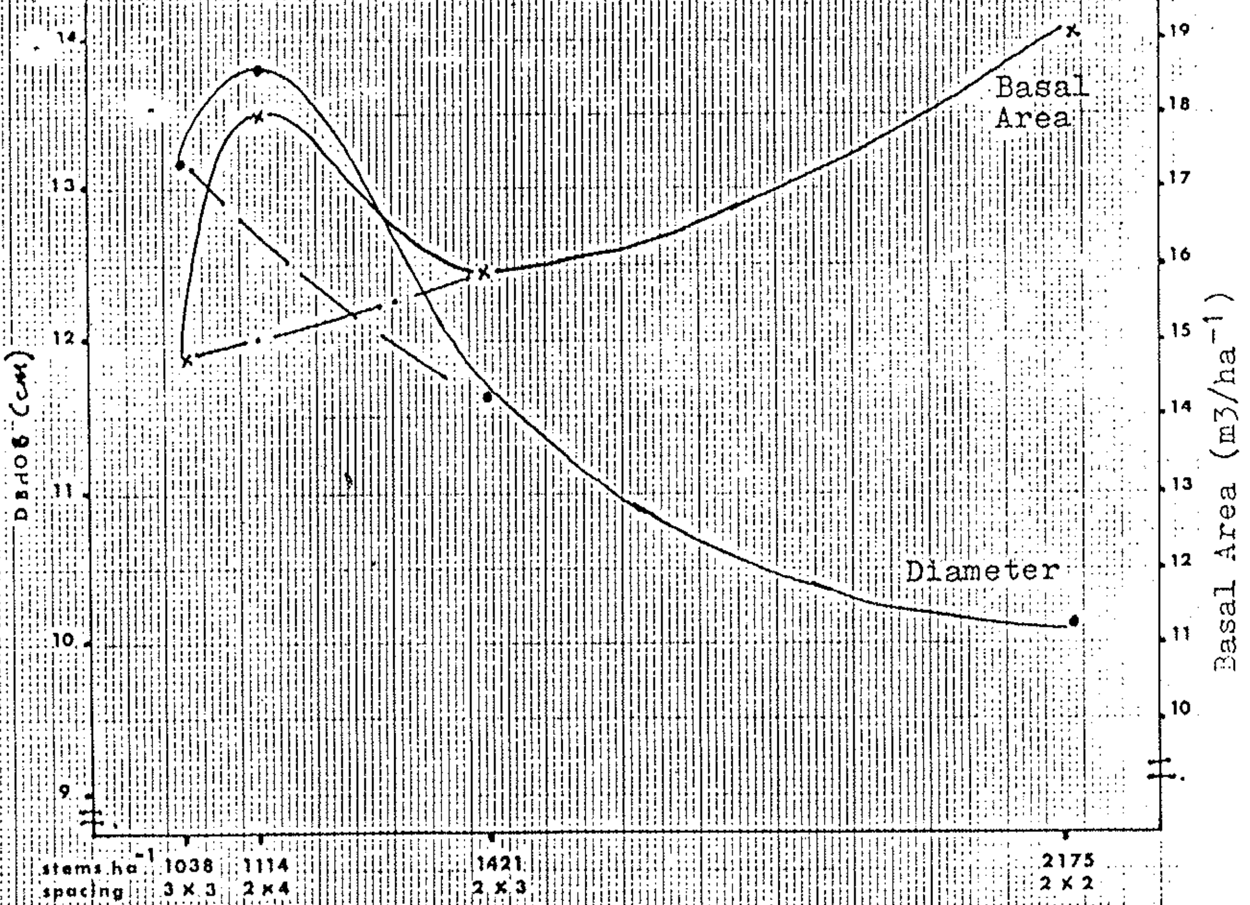


Fig. Growth of 8½ year old P. radiata at various spacings



EUCALYPT SPACING TRIAL

W.P. 9/75 File No. 232.424H

This trial was to determine the effect of stocking rate on the growth of some eucalypt species grown in the Sunklands. Eucalyptus resinifera was planted in 1975 and E. calophylla, E. micrQcorys and E. globulus in 1976. The trees were planted at spacings of 3 x 0.5m, 3 x 1m, 3 x 2m, 3 x 3m, 3 x 4m, and 3 x 6m.

The trial was not replicated, with height and diameter data being collected from every 5th row in each plot. Trees were measured 7 years after outplanting for E. resinifera and 6 years for the other species.

There was no obvious relationship between height and stocking rate. (FIGURE 1). E. globulus was the tallest and E. microcorys the shortest.

Basal area hectare^{-1} increased with stocking rate for all species (FIGURE 2). For any given stocking rate, E. calophylla had the greatest B.A ha^{-1} and E. microcorys the lowest.

E. globulus had a larger height/diameter ratio than E. calophylla. Survival rate for E. calophylla was approximately 60%, with other species being in the order of 90%. This may be due to site differences.

Of the species assessed, E. globulus and E. calophylla showed the best potential for use in the Sunklands. These species growing at high stocking rates could produce pulpwood volume comparable with Pinus radiata, but it is premature to determine other uses such as sawlogs and poles.

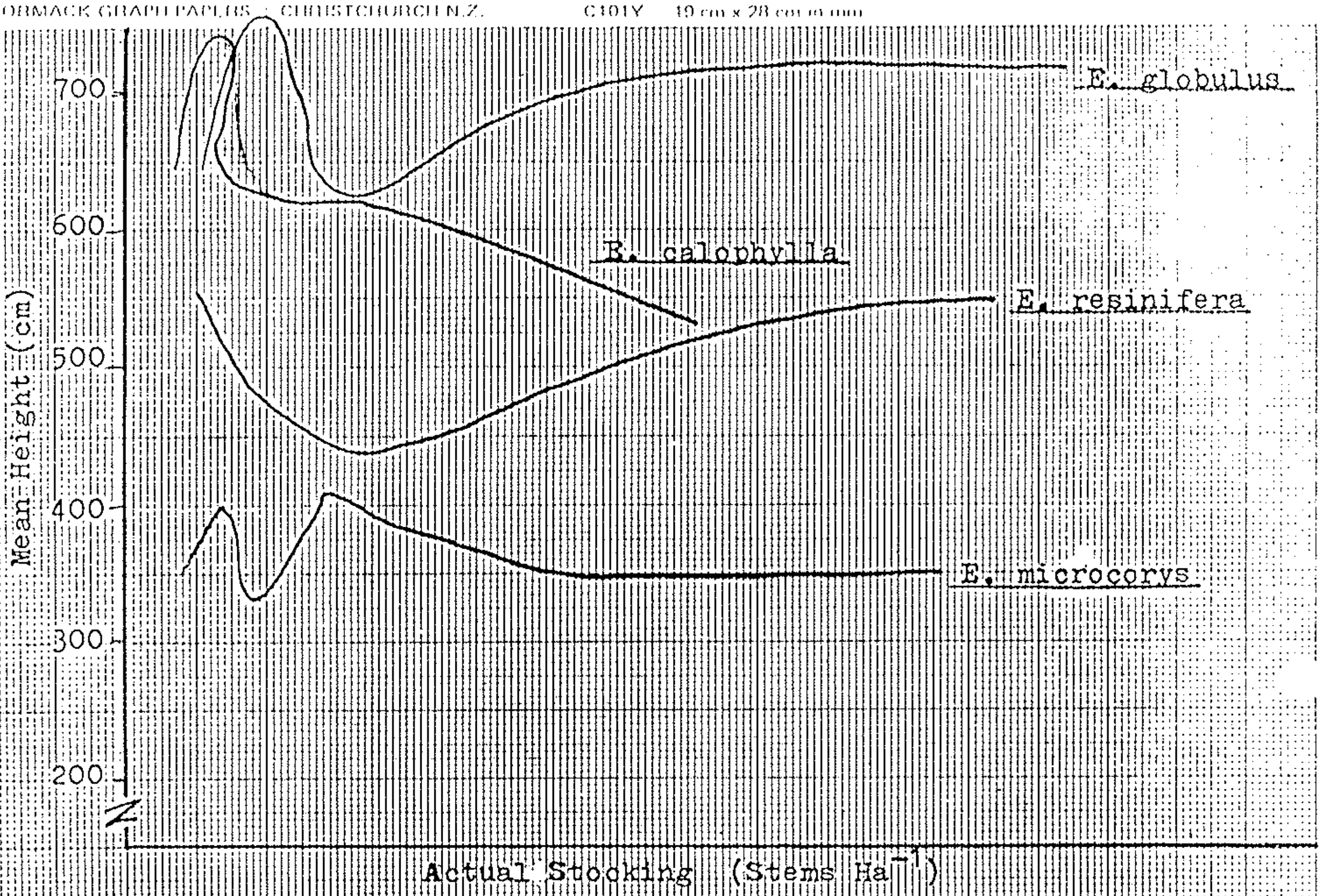
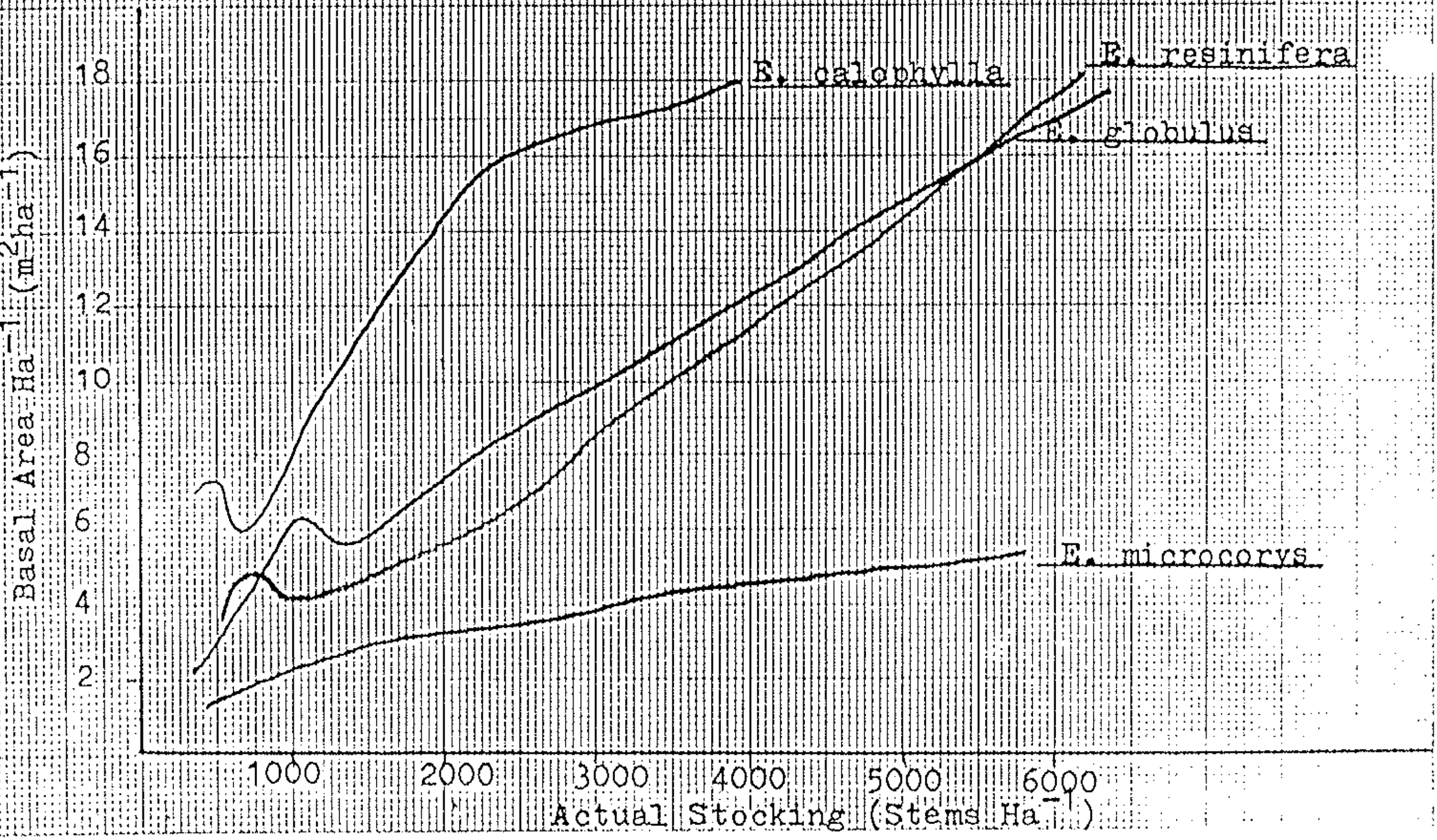


FIGURE 1: Effect of stocking rate on mean tree height 6 years after out planting (7 years for E. resinifera).

FIGURE 2: Effect of stocking rate on basal area ha^{-1} 6 years after outplanting (7 years for E. resinifera).



WETTING AGENTS FOR ESTABLISHING *P. radiata* D. DON IN BASSENDEAN SANDS

File No.: 232.294

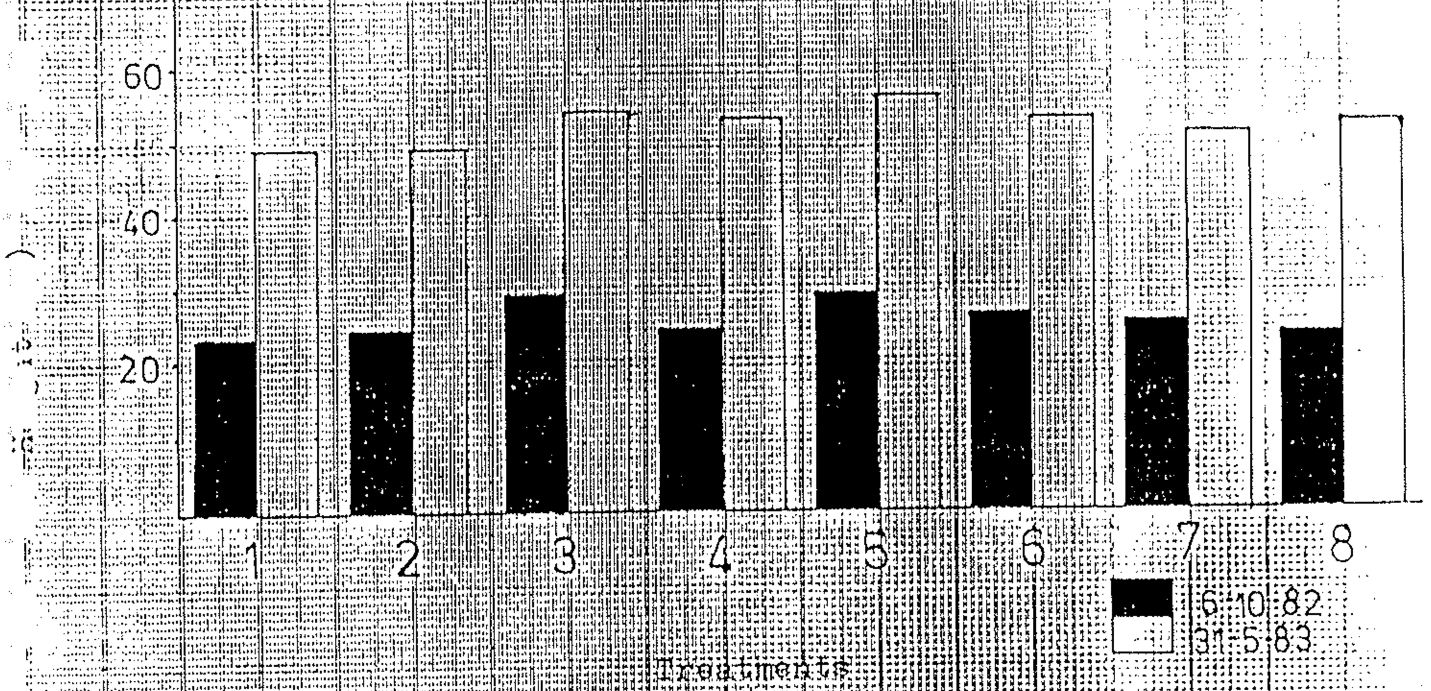
From previous research, second rotation burning on Bassendean sands causes water repellance which may have a detrimental effect on pine seedling growth. This trial was to investigate whether the application of a wetting agent increased growth and survival rate of *P. radiata* on this water repellant soil.

Designed as a randomized block arrangement, the trial consisted of eight treatments (see key, Figure 1) with three replicates. Treatments consisted, in all cases of backfill soil mixed with the wetting agent, except in one where the roots were dipped in wetting agent before planting. Three different wetting agents were used, (Terrasorb 600) (Igetagel) and (Klen RF68) at two different rates. Plots were 3m x 20m and contained approximately 10 treated seedlings. Each seedling was measured for height and survival in Spring 1982 and Winter 1983.

Results, to date, show no significant increase in seedling growth by using any of the wetting agents. The survival rate in four of the treatments was significantly lower than in the control. These four treatments were roots dipped in Terrasorb 600 and both rates of Terrasorb 600 and 20g of Igetagel in backfilled soil.

These results indicate wetting agents do not increase *P. radiata* growth and they can have a detrimental effect on survival. Therefore wetting agents should not be used operationally.

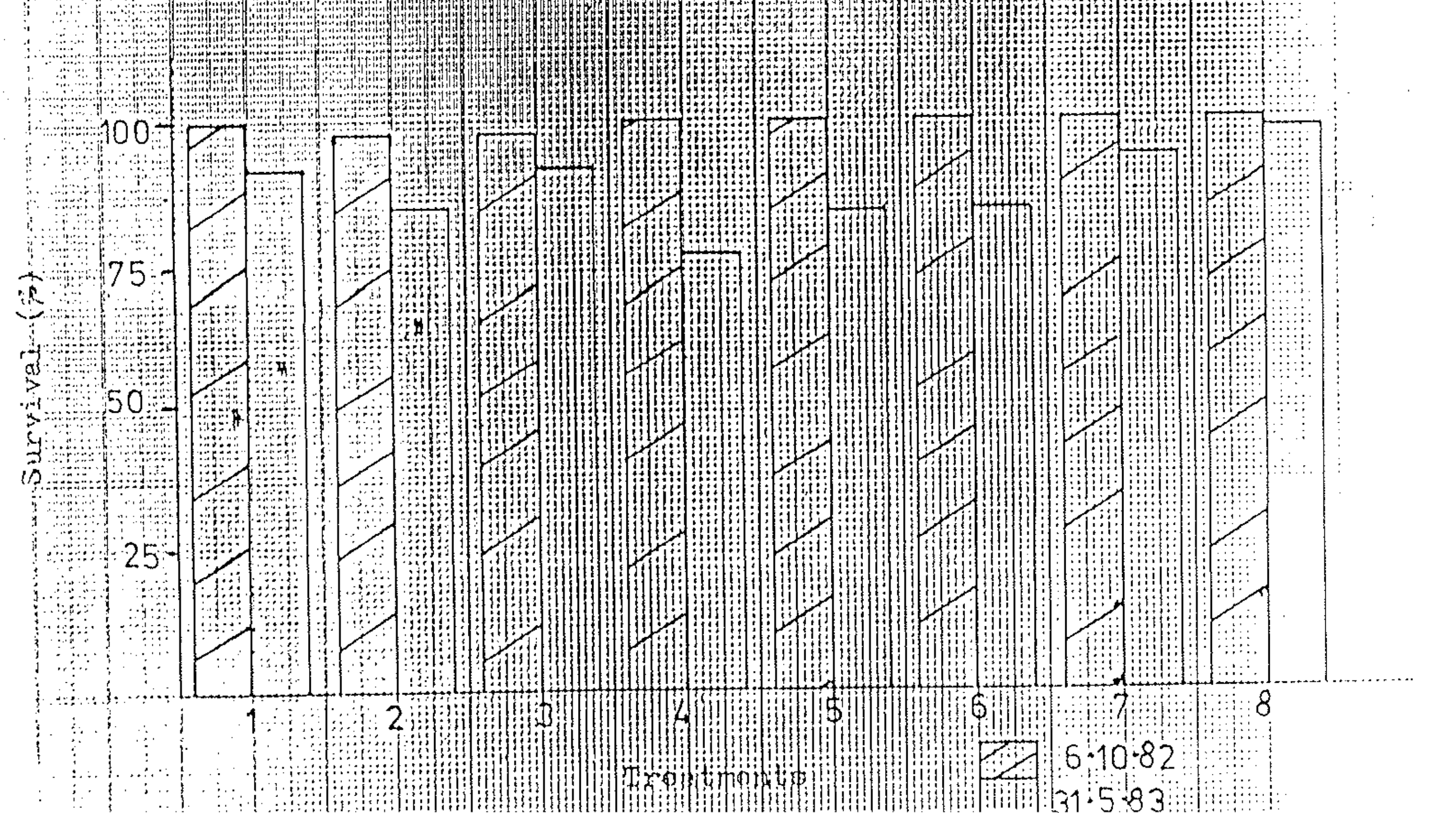
FIGURE 1: Height growth of *P. radiata* on Bassendean sands in response to wetting agents.



KEY (TREATMENTS)

1. Control
2. Terrasorb 600 (roots dipped)
3. 5g Igetagel (in back filled soil
4. 20g Igetagel (in back filled soil
5. 5g Terrasorb 600 (in back filled soil)
6. 20g Terrasorb 600 (in back filled soil)
7. 0.2ml Klen (in back filled soil)
8. 2ml Klen (in back filled soil)

FIGURE 2: Survival (percentage) of *P. radiata* on Bassendean sands in response to wetting agents.



SPOT APPLICATION OF "VELPAR" AS A MEANS OF CONTROLLING *E. calophylla* REGROWTH IN SUNKLAND PINE PLANTATIONS

W.P. 1/80 File No. 243/22

"Velpar L" (a liquid formulation containing 250 $gm.l^{-1}$ of hexazinone) and "Velpar 20G" (a granular formulation containing 200 $gm.kg^{-1}$ of hexazinone) were evaluated for efficacy in controlling *E. calophylla* on yellow sandy loams in the Donnybrook Sunklands. Designed as a factorial arrangement, the trial consisted of three rates of each formulation administered to the surface of the soil as a spot application and repeated over two seasons. "Velpar L" was also injected into the soil at the same rates. The effect on two height classes of regrowth was also studied and the trial was replicated twice. Treatments were delivered through modified sheep drenching guns. There was an inconsistency between the seasons in respect to the placement of the chemical in relation to stem of the regrowth. In the summer series the "Velpar" was placed approximately 10cm away from each stem, while in the winter series the point of placement corresponded to the drip line. Rainfall for 1980 can be seen in TABLE 1.

Treatment in summer proved to be more effective than treatment in winter and small regrowth ($<$ 2.0m in height) was more easily killed than larger regrowth ($>$ 2m in height). The highest rates of treatment generally gave the best results (Figures 1 & 2). There was no evidence to suggest that any differences existed between formulations of "Velpar" or the method of placement. The better result of the summer treatment may be due to abnormal rain in February which allowed penetration of the chemical into the roots at a time when the metabolic rate of regrowth is high.

To achieve an acceptable kill it appears that regrowth must be treated when it is below 0.5m in height (See FIGURE 3) and 4ml (1.0gm, a.i.) of "Velpar L" (or 5gm (1.0gm.,a.i.) of "Velpar 20G") should be placed close to the stem of the regrowth. However, this technique is not as cost effective as treatment of regrowth by foliar spraying with either "Roundup" or "Tordon 5-15H".

TABLE 1

Months	J.	F.	M.	A.	M.	J.	J.	A.	S.	O.	N.	D.
mm	0.8	23.2	6.3	81.7	75.8	160.8	223.8	78.1	70.2	34.7	20.2	15.8

Table 1: Rainfall (Busselton) for the year 1980.

FIG. 1

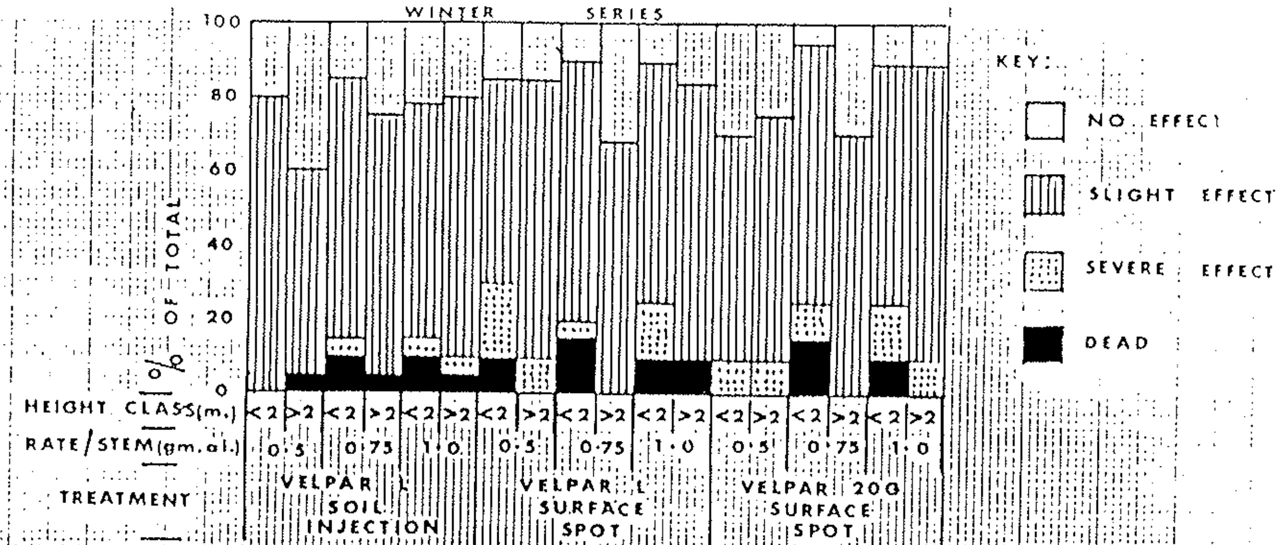
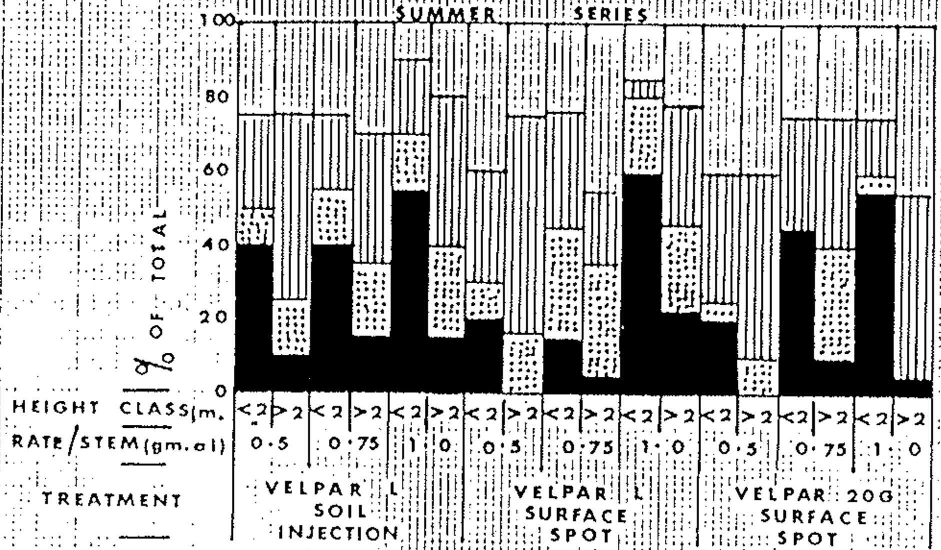


FIG. 2



Figs. 1 & 2: Efficacy of "Velpar" twelve months after the treatment of _E. calophylla_ on yellow sandy soils in the Donnybrook Sunkland.

FIG. 3

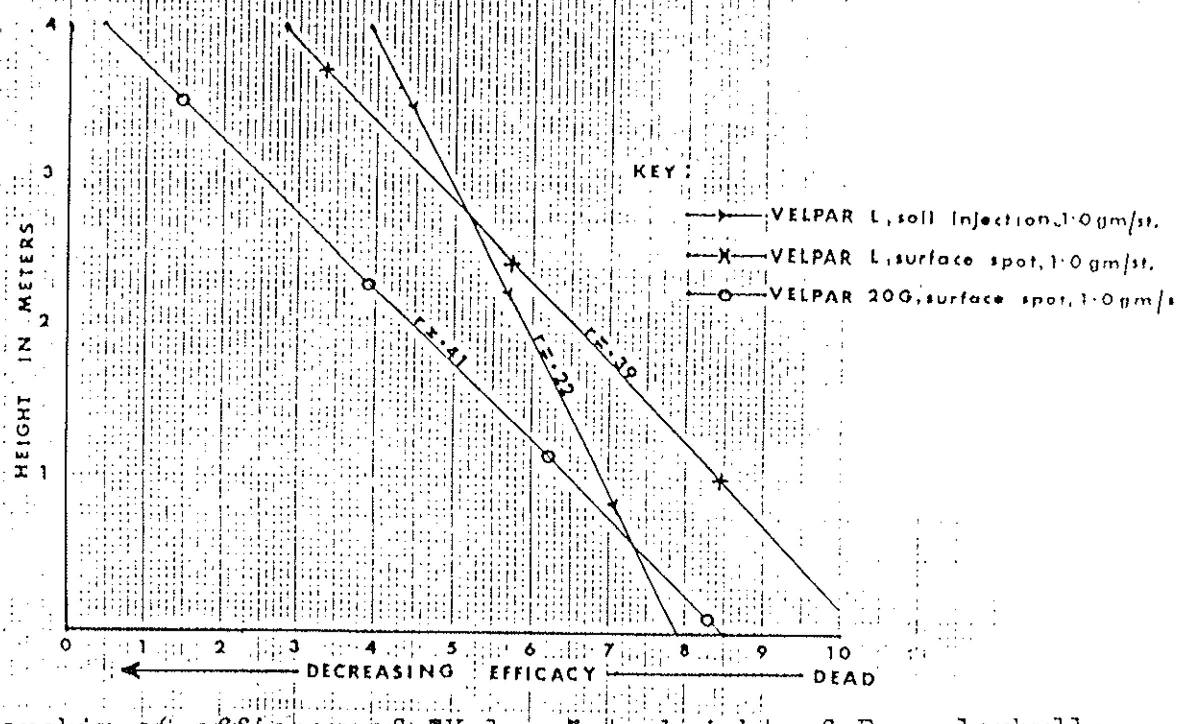


Fig. 3: Relationship of efficacy of "Velpar" to height of _E. calophylla_ regrowth on yellow sandy soils in the Donnybrook Sunklands.

The Use of "Velpar L" and "Velpar 20G" to Control Scrub in Recently Planted *P. radiata*

R.W.P. 25/80 File No. 243.23

The aim of the trial was to determine if "Velpar L" (250 $gm.l^{-1}$ hexazinone) and "Velpar 20G" (200 $gm.l^{-1}$ hexazinone) were suitable for controlling woody weeds in recently planted *P. radiata* plantations.

The experiment was located in Baudin plantation, compartment 11 and was designed as a randomised block with 4 replicates of the following 7 treatments.

(1) Total cover of "Velpar L" sprayed at 1.25 $kg.ha^{-1}$ a.i.(5 $l.ha^{-1}$)
(2) " " " " " " 2,50 $kg.ha^{-1}$ a.i.(10 $l.ha^{-1}$)
(3) " " " " " " 3.75 $kg.ha^{-1}$ a.i.(15 $l.ha^{-1}$)
(4) "Velpar 20G" broadcast at 1.25 $kg.ha^{-1}$ a.i.(5 $kg.ha^{-1}$)
(5) " " " " 2.50 $kg.ha^{-1}$ a.i.(10 $kg.ha^{-1}$)
(6) " " " " 3.75 $kg.ha^{-1}$ a.i.(15 $kg.ha^{-1}$)
(7) Control - no herbicide treatment.

"Velpar L" (liquid) was applied using a pressurised hand held boomspray. Output was 225 $l.ha^{-1}$. "Velpar 20G" (granules) was applied in strips down and across plots using "pepper pot" applicators. Pines were not deliberately avoided. Treatments were applied in November 1980.

"Velpar L" was consistantly more effective than "Velpar 20G" at controlling woody weeds (Table 1). There were no significant differences in efficacy between the rates of "Velpar L". However the lowest rate of "Velpar 20G" was significantly less effective than the higher rates, and there was no significant difference between it and the control.

Survival was not effected in any of the herbicide treated plots, although 30% of trees in plots receiving the highest rate of "Velpar L" showed symptoms of phytotoxicity. Two years after treatment trees in plots that were treated with each of the formulations of "Velpar" were significantly taller than trees in the control plots (Table 2). Similarly, diameters (D.B.H.O.B.) of trees in all treated plots were significantly larger than those of the control (Table 2). The absence of a mechanically maintained weed free treatment precludes the possibility of seperating the effect of weed control from hexazinone. There was no increase in diameter growth above 2.5 $kg.ha^{-1}$ a.i. and there was some evidence to suggest that a reduction of growth may occur above this rate (Figure 1). The increase in tree volume attributable to spraying with "Velpar L" at 5 l.ha-1 was 1.5 $m3.ha^{-1}$ (388%) over the first two years. The current cost to apply "Velpar L" at 5 $l.ha^{-1}$ (approx. \$120 $.ha^{-1}$) when compounded over a 30 year rotation and applying present timber values, indicates that an approximate 30 $m3.ha^{-1}$ increase is necessary to make weed control economic. As most literature suggests a diverging growth curve that favours trees that received weed control, a growth advantage exceeding 30 $m3.ha^{-1}$ is highly likely.

.../2

Table 1.

	"VELPAR L" (plants .m2^{-1})							"VELPAR 20G" (plants .m2^{-1}					
	Ctrl Plts m2^{-1}	1.25 kg.ha^{-1} a.i		2.5 kg.ha^{-1} a.i		3.75 kg.ha^{-1} a.i		1.25 kg.ha^{-1} a.i		2.5 kg.ha^{-1} a.i		3.75 kg.ha^{-1} a.i	
Ag. parviceps	2.8	0	*	0.4	N.S	0.4	N.S	0	*	0.4	N.S	0	*
Ag. linearis	0	0	N.S	5.6	N.S	0	N.S	4.8	N.S	1.4	N.S	0.4	N.S
Ac. mooreana	3.2	0.4	***	0.2	***	0	***	2.6	N.S	1.2	**	0.2	***
Lept. ellipticum	8.2	1.0	*	0	**	0.2	**	15.0	N.S	3.0	N.S	1.0	*
B. spathulata	4.6	0.6	***	1.0	***	0.8	***	5.0	N.S	6.0	N.S	6.9	N.S
% total cover	49.8	12.2	***	11.9	***	8.8	***	41.8	N.S	20.8	**	14.2	***

Efficacy of "Velpar L" and "Velpar 20G" on 5 major woody weed species in the Donnybrook Sunklands.

* significantly different to the control at p 0.05
** " " " " " " p 0.01
*** " " " " " " p 0.001

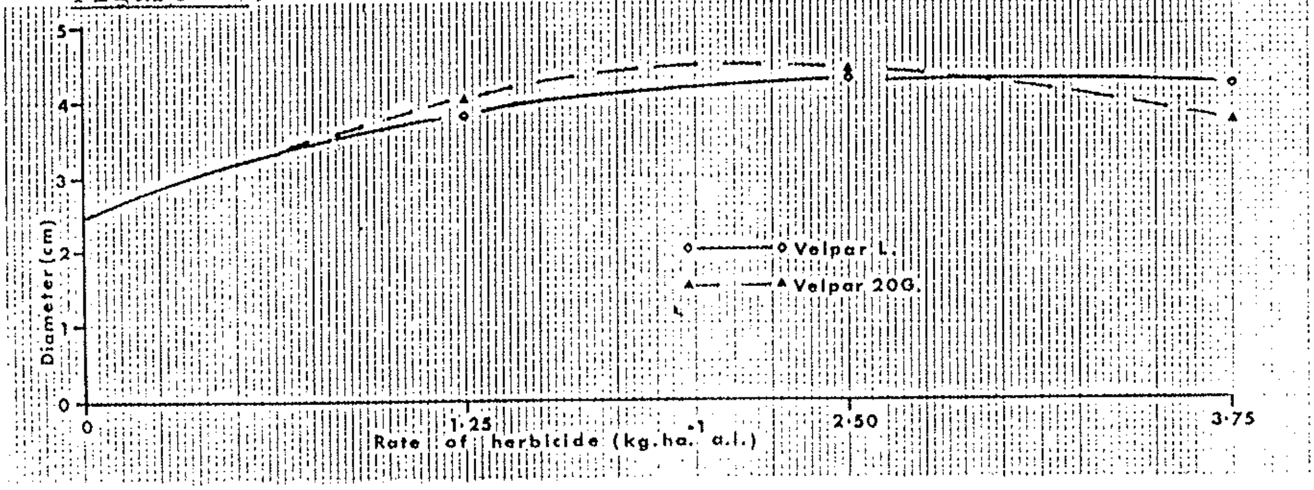
Table 2.

Treatment	Height(m) at age 2.5	DBHOB(cm) at age 2.5
Control	246	2.45
"Velpar L" 1.25 kg.ha^{-1} a.i.	306 **	3.78 *
"Velpar L" 2.50 kg.ha^{-1} a.i.	312 **	4.29 **
"Velpar L" 3.75 kg.ha^{-1} a.i.	319 ***	4.20 **
"Velpar 20G" 1.25 kg.ha^{-1} a.i.	292 *	3.98 **
"Velpar 20G" 2.5 kg.ha^{-1} a.i.	332 ***	4.37 ***
"Velpar 20G" 3.75 kg.ha^{-1} a.i.	300 **	3.71 *

The effect on the growth of P. radiata by applying "Velpar L" and "Velpar 20G", over the top, 5 months after planting.

* significantly different from the control at p 0.05
** " " " " " " p 0.01
*** " " " " " " p 0.001.

Figure 1.



D.B.H.O.B. of 2 year old P. radiata 19 months after applying "Velpar L" and "Velpar 20G".

The Control of Eucalypt Regrowth by Stem Injection with "Roundup"

R.W.P. 2/82 File No. 243.28

Located in Jarrahwood plantation, compartment 5, this trial was established in January 1982 to determine the minimum dose of "Roundup" (360 gm.l^{-1} glyphosate), administered as an injection to the stem, that is required to kill E. calophylla and E. marginata.

The trial was arranged as a randomised block with four replications. Treatments were applied in the following concentrations of chemical in water:

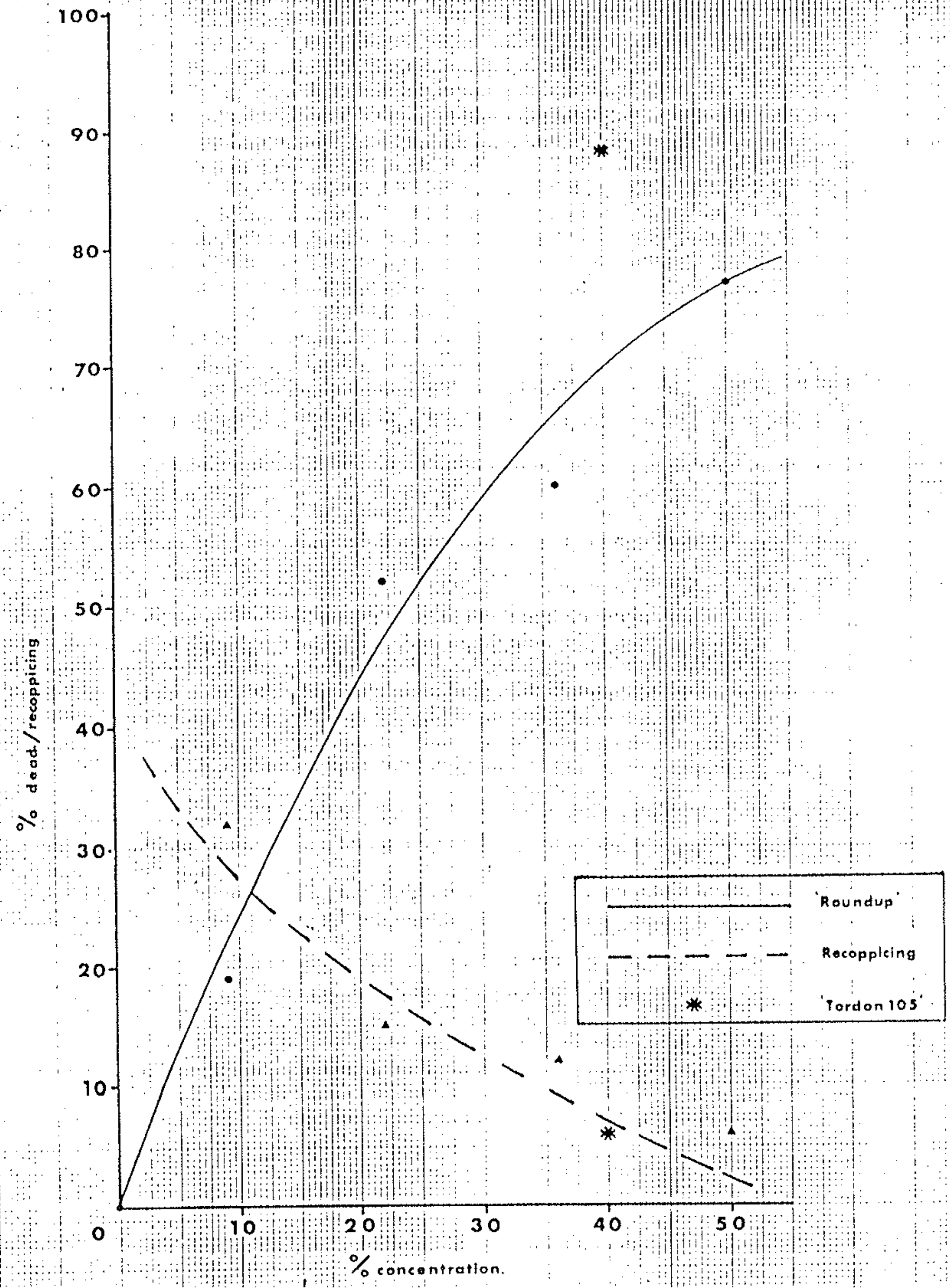
"Roundup"; (1) 50%
(2) 36%
(3) 22%
(4) 9%
"Tordon 105" (5) 40% (routine practice at the time)

Injection of the mixtures was achieved by notching the stems of the regrowth using a 25mm wide axe. Notches were placed at a convenient height (for the operator) on the stem and this ranged from 400 to 800mm from the ground. A 2ml dose of mixture was delivered into each notch through a drenching gun, and the dose frequency was one notch for every 25mm of stem diameter. The height of regrowth ranged from 1.5 to 3.5 metres, and stem diameters ranged between 20 and 100mm.

Twelve months after treatment there were significantly ($p < .05$) more deaths associated with the 50% concentration of "Roundup" and the 40% concentration of "Tordon 105" (figure 1). The incidence of recoppicing increased as the concentration of "Roundup" decreased. It was notable that mortality increased, irrespective of concentration, if the point of injection was close to ground level or below the lowest green branch. If this criterian is followed it is likely that the percentage mortality would increase for the lower concentrations. However, injecting regrowth close to the ground is likely to increase stress on operators and may not be a practical proposition. There was no apparent difference in susceptibility between E. calophylla and E. marginata.

It is recommended that a 40% concentration (1 part "Roundup" to 1½ parts water) be used for the treatment of eucalypt regrowth by the stem injection technique.

Figure 1 Percentage of dead and recoppicing eucalypt regrowth twelve months after stems were injected with "Roundup" and "Tordon 105".



<u>Operational Evaluation of "Roundup" (glyphosate) and "Banvel" (dicamba) to control eucalypt regrowth by the stem injection technique.</u>

R.W.P. 3/82 File No. 243.27

Established in January 1982 in Jarrahwood plantation, compartment 5, this trial aimed to compare the effect of "Roundup" (glyphosate), "Banvel" (dicamba) and the currently used "Tordon 105" (2,4,5-T/Picloram) applied at equivalent cost over an operational area.

Treatments were:

(1) "Roundup" - 1 part "Roundup" to $1\frac{3}{4}$ parts of water (36% concentration); cost: $0.0126 per notch,

(2) "Banvel" - 1 part "Banvel" to $\frac{1}{2}$ part of water (66% concentration); cost: $0.0120 per notch,

(3) "Tordon 105" - 1 part "Tordon 105" to $1\frac{1}{2}$ parts of water (40% concentration); cost: $0.0126 per notch.

Three 1.5 hectare plots were located adjacent to each other, and all eucalypt regrowth was treated in an identical way; viz.: notching using a 25mm wide axe was at a convenient height on the stem (ranging between 400 and 800mm from the ground), and one notch was cut for every 25mm of stem diameter. Each notch received 2ml of the chemical mixture, delivered through a drenching gun. The height of regrowth ranged between 0.5 and 3.5 metres, and where it was too small to notch (< 20mm stem diameter), stems were severed and the chemical administered to the stump. The same members of an operational gang treated each area.

The table below shows the percentage of regrowth that was dead, the percentage that initially appeared dead (at the 6 month assessment) but had subsequently recoppiced after 12 months, and those that were partially effected twelve months after treatment.

	% dead 12 months after treatment	% recoppicing 12 months after treatment	% showing partial effect 12 months after treatment
"Roundup"	64	11	25
"Banvel"	36	25	39
"Tordon 105"	51	21	28

"Banvel"does not appear to be a suitable chemical for controlling eucalypt regrowth by stem injection. While the percentage of regrowth stools that were killed by "Tordon 105" and "Roundup" appears to be low, it is higher than is achieved in routine practice using "Tordon 105" at a 40% concentration. Assessments have shown that this is between 15 and 50%. A higher percentage of kill is likely if the point of injection is as close to the ground as possible or below the first green branch. These results indicate that "Roundup" is more cost effective than "Tordon 105".

Optimum Concentration of "Roundup" and "Tordon 5-15G" to Control Eucalypt Regrowth by the Foliar Spray Method

Interim Summary

R.W.P. 46/82 File No. 243.322

Foliar spraying is seen a technique that will enable the control of eucalypt regrowth in plantations to be commenced soon after pines are planted. It is envisaged that this will have two advantages: (1) eucalypt regrowth will be eliminated before any competitive effect on the growth of pines develops, and (2) the cost of controlling eucalypt regrowth will be reduced.

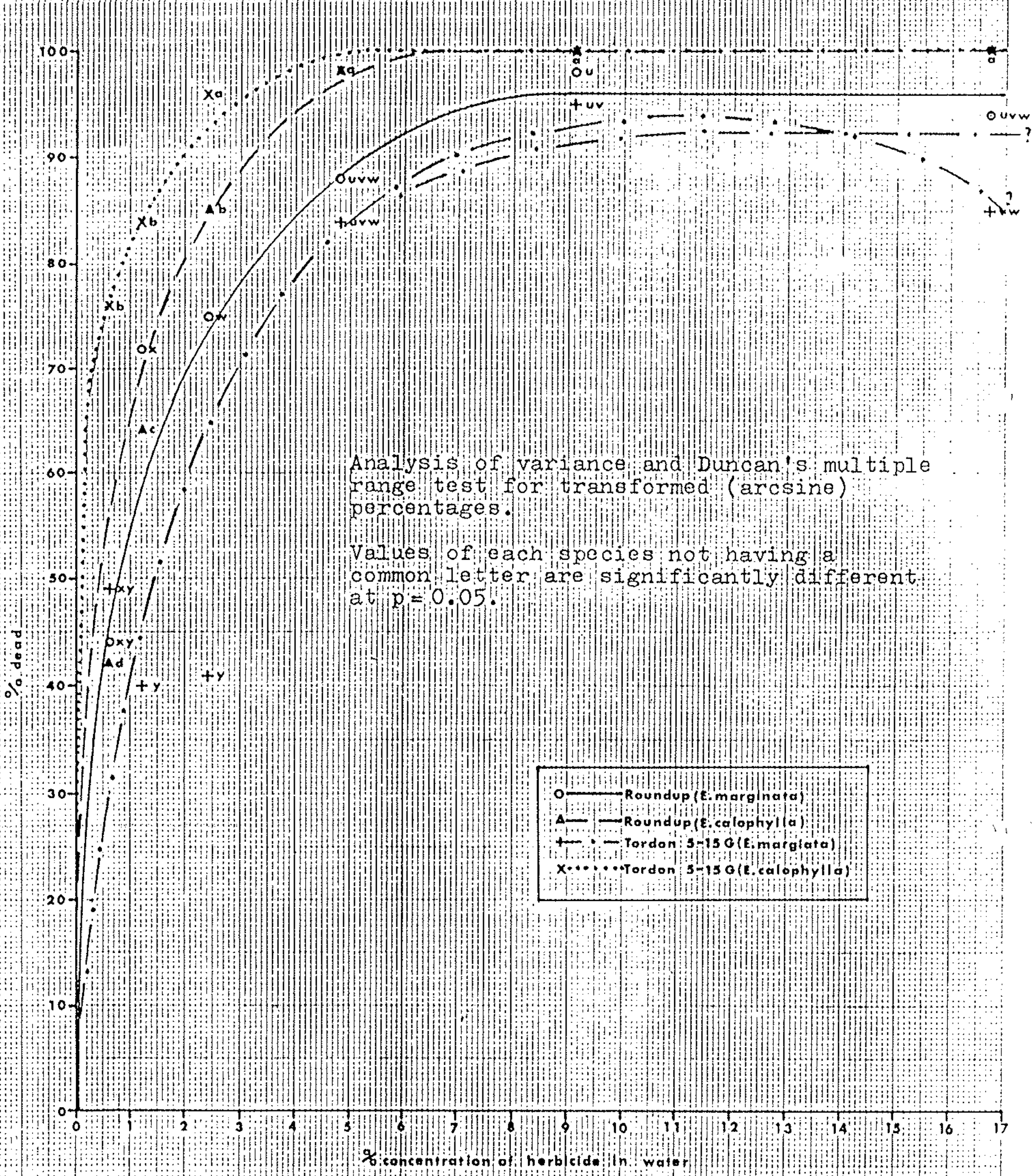
A trial was established in Baudin plantation, compartment 9, where "Roundup" (360 $gm.l^{-1}$ glyphosate) and "Tordon 5-15G" (150 $gm.l^{-1}$ triclopyr and 50 $gm.l^{-1}$ picloram) were compared at the following spray concentrations of herbicide in water: 16.7%, 9.1%, 4.8%, 2.4%, 1.2%, 0.6%, o (control). The trial was arranged as a randomised blockwith 4 replicates. Treatments were applied at the beginning of December 1982 and herbicide mixtures were sprayed onto regrowth, ensuring complete coverage, using drench guns fitted with Rega No. 6 variable nozzles. The drench guns were calibrated to deliver 5 ml per dose and the number of doses per stool was recorded. The height of regrowth ranged between 100 mm and 1000 mm.

After 40 days "Tordon 5-15G" appeared to be significantly less effective against E. marginata and more effective against E. calophylla than "Roundup". An assessment 225 days after treatment showed that there were no significant differences ($p < 0.05$) between the effectiveness of "Tordon 5-15G" and "Roundup" against E. calophylla at concentrations above 5% (figure 1). Below this level "Tordon 5-15G" was more effective. To control E. calophylla the optimum concentration of "Tordon 5-15G" appears to be 4.8% (cost $\$0.73.l^{-1}$), while for "Roundup" it appears to be 6.25% (cost $\$1.05.l^{-1}$). "Tordon 5-15G" is less effective against E. marginata than "Roundup" although the percentage of dead stools had increased since the first assessment. The optimum concentration of "Roundup" to control E. marginata is 8% (cost $\$1.35.l^{-1}$) while for "Tordon 5-15G" it is 10% (cost $\$1.51.l^{-1}$). Costs are based on the following prices as at July 1983: Roundup $\$16.86.l^{-1}$; Tordon 5-15G $\$15.11.l^{-1}$.

Figure 1.

W.P. 46/82 Optimum concentration of 'Roundup' and 'Tordon 5-15G' to control eucalypt regrowth by the foliar spray method.

Assessment 225 days after treatment.



Scrub control in a *P. radiata* plantation

This experiment was to investigate the effect of the season, and rate, of a herbicide spray in controlling dense scrub in a one year old *P. radiata* plantation.

Four rates of a 245-T ester spray were applied; 0.1%, 0.2%, 0.3% and 0.4% active ingredient. A control, where no chemical was applied, was included. The main target species was *Bossiaea aquilifolium* which had formed a dense understorey. Three times of application were tested; September, November and February.

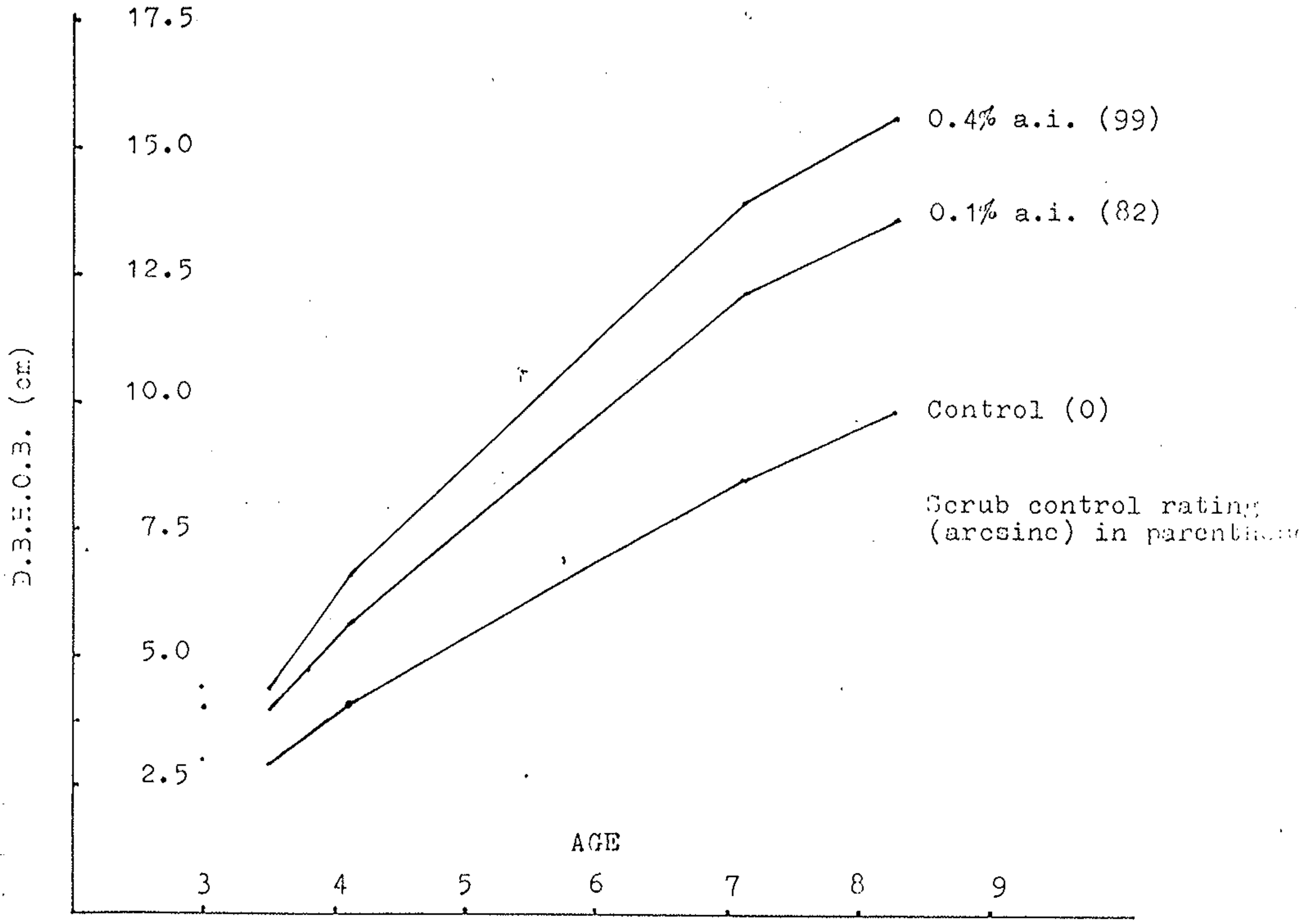
A 0.4% a.i. spray in September gave the most effective scrub control (Table 1). This lead to a 60% increase in diameter over the control by age 8 years (Figure 1). A 0.1% a.i. spray in September while achieving a high level of scrub control (Table 1) did not lead to as large a pine growth response as the 0.4% a.i. spray.

This trial indicates that complete scrub control on these sites is desirable to promote pine growth.

TABLE 1 Scrub mortality (arcsine value) resulting from 245-T ester spray treatments

Treatment	Month of application		
	September	November	February
Control	0	0	0
0.1% a.i.	82	65	7
0.2% a.i.	75	75	22
0.3% a.i.	88	88	27
0.4% a.i.	99	84	63

FIGURE 1 Response of *P. radiata* to scrub control by the application of 245-T ester sprays. Treatments applied in September.



The Tolerance of P. radiata and Various Eucalypts to Pre-plant Herbicides

R.W.P. 19/79 File No. 243.131

Located on sandy soil in Vasse Plantation, compartment 10, this trial was to screen soil active pre-plant herbicides, of the triazine group, in respect to their effect on the crop tree species.

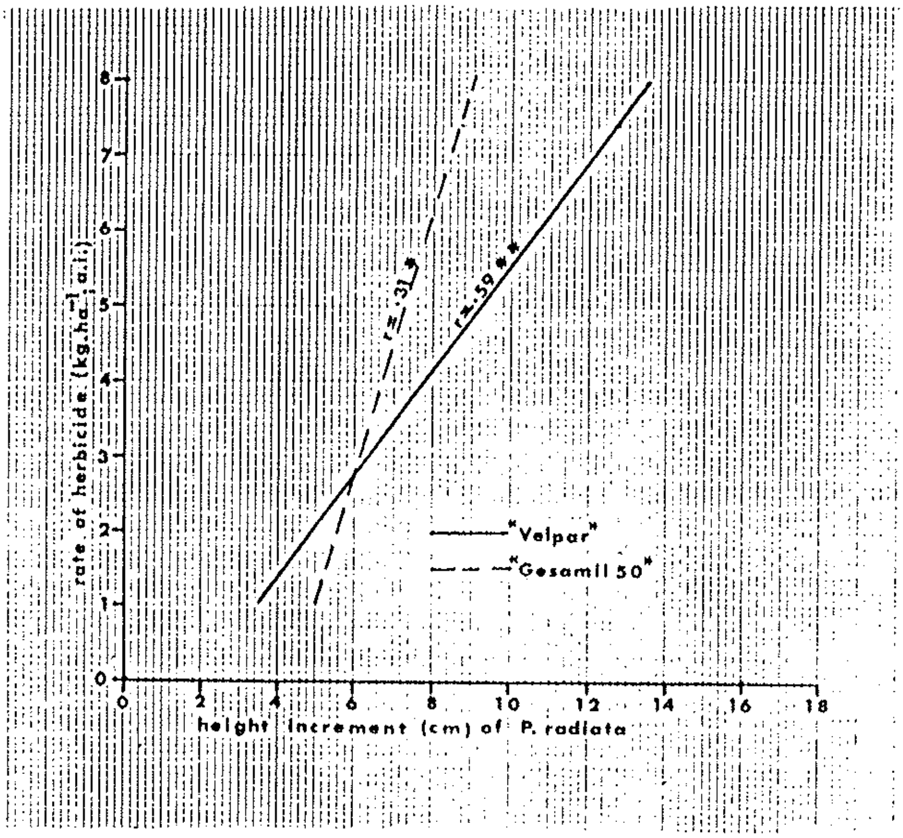
The site was ploughed and smoothed prior to spraying the following herbicides, using a "Fision's" mini-log sprayer:

(1) Gesaprim 80 (800 $gm.kg^{-1}$ atrazine)
(2) Gesamil 50 (500 $gm.kg^{-1}$ propazine)
(3) Gesatop 80 (800 $gm.kg^{-1}$ simazine)
(4) Velpar (900 $gm.kg^{-1}$ hexazinone)

The commencing spray rate, for each herbicide, was equivalent to 8.0 $kg.ha^{-1}$ of active ingredient. _P. radiata_, _E. globulus_, _E. rudis_, _E. camanldulensis_, _E. cladocalyx_, _E. wandoo_ and _E. calophylla_ were represented by one line in each plot. The distance between plants, within the line was 1.0m while lines were 0.15m apart. Each plot consisted of 24 trees and was replicated 3 times. All plots were sprayed on the 28th August 1979 and trees were planted on the following day. The output of the sprayer was 133 $l.ha^{-1}$. Heights of trees was measured 12 days after planting and again 170 days later.

An assessment 47 days after planting revealed that "Velpar" was toxic of all the eucalypts throughout the range of application rates (0.75 $kg.ha^{-1}$ to 8.0 $kg.ha^{-1}$). _P. radiata_ was not effected by "Velpar" nor was there any phytotoxic effect apparent on any species attributable to the other herbicides. After 170 days, survival was lower where "Gesatop" had been applied at rates above 5.0 $kg.ha^{-1}$, in respect to most eucalypts, and above 5.0 $kg.ha^{-1}$ for _P. radiata_. This was especially so for _E. cladocalyx_ where survival was significantly less ($p < 0.01$) than the control. Likewise, "Gesaprim" at rates above 5.0 $kg.ha^{-1}$ was responsible for lower survival of _E. globulus_ ($p < 0.05$), _E. cladocalyx_ ($p < 0.05$) and _E. calophylla_ ($p < 0.001$). "Gesamil" had no effect on survival or height growth of the eucalypts. However, there was a positive correlation ($p < 0.05$) between rates of "Gesamil" and height increment of P. radiata (Figure 1). There was also a strong correlation ($p < 0.01$) between the rate of "Velpar" and height increment of P. radiata (Figure 1). There was no correlation between the height increment of the eucalypts and rate of any herbicide with the exception of "Velpar". "Gesaprim" and "Gesatop" did not significantly influence the height growth of P. radiata.

Figure 1. Correlation between the height growth of P. radiata, 170 days after planting, and the rate of "Velpar" and "Gesimal 50" applied the day before planting.



The Tolerance of P. radiata to Different Herbicides

R.W.P. 31/82 File No. 243.31

Located on yellow sands in Vasse plantation, compartment 1, this trial was established to determine the level of tolerance of P. radiata to an over-spray of different herbicides applied in 3 different seasons.

Designed in a factorial arrangement, the trial comprised 10 single-tree replicates of the following treatments applied in October, February and April:

1) "Banex" (200 $gm.l^{-1}$ dicamba) at 1, 2 and 4 $l.ha^{-1}$ of product.
2) "Garlon 480" (480 $gm.l^{-1}$ triclopyre) at 2.8, 5.5 and 11 $l.ha^{-1}$ of product.
3) "D-50" (500 $gm.l^{-1}$ 2,4-D amine) at 1, 2 and 4 $l.ha^{-1}$ of product.
4) 2,4-DB Herbicide (397 $gm.l^{-1}$ 2,4-DB) at 1.5, 3.6 and 6 $l.ha^{-1}$ of product.
5) "Farmco TA 20" (200 $gm.l^{-1}$ 2,4,5-T amine) at 2.8, 5.5 and 11 $l.ha^{-1}$ of product.
6) "Velpar L" (250 $gm.l^{-1}$ hexazinone) at 2,5, 5 and 10 $l.ha^{-1}$ of product.
7) "Roundup" (360 $gm.l^{-1}$ glyphosate) at 2, 4 and 8 $l.ha^{-1}$ of product.
8) Control - no herbicide.

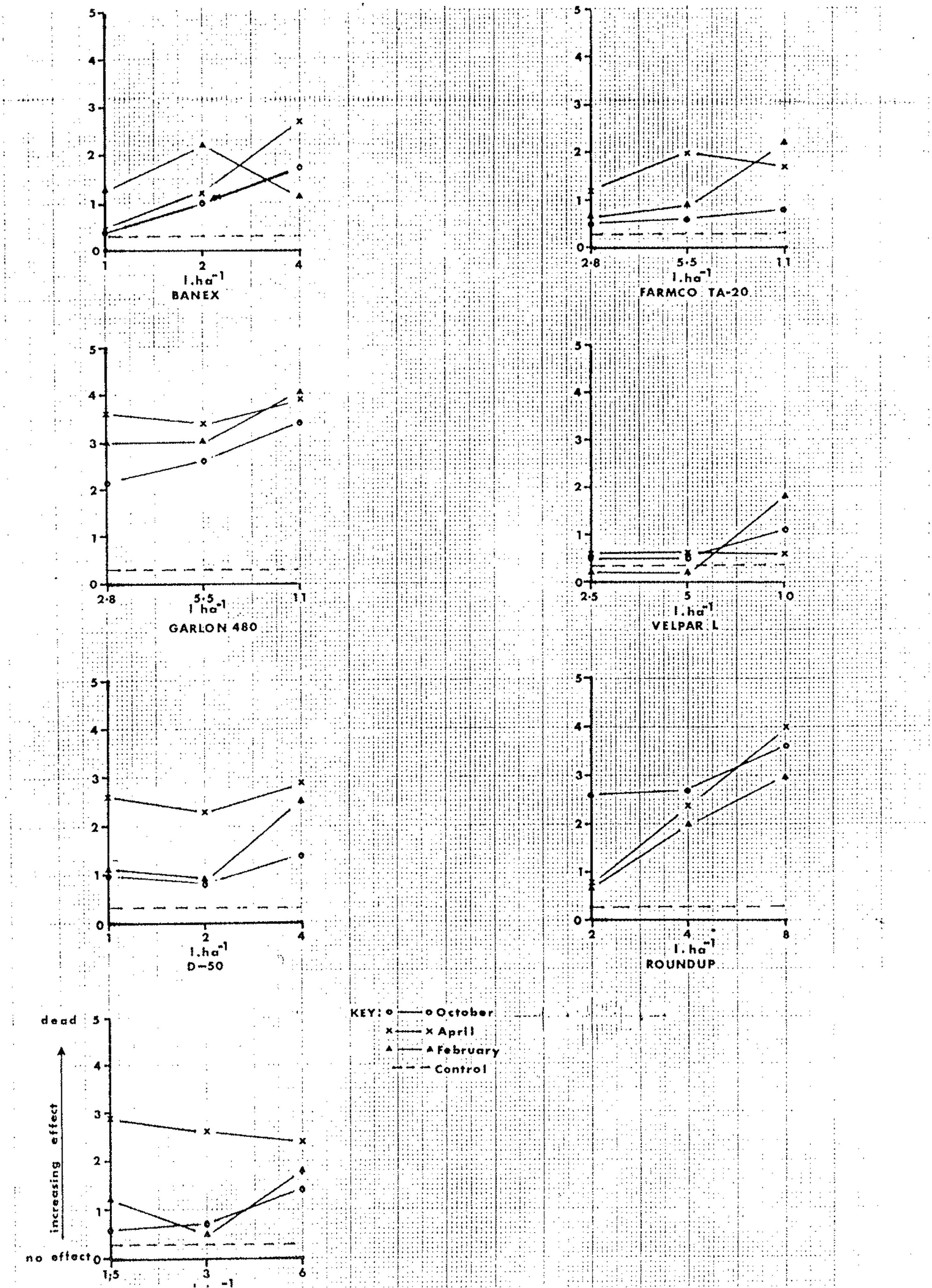
Treatments were applied with a pressurised boomspray calibrated to deliver 155 $l.ha^{-1}$ of water.

The effect of each herbicide on pines was assessed 1 month after spraying.

"Velpar L" was the least damaging to pines although spraying October and February at 10 $l.ha^{-1}$ may cause some damage. "2, 4-DB Herbicide", "D-50", "Farmco TA 20" and "Banex" appeared to be safe to pines when sprayed at certain times of the year (Figure 1). "Garlon 480" was the most damaging with severe effects being recorded at every level. Likewise, pines did not tolerate "Roundup" except at 2 $l.ha^{-1}$ applied in February and April.

As "Velpar L" is known to control weeds at 5 $l.ha^{-1}$ it is the only herbicide that can be recommended for overspraying P. radiata to control weeds.

Figure 1. The effect on P. radiata of an overspray of different herbicides in 3 different months.



ESTABLISHMENT AND FERTILIZER PLOTS - 1969

File : 233.121

In 1969 a number of trial plots were set up to investigate which of several pines would grow best in the sunkland and the need for fertilizer at establishment.

The sites, scattered through the sunkland, were cleared, windrowed and disc ploughed in early 1969. The pines were planted in the winter and fertilizer was applied in the spring. Parts of some plots were mounded. The fertilizer treatments were:-

1. Control
2. 85 g/plant Super Cu Zn.
3. 85 g/plant Super Cu Zn + 28 g/plant urea.

9 species of pine were tested, although not all of these were represented in each trial.

Data from seven of the plots were compared. The pines were five years old at this stage. The trends in growth and survival were:-

<u>Height</u>: radiata ≫ taeda > elliottii > caribaea / serotina / muricata > canariensis > brutia > nigra

	radiata	taeda	elliottii	caribaea, serotina, muricata	canariensis	brutia	nigra
$m\,yr^{-1}$	0.7	0.5	0.4		0.2	0.1	0.1

(Super Cu Zn)

: Super CuZn ≫ Super CuZn + Urea ≫ Control (average for all species

<u>Survival</u>: Serotina > radiata / taeda / elliottii > canariensis / brutia > nigra

: Super CuZn > Super CuZn + Urea ≫ Control (average for all species)

From these trials it was evident that phosphorus, and possibly copper and zinc were necessary for good survival and growth and <u>P. radiata</u> was the best species to grow. Nitrogen has subsequently been shown to be of benefit to the pine, but in forms other than that in urea.

PLACEMENT TRIAL

Local Experiment File No. R.9.3.6.

This trial was to test three methods of placing 453.6 gms of Super 22 percent close to the stem of P. radiata seedlings. The three methods of placement were:

a) spot - 453.6 gms of superphosphate 22 percent was placed in a circle around the stem and within a radius of 10 cms from it.
b) strip - 226.8 gms of Super 22 percent was placed in a strip 30 cms long and 91 cms long on each side of the plant and at a distance of 30 cms.
c) broadcast - 453.6 gms of Super 22 percent was evenly spread over 1 square metre with the plant located in the centre.

Treatments were applied one month after planting. There was no significant difference between treatments in height growth, although there was slightly greater growth in response to the spot application.

INITIAL FERTILIZER PILOT TRIAL - TELERAH

File No. 244.113.12

The aim of this trial was to see whether P and minor elements were required for the establishment of *P. radiata* on three soil types in the Sunkland.

P. was applied as Superphosphate (9.1% P) at 200g/tree. A "complete" minor element application (Minorels) was applied to one treatment at 55g/tree and a solid application of zinc was applied to another. (see Table 1). The design of the trial prevented statistical analysis. One year after establishment, the trees which received P were growing faster than those which did not. (Table 1). The applications of Minorels and zinc both resulted in further increases in growth.

Growth was greatest on the gravel, than the yellow sand and poorest growth occurred on the grey sand. (Table 1).

There were foliar deficiencies of P for all treatments on all sites. (Table 2) Zinc deficiencies were most common on the yellow sand, while nitrogen and copper deficiencies occurred on the grey sand. The application of Minorels appeared to provide adequate Cu and Zn, except on the grey sand.

While deficiencies of nutrients were more pronounced on some sites, the nutrients limiting *P. radiata* growth in the Sunkland generally, are P,N, Cu and Zn. The deficiencies are most pronounced on the grey sand sites. It appears possible to establish *P. radiata* on gravelly soils. It may, however, prove difficult to sustain growth on this type of site despite the very promising early growth.

TABLE 2: Foliar deficiencies in *P. radiata* one year after establishment.

Site	Fertilizer At Establishment			
	Nil	200g/tree Super	200g/tree Super 55g/tree Minorels	200g/tree Super CuZn 'A'
Gravel	P, Zn	P	P	P
Yellow Sand	P, Zn	P, Zn	P	P, Zn
Grey Sand	N,P,Zn,Cu	N,Cu	N,P,Cu	N,P,Cu

TABLE 1: Height of *P. radiata* one year after establishment in response to various fertilizer applications.

Site	Fertilizer At Establishment				
	Nil	200g/tree Super	200g/tree Super 55g/tree Minorels	200g/tree Super Cu Zn'A'	
Gravel	74.7	151.9	144.7	138.2	127.[illegible]
Yellow Sand	90.9	124.7	115.5	133.5	116.[illegible]
Grey Sand	93.2	72.2	118.0	106.1	97.[illegible]
	86.3	116.3	138.0	125.9	

MINOR ELEMENT SCREENING TRIAL

W.P. 18/71 File No. 244.113.1

The aim of this trial was to identify which minor elements are required for the successful establishment of *P. radiata* in the Donnybrook Sunkland. The trial was repeated on two sites, Molloy 10 and Willcock B7. The following treatments were applied:

1. Super @ 200g/tree (control)
2. Super @ 200g/tree + Minorels 55g/tree (Min)
3. Super @ 200g/tree + Copper (Cu)
4. Super @ 200g/tree + Zinc (Zn)
5. Super @ 200g/tree + Nickel (Ni)
6. Super @ 200g/tree + Baron (B)
7. Super @ 200g/tree + Molybdemum (Mo)
8. Super @ 200g/tree + Iron (Fe)
9. Super @ 200g/tree + Magnesium (Mg)
10. Super @ 200g/tree + Silicon (Si)
11. Super @ 200g/tree + Manganese (Mn)
12. Super @ 200g/tree + Cobalt (Co)

During the winter months the Molloy plot was flooded, ruining the trial. No trends in height growth were apparent, a trend was evident, however in survival; where copper and nickel were applied there was poorer survival compared to other plots, including the control.

Applications of copper and nickel also lead to poorer survival at the Willcock plot, as did molybdemum. The application of manganese was the only one to give greater height growth than the control. The application of nickel gave worse ($p<0.05$) growth than that in response to the control.

The results of this trial generally contradict those from other trials and should be treated with caution due to the problems encountered.

Fig. 1. Height increment growth of *P. radiata* in the first year after establishment, in response to various initial fertilizers.

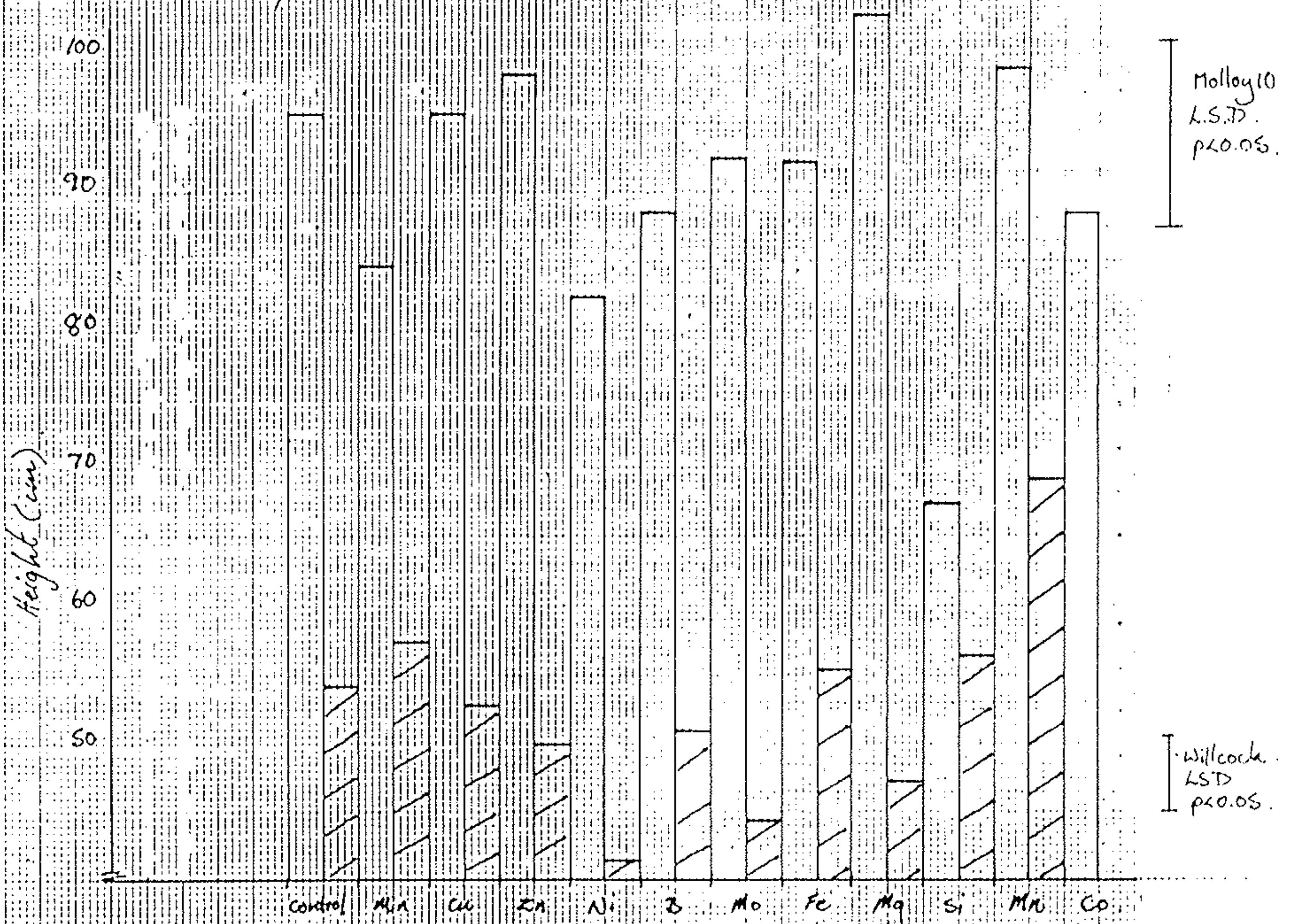
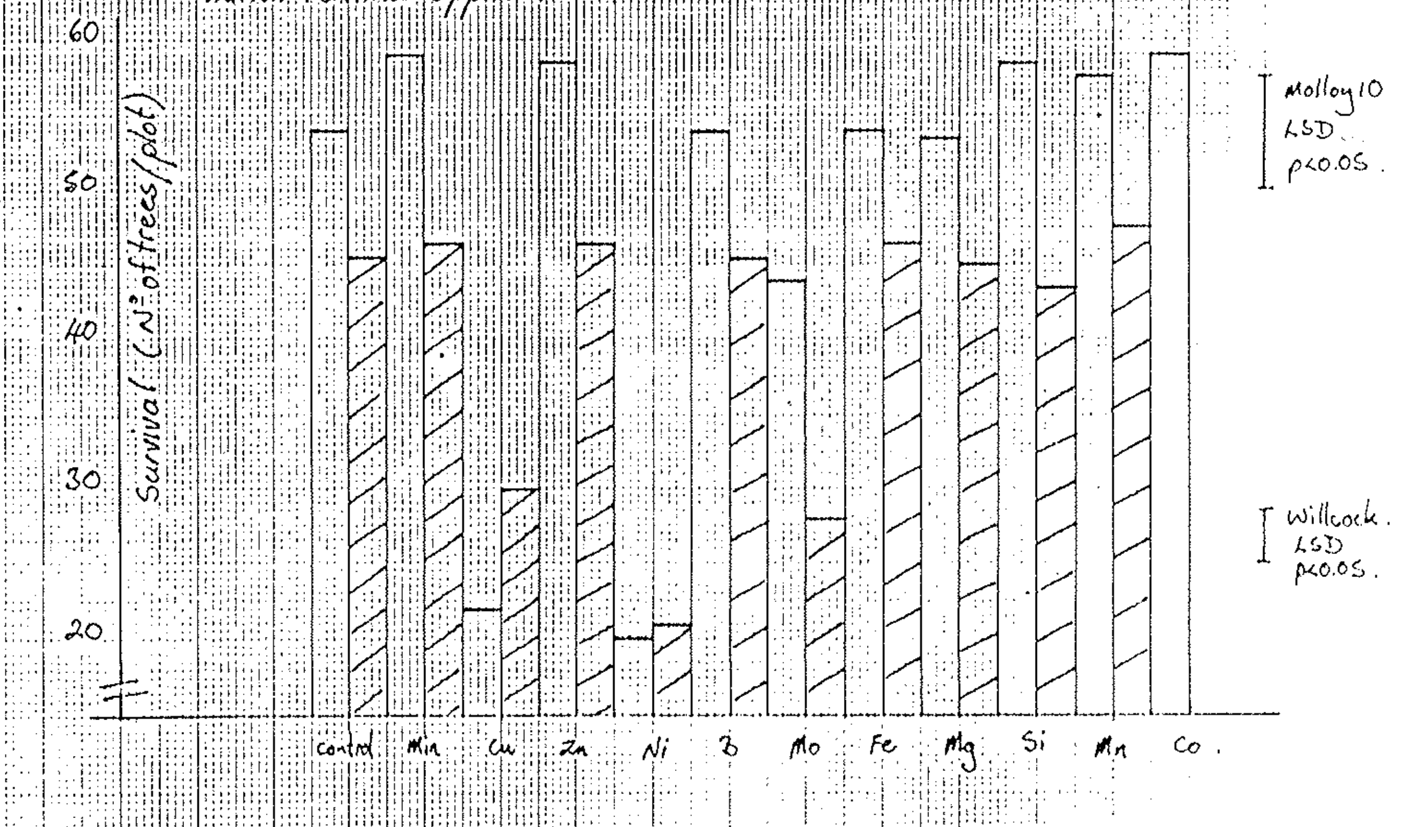


Fig. 2. Survival of *P. radiata* one year after establishment in response to various initial fertilizer applications



OPTIMUM RATES OF SUPERPHOSPHATE 22% FOR PINUS TAEDA

Duplicate of W.P. 19/71 File No. 244.113.1(3)

This trial was to determine the optimum initial rate of superphosphate 22% applied to *Pinus taeda* on yellow sands in Jarrahwood compartment 3.

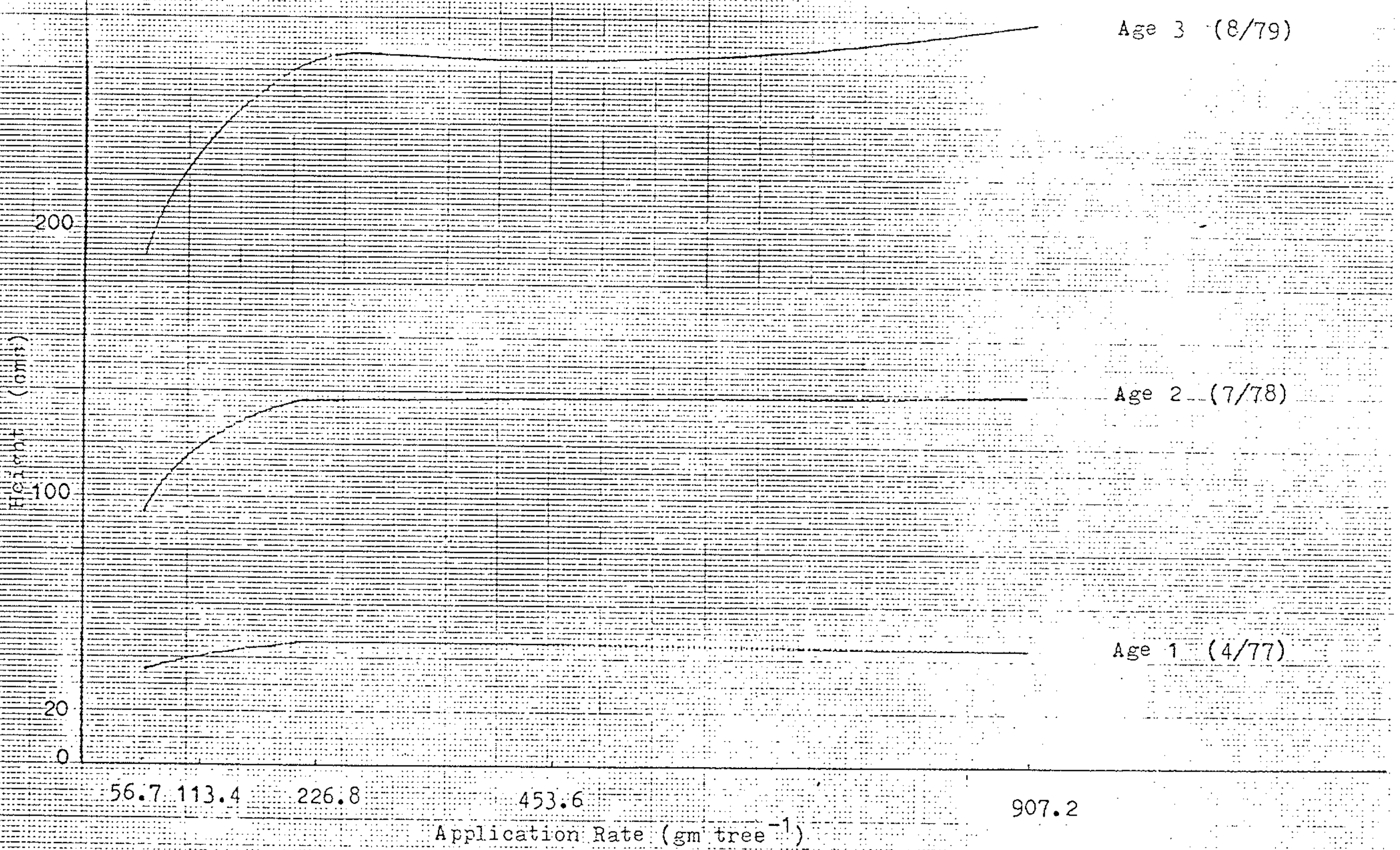
A latin square design was used for this trial, which was located off clover. Five rates of superphosphate, ranging from 56.7 to 907.2 gm tree^{-1} were applied by hand one month after planting. Fertilizer was placed in a circle around each tree, at least 10cm from the stem.

The optimum initial rate of superphosphate was between 113.4 and 226.8 gm tree^{-1} (Fig. 1). Annual height increment was still increasing at age three years, indicating a continued response to the initial fertilizer at this age. Analysis of variance of the height increments from one to three years showed significant differences between treatments ($p < 0.05$).

An initial application rate of 200 gm tree^{-1} is recommended. Refertilization at least until age three years appears unnecessary. This trial should have continued longer to determine when refertilization is required.

Further trials should examine the fertilizer requirements of *P. taeda* growing on clovered sites. Simulation of mechanical placement methods could be included in such work.

FIGURE 1: Effect of initial application rate of superphosphate on height growth of *P. taeda* growing on yellow sands in the Donnybrook Sunklands.



Optimum initial rates of Superphosphate 22% on P. pinaster in the Donnybrook Sunkland

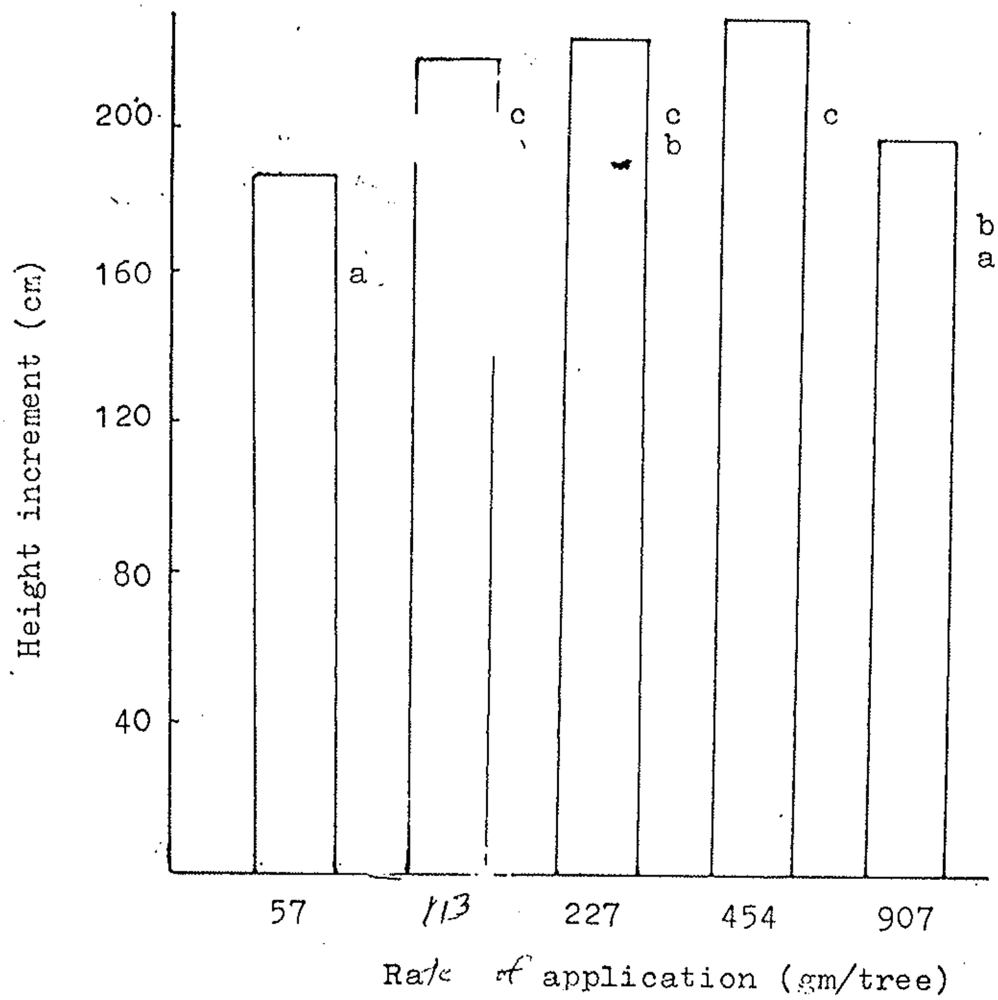
The objective of this trial was to determine the optimum initial rate of application of Superphosphate 22% for Pinus pinaster grown on yellow sandy loam in Jarrahwood Plantation on an uncleared site.

The experimental design was a 5 x 5 latin square, using five rates of application - 57, 113, 227, 454 and 907 g /tree. The fertiliser was applied one week after planting of the two year old stock, and was placed in a 10cm radius circle around the tree.

Analysis of variance of height increment over three years showed site differences occurred over the trial area, and a significant difference between treatments ($p < 0.05$). The results in Fig indicate that 113 g /tree is optimum as height increm sulting from applications of 113 227, and 454 g /tree are not significantly different, and cost of fertiliser should be considered. The highest rate resulted in depressed height growth. The data had showed increasing height increments in each successive year.

The trial indicates that 113 g /tree is the optimum initial rate of application of Superphosphate 22% for P. pinaster in the Sunkland.

Figure 1: Effect of rate of application of Superphosphate 22% on height increment of *P. pinaster*. Bars with the same letter are not significantly different at $p = 0.05$.



Preliminary Report: Nursery Zinc Trial W.P. 11/78

Aims: (1) Determine if heavier and more frequent zinc applications in the nursery can increase the zinc content of *P.radiata* seedlings.

(2) Determine the duration of any increase in zinc content and concentrations after the seedlings are planted in the field.

Results:

Treatment		Mean Zinc Concentrations at Lifting		
Time of* Application	Zinc spray concentration	Needles (ppm)	Stems (ppm)	Roots (ppm)
Control	No Zinc spray	32	26	6
0	1.5%	92	70	14
-1	"	110	77	10
-1, -2	"	162	89	22
-1, -2, -3	"	172	94	19
0	3.0%	167	86	14
-1	"	173	113	23
-1, -2	"	242	124	13
-1, -2, -3	"	266	123	22
	L.S.D. $p<0.05$	32.1	19.6	-

* 0 = 9 days prior to lifting
-1 = 1 month prior to lifting
-2 = 2 months prior to lifting
-3 = 3 months prior to lifting

Both the heavier zinc application, (i.e., 3% compared with 1.5%) and the more frequent applications increased foliar zinc concentrations. Zinc concentrations in the needles are higher than in the stems and the stems higher than in the roots. The concentrations in the stems show a similar pattern to the concentrations in the needles. The zinc concentrations in the roots show no distinct pattern.

Seedling dry weight at lifting and 2 and 4 months after planting in the field have shown no significant effect to the zinc applications. Sampling will continue for at least 12 months to determine the duration of the higher zinc concentrations. If the sampling programme shows that the zinc concentrations remain above the critical level for the first year then heavier zinc applications in the nursery will be recommended.

Nutrient Requirements of P. radiata seedlings in the Nannup Nursery

The balance between the nutrients removed from the nursery and those applied is shown below. The data used comes from a nursery zinc application trial carried out in 1978.

Mean seedling dry weight at lifting (21/6/78): 3.70g of this 85% was shoots and 15% roots.

Dry weight removed by 3,000,000 seedlings:

$$\frac{3.70g}{1000} \times 3{,}000{,}000 = 11{,}100 \text{ kg} \quad (9435 \text{ kg shoots} + 1665 \text{ kg roots})$$

Nitrogen, Phosphorus and Potassium concentrations in seedlings.

	N	P	K*
Shoots	1.93%	0.103%	0.6%
Roots	0.70%	0.043%	0.3%

* Estimate only - estimated using foliar analysis from field sampling.

Quantities of nutrients removed:

	N	P	K
Shoots	182.10 kg	9.72 kg	56.61 kg
Roots	13.97 kg	0.72 kg	4.99 kg
Total	196.07 kg	10.44 kg	61.60 kg

Nutrients applied under present nursery regime

	Nitrogen		Phosphorus		Potassium	
Fertiliser kg/ha	%N	kg	$\%P_2O_5$	kg	$\%K_2SO_4$	kg
Blood and Bone 225	5	11.25	9.15	20.60	-	-
Potatoe E 400	3.5	14.00	17	68.00	8	32.00
Agras 18:18 400	18	72.00	18	72.00	-	-
Total kg/ha	N =	97.25	P_2O_5 =	160.60	K_2SO_4 =	32.00
Elemental nutrient/ha	N =	97.25	P =	70.12	K =	14.30
x3.5* ha		340.40		245.4		50.20

*Area planted to produce 3 million seedlings.
This analysis does not include any nutrient input from the legume green crop and fertilisation of the green crop.

Comments on the Nursery Fertiliser Regime

The recovery of nutrients applied to crops varies between different nutrients, crop species and soil types. The recovery is never 100% and is usually much less. For example it is estimated that annual crops take up only 5-10% of applied phosphorus, exceptionally high values of up to 20% have been found for phosphate - demanding crops on phosphate poor soils (Russell 1973 p.590).

The heavy clay soil of the Nannup nursery would have a very high phosphate fixation capacity, consequently large amounts of phosphorus need to be applied to meet the requirements of the pine seedling crop. The phosphorus concentration of 0.103% found in the needles of seedlings from Nannup is lower than the critical levels suggested by C.S.I.R.O. for young shoots on mature trees (0.12%). It seems likely that phosphorus is limiting growth in the nursery.

The percentage recovery of applied nitrogen is similar to that for phosphorus. From the foliar nitrogen concentrations it is obvious that the seedlings are acquiring adequate nitrogen. Both the legume green crop and the inorganic nitrogen fertiliser applications would contribute to the nitrogen supply.

The foliar potassium concentration in the seedlings is not known. If the concentrations found in mature trees are any indication then it appears that each successive seedling crop is removing potassium from the nursery soil.

Fertilisation could be made more efficient by: increasing phosphorus and potassium applications; increasing the frequency of fertilisation, this would reduce the leaching of nitrogen and the immobilisation of phosphorus; use inorganic fertilisers rather than Blood and Bone. The organic nitrogen and phosphorus compounds in Blood and Bone have to be broken down before they are available to the seedlings. Alternative fertiliser regimes are attached.

Other factors that may influence seedling growth are:

(1) Water stress may reduce growth during any stage of growth. The nursery soil is well drained both internally and externally and this could cause rapid drying of the soil. The efficient use of fertilisers depends to some extent on the supply of water to the plant, if water is limiting growth then nutrient use is inefficient. Soil moisture content could be simply monitored by using a tensiometer. Soil moisture readings could be used to determine when to irrigate the nursery.

(2) The use of organic fertilisers such as Blood and Bone may cause problems with fungal pathogens e.g., damping off at germination. The organic matter in such fertilisers provides an ideal medium for the build up of pathogens in the soil, thus increasing the likelihood of infection. Due to this fact, and the slow release of nutrients from organic fertilisers their use should be discouraged.

Reference: E.W. Russell (1973)
Soil Conditions and Plant Growth
10th Ed. Longmans: London.

Nursery Fertiliser Regimes

Present Regime

July/August	200 kg/ha Potatoe E 75 kg/ha Blood and Bone Ploughed in 10cms
Oct/Nov	200 kg/ha Agras No. 1
Dec/Jan	200 kg/ha Potatoe E 150 kg/ha Blood and Bone
February	200 kg/ha Agras No. 1
Total	1025 kg/ha made up of: 400 kg Potatoe E 400 kg Agras No. 1 225 kg Blood and Bone
Nutrients	N : 97.3 kg P : 70.1 kg K : 14.3 kg

Ratio N:P:K - 6.8:4.9:1

Alternative Regimes

(1)

August (closer to	250 kg/ha Vigran 9-9-9 planting then previously) Ploughed in 10cms
Oct/Nov	125 kg/ha Agras No. 1 50 kg/ha Superphosphate
Dec/Jan	250 kg/ha Vigran 9-9-9 50 kg/ha Superphosphate
Mid Feb.	150 kg/ha Agras No. 1 100 kg/ha Superphosphate
Mid March	250 kg/ha Vigran 50 kg/ha Superphosphate
Total	1275 kg/ha made up of: 250 kg/ha Superphosphate 275 kg/ha Agras No. 1 750 kg/ha Vigran 9-9-9
Nutrients	N : 17.50 kg P : 73.9 kg K : 56.0 kg

Ratio N:P:K - 2.1:1.3:1

(2)

August	200kg/ha superphosphate 30kg/ha Muriate of Potash Ploughed in 10cms
Oct/Nov	125 kg/ha Agras No. 1 100kg/ha superphosphate
Dec/Jan	125kg/ha Agras No. 1 30kg/ha Muriate of Potash 100kg/ha Superphosphate
Mid Feb.	150kg/ha Agras No. 1 100kg/ha Superphosphate
Mid Mar.	175kg/ha Agras No. 1 100kg/ha Superphosphate 30kg/ha Muriate of Potash
Total	1265kg/ha made up of: 600kg Superphosphate 575kg Agras No. 1 90kg Muriate of Potash
Nutrients	N : 103.5 kg P : 103.0 kg K : 44.8 kg

Ratio N:P:K - 2.3:2.3:1

NP INITIAL FERTILIZER TRIAL

File No. 244.113.14

This trial was established to see whether applications of some combined nitrogenous and phosphate fertilizers would give greater growth to that achieved through the application of a phosphatic fertilizer.

The fertilizer treatments, and their compositions are presented in Table 1. The fertilizer was buried 10 centimetres below the soil surface near the base of the newly planted pine. The trees were measured for four years after transplanting.

Where both nitrogen and phosphorus was applied growth was far greater in the first year than where only phosphorus was applied. For the NP fertilizers, at a given rate of P, the amount of N or form of P did not appear to significantly affect growth.

In the third year since transplanting there was little difference between the NP fertilizers and the P fertilizer where greater than 9g/tree of P was applied. This may reflect the ephemeral response to nitrogen on these soils.

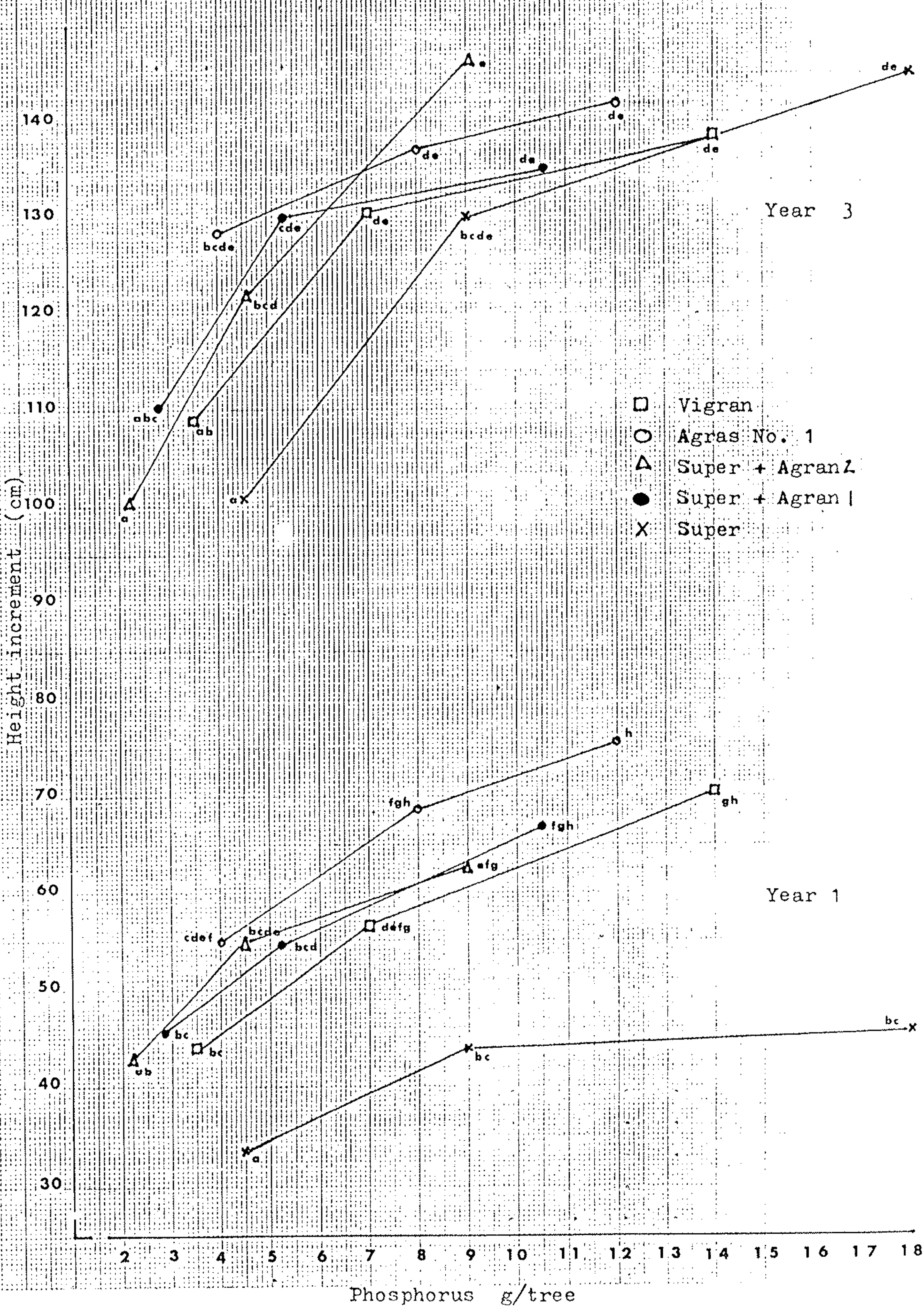
The cost of Agras and Vigran is far greater than the Super or Super and Agran mixes suggesting these fertilizers would not be cost efficient means of supplying N and P. The ratio of N:P which is optimal for pine in the Sunkland is 1:2. The fertilizers in this experiment had ratios of between 2·4:1 and 3·7:1. Therefore, greater growth in response to NP mixtures could be expected than was achieved in this experiment.

TABLE 1: Initial fertilizer treatments.

Fertilizer Type	N %	P %	K %	N:P	Forms of nitrogen	and phosphorus
"Agras No. 1"	17.5	7.6		2.3	Ammonium sulphate	Ammonium phosphate
"Super + Agran 1"(c)	13.4	5.5		2.4	Ammonium nitrate	Monocalcium phosphate
Super + Agran 2"(c)	16.8	4.5		3.7	Ammonium nitrate	Monocalcium phosphate
"Super 22%"		9.1				Monocalcium phosphate
Vigran 999"	9.0	3.5	7.4	2.5	Ammonium sulphate	Ammonium phosphate

c) These fertilizer types are mixtures of "Super22%" and "Agran 34.0" prepared by the Forests Department.

FIGURE 1: Height growth of *P. radiata* in response to initial fertilization.



INTERNAL MOUND APPLICATION OF THE INITIAL FERTILIZER FOR SUNKLAND PLANTATION PINE

The establishment of pine, principally P. radiata on the poor soils of the Donnybrook Sunkland has resulted in the increasing use of nitrogenous and phosphatic fertilizers by the Western Australian Forests Department.

The initial fertilizer requirements of the young pine are currently provided as a surface spot application at the time of planting in winter. This is applied from a hopper mounted on the planting machine, or manually in wetter areas of the plantation where the pine is hand planted. Line application of fertilizer during the mounding operation in autumn is a potential mechanical means of applying fertilizer to the wetter areas of the plantation.

These experiments were established to determine whether line application of Superphosphate 22% and Agras 18:18 (an inorganic NP fertilizer) was a more effective means of applying initial fertilizer than a surface spot application.

METHOD

Both trials were established in Jarrahwood Plantation, 30km east of Busselton. The native forest was cleared, windrowed and burnt. The area was disc ploughed and the planting lines were mounded.

Experiment 1

Four rates of fertilizer were applied:

1. 363g/tree (= to 143g/metre) Superphosphate 22% Spot application.
2. 143g/metre Superphosphate 22% mound application.
3. 285g/metre Superphosphate 22% mound application.
4. 570g/metre Superphosphate 22% mound application.

../2

The mound applied fertilizer treatments were laid out by hand in a continuous line along the mound. The mound was reformed to simulate mechanical placement of the fertilizer within the mound. One year old P. radiata seedlings were then planted into the mound. The surface spot application was applied at the time of planting.

The experiment was laid out as randomized block of seven replicates with line plots of 40 trees. Height was assessed annually for three years.

Experiment 2

Five rates of Agras 18:18 were applied.

1. 100g/tree surface spot application.
2. 40g/metre (= 100g/tree) mound application.
3. 80g/metre (= 200g/tree) mound application.
4. 160g/metre (= 400g/tree) mound application.
5. 320g/metre (= 800g/tree) mound application.

In the latter four treatments the fertilizer was laid in a continuous band along the mound. The lines were remounded in order to bury the fertilizer. One year old P. radiata seedlings were planted in July, two months after fertilizer application. The surface spot application of fertilizer was applied at the time of pine planting. All treatments received a low volume foliar spray of $ZnSO_4$, $CuSO_4$ and $MnSO_4$ in December.

The experiment was laid out as a randomized block with four replicates of 25 tree row plots. The trees were spaced 2.5 metres apart in the row.

Height was assessed annually. Diameter at 1.3 metres was measured at age three years and used to calculate basal area.

RESULTS

Experiment 1

By age two years there was a significant ($p < 0.05$) height growth response to 1600kg/ha of Superphosphate compared to the other treatments (Table 1). The surface spot application treatment had given a significant ($p < 0.05$) increase in height growth over the equivalent rate per hectare of line applied fertilizer.

TABLE 1

Experiment 2

Survival of the pine was greater than 90% at age one year for all treatments, with mortality being highest for the surface spot application of Agras (Table 2).

TABLE 2

By age three years the two higher rates of line applied Agras were significantly different ($p < 0.05$) in height increment than the two lower rates and the spot application treatment (Fig. 1). Optimum response was obtained at 160g/metre (Fig. 2).

FIGURE 1

FIGURE 2

There was no significant difference ($p < 0.05$) between the surface spot application and equivalent line application rate at age three years for height (Fig. 1), diameter or basal area (Table 2).

TABLE 1 Height growth (C.A.I.) of *P. radiata* in response to fertilizing with Superphosphate 22%.

Treatment	Height (cm) 1st Increment	2nd Increment
1600kg/ha	81.3	144.1
363g/plant	77.9	130.3
800kg/ha	76.0	127.4
400kg/ha	69.3	123.3
Significance	$p < 0.05$	$p < 0.05$

TABLE 2 Survival and growth of *P. radiata* after fertilizing with Agras 18:18.

Treatment	Survival (%) at age one year	D.B.H.O.B. (cm) at age three years	B.A. (m^2) at age three years
100g/tree	93	2.65	.0164
40g/metre	100	2.84	.0208
80g/metre	100	3.37	.0264
160g/metre	97	4.12	.0352
320g/metre	99	4.36	.0416
Significance		$p < 0.05$	$p < 0.05$

Fig1 Height growth of P.radiata in response to fertilizing with Agras

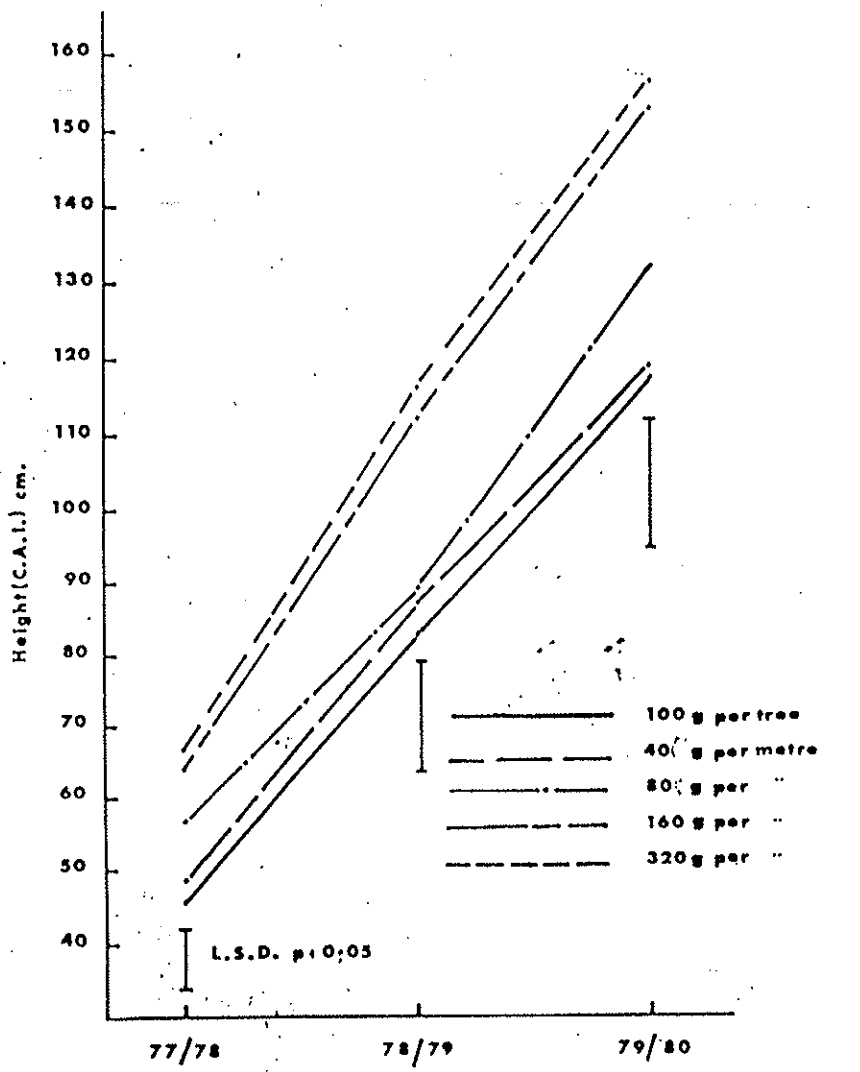
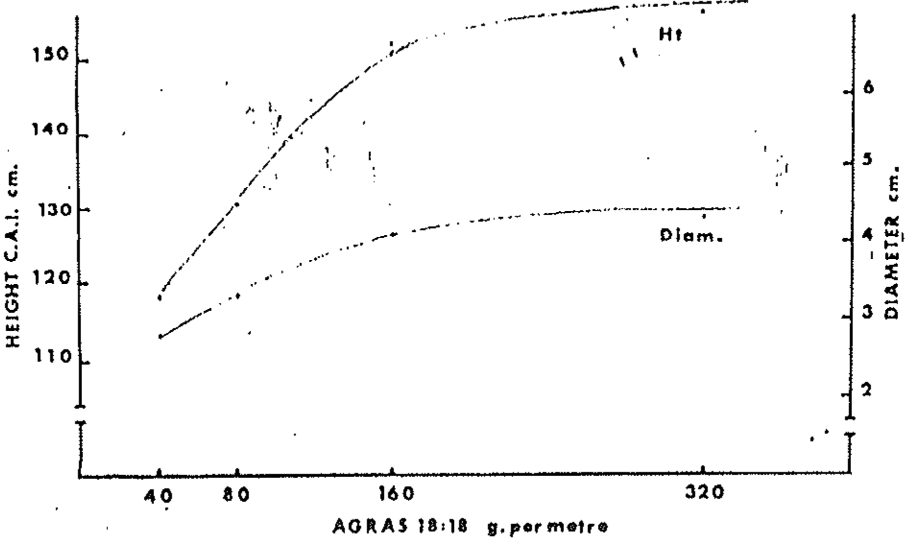


Fig 2 Growth of P.radiata in response to rates of fertilizer



DISCUSSION

These results show that buried line application of Agras 18.18 is an equally effective means of applying fertilizer to the young pine compared to surface spot application. Optimum response would be obtained at 160g of fertilizer per metre. In contrast, when Superphosphate was applied surface spot application was the more effective method.

Evidence from other trials suggests burying Agras leads to better survival and growth of young pine than a surface application. The correct placement of Agras appears important in ensuring toxic effects on the young pine are avoided.

Application of fertilizer mechanically along the mound appears feasible if Agras were to be used. Should Superphosphate be used, much higher rates would need to be applied to achieve the same pine growth as for a spot application next to the plant.

BIOSUPER EVALUATION EXPERIMENT

Local Experiment File No: 244.113.16A

This study was initiated to compare the efficiency of Superphosphate 22%, rock phosphate and 'biosuper' as sources of phosphate for one year old *P. radiata* D. Don under Sunkland soil conditions. 'Biosuper' is a biological fertiliser made by pelleting 5 parts of rock phosphate, 1 part of elemental sulphur and a small quantity of innoculum of thiobacilli.

Four rates : 50, 100, 200 and 400 grams/tree of each fertiliser type was applied as a spot application and speared in 10 - 15cm away from each plant.

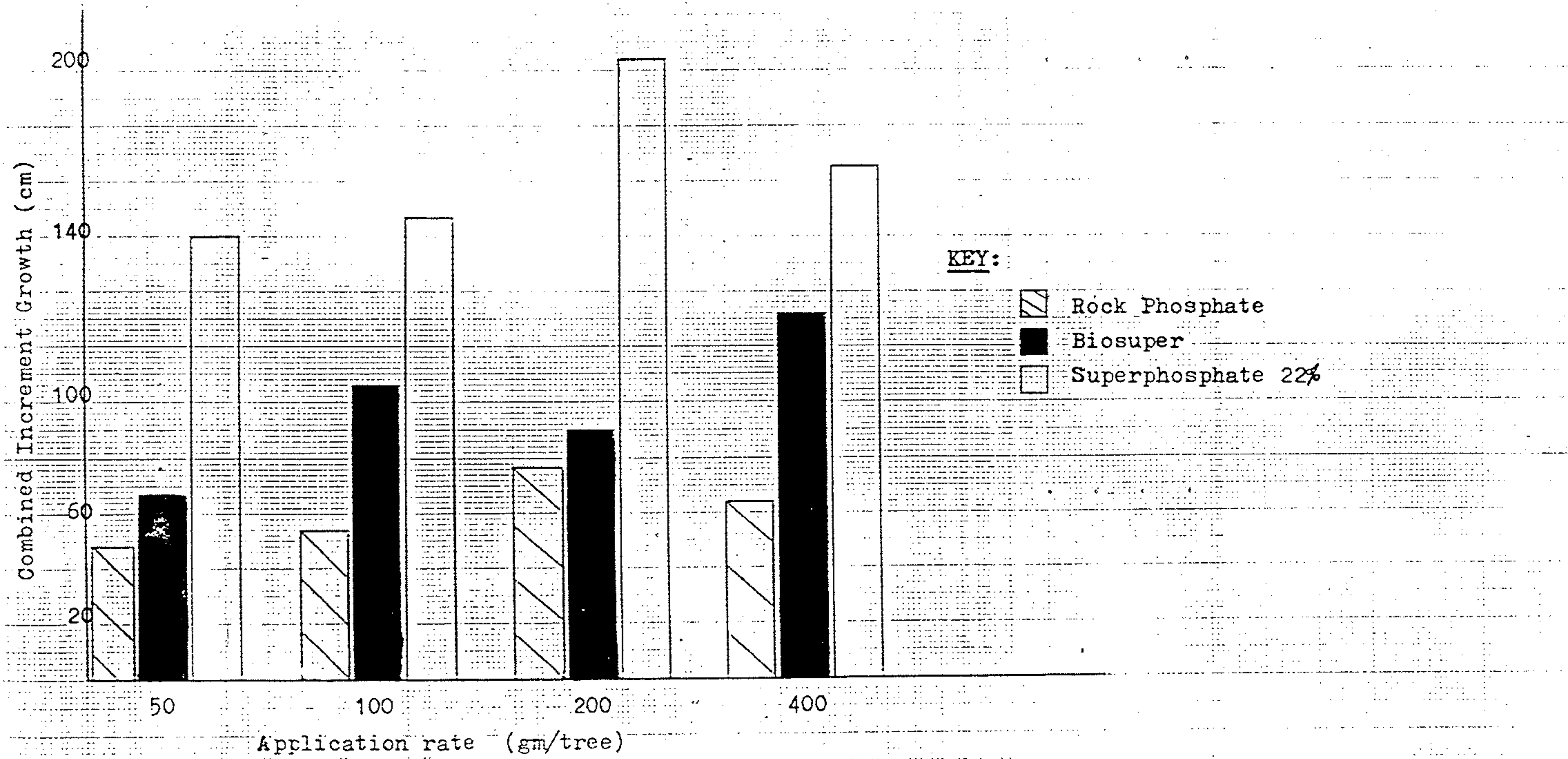
Analysis by factorial design of the combined increment growth (1976 - 1978) showed that Superphosphate 22% was better ($p < 0.01$) than biosuper or rock phosphate. 200 grams per tree was the best rate, being significantly better ($p < 0.05$) than 50 grams per tree.

Foliar analysis trends indicated marginal foliar levels of phosphate with rock phosphate being especially low (see Table 1)

TABLE 1: 1978 Foliar analysis data - % Phosphorus

GMS/TREE	SUPERPHOSPHATE 22%	BIOSUPER	ROCK PHOSPHATE
50	.076	.076	.061
100	.089	.077	.051
200	.104	.085	.066
400	.098	.148	.076

FIGURE 1: Effect of initial application rates of rock phosphate, biosuper and superphsphate on combined increment growth (1976 - 1978) of P. radiata in the Donnybrook Sunklands.



Aspects of the N and P nutrition of P.radiata

W.P. 6/77 File 244.113.14

Two rates of Super and Triple Super were applied to P.radiata either alone or with ammonium sulphate. Two blocks of the trial were in Jarrahwood Plantation, the other was in the Collie Coal Basin. The fertilizer was applied to the soil surface around the tree.

There was no significant differences between treatments in height growth in the first year but considering the data from the Sunkland and Collie Coal Basin individually some trends are evident.

P.radiata grew better without fertilizer at Collie, reflecting higher native nutrient levels in the coal basin than in the Sunkland. Nitrogen alone depressed the growth of P.radiata at both sites. Phosphorus markedly improved growth in the Sunkland but not at Collie. Nitrogen in combination with phosphorus slightly improved the growth of P.radiata compared to phosphorus alone in the Sunkland but the reverse occurred at Collie.

Survival at both sites was slightly improved by applications of phosphorus but was depressed by nitrogen or NP combinations.

Deficiencies of copper and zinc were widespread at Collie.

The lack of response to N and P at Collie may be due to other nutrients such as zinc and copper limiting growth. The higher native nutrient levels may also have mitigated against a response.

In the Sunkland phosphorus is essential for the establishment of P.ratiata. This trial showed small additional gains in growth occur when nitrogen is also applied. Excessive amounts and incorrect placement of nitrogen however can lead to deaths and reduced growth.

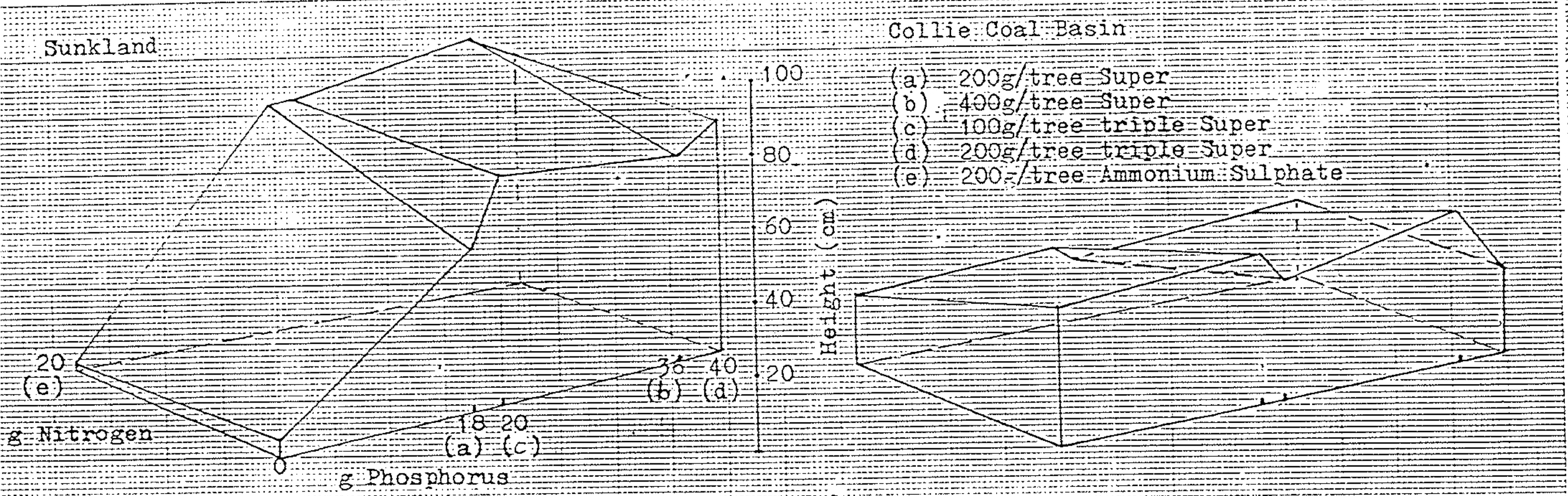


Fig. 1 Height growth (year 1) of P.radiata in response to N and P fertilizer

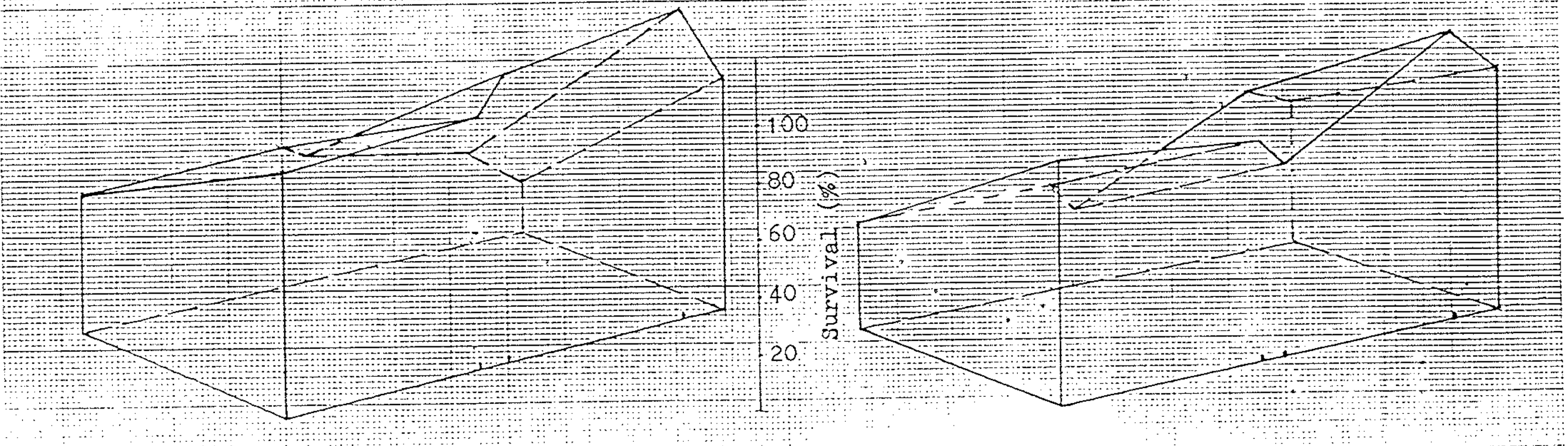


Fig. 2 Survival of P.radiata following applications of nitrogen and phosphorus

EFFECT OF LIMING ON ESTABLISHMENT AND GROWTH OF *P. radiata*

W.P. 9/77 File No.: 244.113.110

The soils of the Sunkland are slightly acidic. This trial was set up to see whether lime would raise the pH and hence affect pine establishment and growth.

The three treatments were:-

1. No lime.
2. 2.5 tonne/hectare lime.
3. 5.0 tonne/hectare lime.

There were four replicates of each treatment. All pine trees received 200 g/plant of Agras No. 1 at establishment and a zinc, manganese and copper sulphate spray six months later.

Liming significantly decreased height growth of the pine and there was a trend of a decrease in survival. Soil pH was increased by the application of lime.

Lime should not be applied to newly established pine on these soils. Only when soils are very acidic should liming be considered.

TABLE 1: The effect of lime on the survival and growth of *P. radiata* in the Sunklands.

TREATMENT	HEIGHT INCREMENT (cm) (One Year Old)	SURVIVAL (ARCSIN)	pH
Control	58.3 a	51 a	6.1 a
2.5 tonne/ha lime	49.4 ab	49 a	6.7 b
5 tonne/ha lime	43.0 b	39 a	6.6 b
	$p < 0.05$	$p < 0.05$	$p < 0.05$

METHODS OF INITIAL NITROGEN APPLICATIONS FOR PINUS RADIATA

File No. 244.113.112

This study was initiated to investigate the use of cellophane bags as a means of slowing down the release of different nitrogen fertilizers. The trial was in Jarrahwood Compartment 3 on lightly textured sandy soil overlying heavy clay.

Four replications of the following twelve combinations of treatments were applied to one year old and recently planted *Pinus radiata*. The different areas were treated as separate trials and were not combined for analysis. All trees received 150gm of superphosphate 22% at the time of planting.

Fertilizer	Agran Urea Ammonium sulphate Control (in recently planted pines only)
Rate	100g 50g
Method of Application	Surface - applied in a circle not less than 10cm or more than 20cm radius from the stem. Buried - contained in a cellophane bag and buried in a shallow depression.

One Year Old Pine

Statistical analysis showed no significant difference between tree height or height increment.

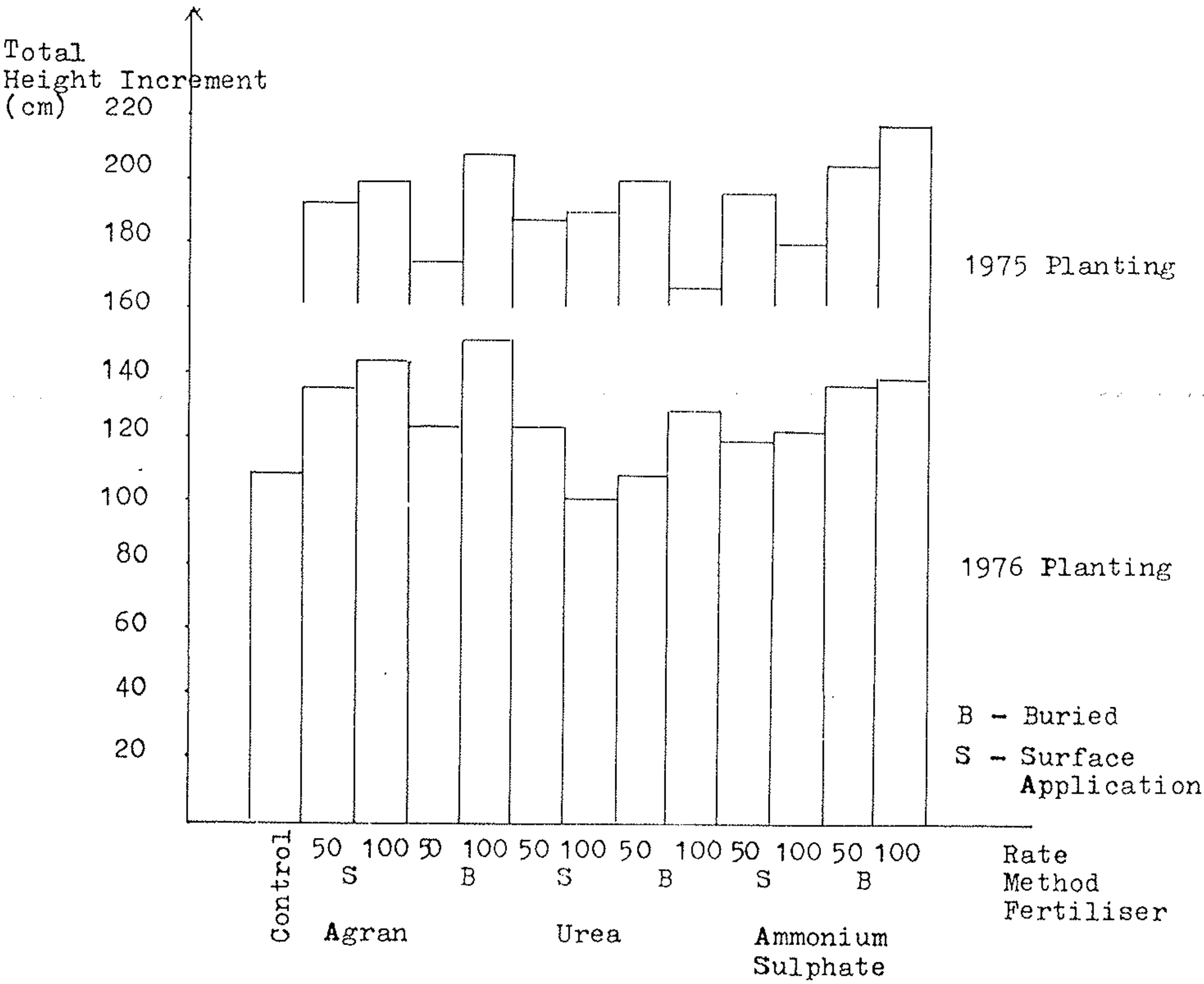
Recently Planted Pine

Agran was responsible for significantly greater (p 0.05) height for all rates and for each method of application than Urea. A significantly greater (p 0.05) height growth response was given by burying 100gm of any of the three fertilizers than the same amount applied to the surface. A surface application of 100gm of Urea showed a slightly toxic effect on height growth response, and both 100gm and 50gm of Urea reduced survival.

.../2

The use of cellophane bags may be of benefit when using nitrogen fertilisers that are likely to be toxic. The necessity to bury the bags may have had an effect on the outcome of this trial as ammonia will have been released in the soil rather than straight into the atmosphere. The logistics of using bags on an operational scale becomes impractical. A better approach may be the coating of nitrogenous fertilisers to attain the desired slow release characteristics.

FIGURE 1: Total Height Increment from 7/76 to 7/78 for all treatments.



N.P. AT PLANTING, P.72 CUNDINUP 1

File No. 244.113.24

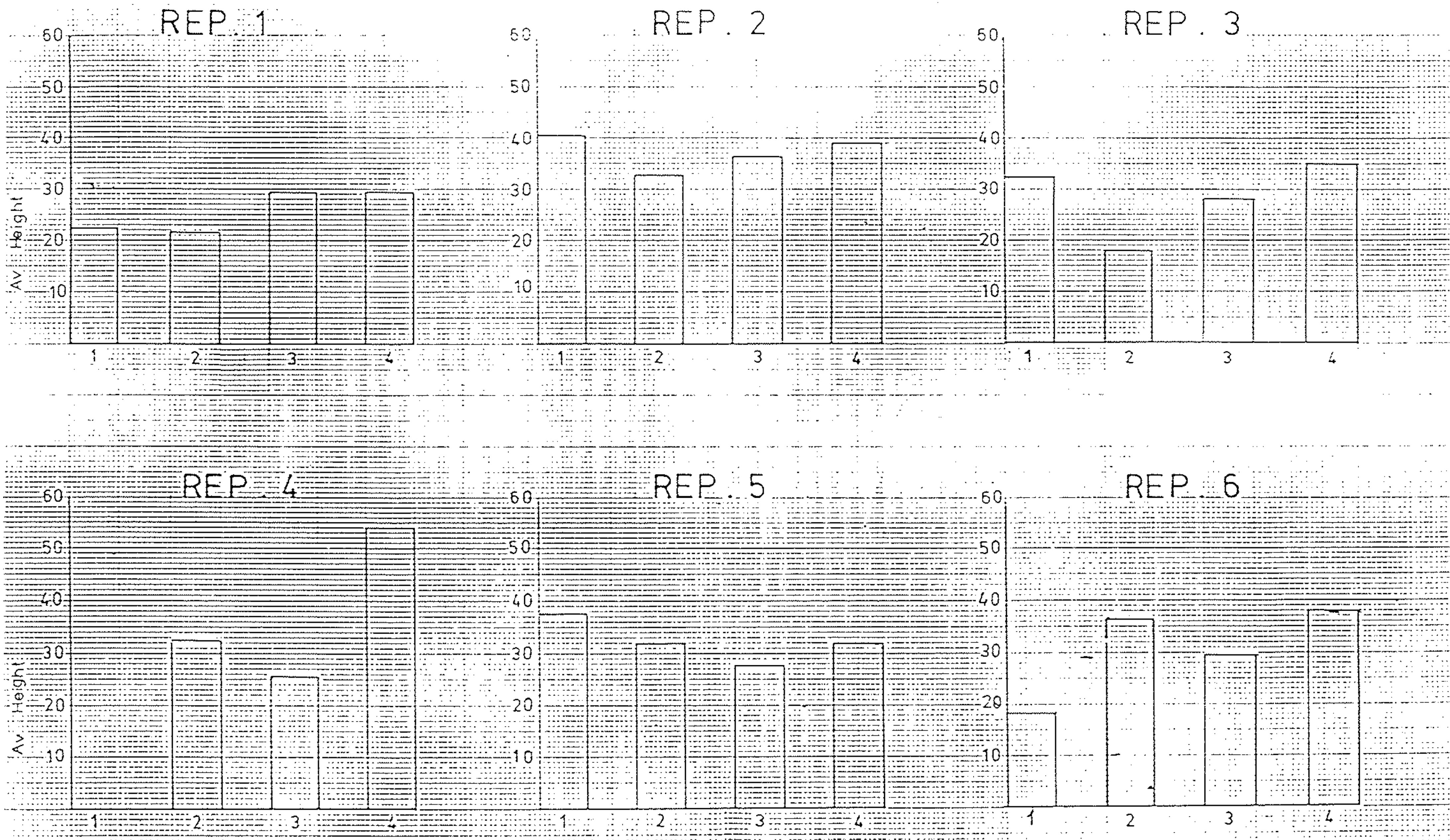
The trial at Cundinup 1 was established to determine whether land that had prior fertilization and legumous pasture would carry a rotation of pine without further use of fertilizer. Only part of the plot was fertilized to determine whether additional P was still necessary and whether additional minor elements were beneficial.

The area was mounded with the mounds running NW-SE and vorox was applied at 2.3kg/ha^{-1}. Four treatments were applied, these were a) Super 22 at a rate of 225g/tree^{-1}
b) no fertilizer at all
c) super 22 at a rate of 225g/tree^{-1} plus 55g/tree^{-1} of minerals o
and d) 55g/tree^{-1} of minerals only.
These treatments were applied on 7/9/72 and were speared in. Each plot was 4 trees x 4 trees and was replicated 6 times giving a total of 384 trees. Each replication of four plots was separated widely so as to cover site variation.

Measurements were taken on the 3/5/73 and it was found that there were no significant differences between the treatments with the exception of 55g/tree^{-1} of minerals which showed higher average measurements than the others. This was due however to only one particularly tree in replicate 4 that boosted the averages. After measurements were taken the whole plot was foliar sprayed with $MnSO_4$ 2.5% and $ZnSO_4$ 2.5%, this took place in November 1973.

After the results were analysed there was no significant differences between treatments with the exception of 55g/tree^{-1} of minerals. This shows that land that has been fertilized prior to planting will support a rotation of pine without additional fertilizer.

It was also noted that survival rates in this trial were very low. This was due mainly to the high incidence of rabbit damage.



1— Super 22% 2— No Fertiliser 3— Super 22% + Minerals 4—Minerals

INITIAL NITROGEN AND PHOSPHATE FERTILISER REQUIREMENTS IN RELATION TO MECHANICAL PLACEMENT METHODS

W.P. 15/79 File No. 244.113.112

This study was initiated because of high mortality following machine planting. This was thought to be due to the placement of fertiliser in close proximity to the stem of Pinus radiata D.Don. seedling.

The aim of the trial was to show which placement method and fertiliser rate would be most suitable at time of planting.

Four fertiliser rates were applied: Agras (18:18) 100, 75 and 50 grams per tree, plus Agras (18:18) 25 grams and Superphosphate 22 per cent 75 grams mixed. Four placement methods were tested for each of the fertiliser combinations, using a Factorial design;

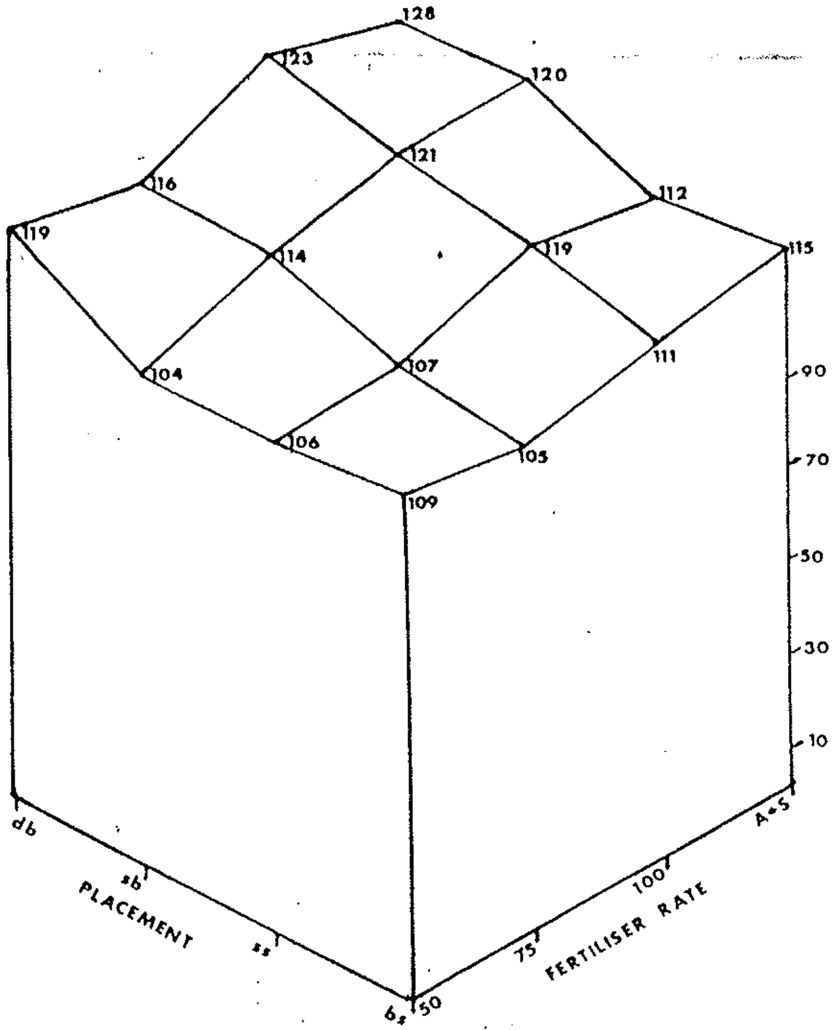
a) Surface spot - the fertiliser was placed $\approx$15 centimetres from and on either side of the pine in the compacting wheel ruts (was the current planting machine method) an the mound.
b) Buried in planting slot - the fertiliser was placed by machine in the planting slot 15 centimetres ahead of the pine.
c) Shallow buried in ruts - the fertiliser was manually covered with 5 centimetres of soil after being placed in the compacting wheel ruts.
d) Deep buried - the fertiliser was manually speared into the ground, 15 centimetres from the pine on either side in the wheel ruts, to a depth of 15 centimetres.

Growth of trees was greater in the northerly block than the southerly block (p 0.001). This was possibly due to soil type, waterlogging or thick scrub in the southerly block. The deep buried technique gave the greatest height growth (p 0.05) and the best survival (p 0.001) of the placement methods (see FIGURES 1 & 2). The buried in the slot method resulted in the worst tree survival, being significantly worse ($p < 0.05$) than other placement methods. Optimum growth and survival will be achieved by a deep buried application of 25 grams of Agras plus 75 grams of Superphosphate.

FIGURE 1: EFFECT OF PLACEMENT METHODS & FERTILISER RATE WITH HEIGHT INCREMENT ON P. RADIATA

KEY:

- db – deep buried
- sb – shallow buried
- ss – surface spot
- bs – buried in slot
- a+s – agras plus super



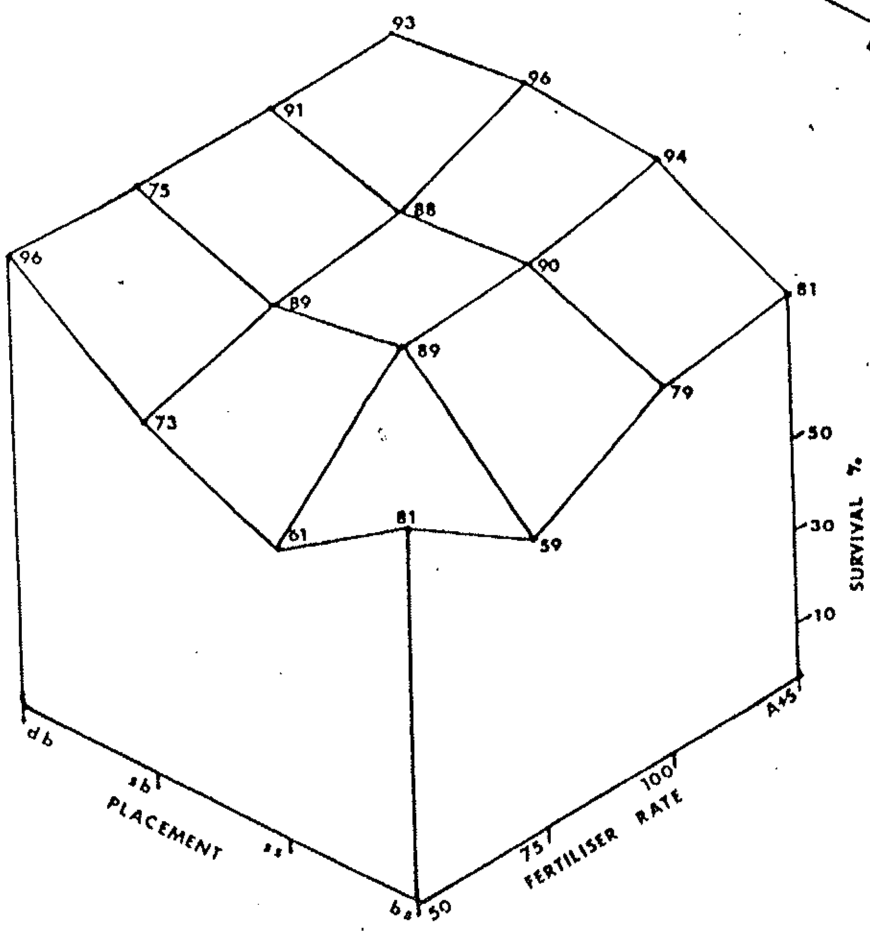


FIGURE 2: EFFECT OF PLACEMENT METHODS & FERTILISER RATE WITH SURVIVAL ON P RADIA

SINGLE SPOT INITIAL N-P FERTILIZER TRIAL

W.P. 10/80 File No.: 244.113.114

For best results from initial NP fertilization of *P. radiata* the placement of the fertilizer is important. To avoid damaging the pine roots it has been found beneficial to bury the fertilizer in a slot on one side of the tree (Woods and Forests Department, S.A.). This provides a zone of soil free from the toxic effects of nitrogen. Placing fertilizer on the soil surface either side of the pine lead to a mortality of 16% for *P. radiata* and 49% for *P. pinaster* in the Sunkland in 1979.

This trial was to see whether placing the fertilizer one side of the tree either on the surface or buried would give better survival and growth than a surface application on both sides of the tree.

The treatments were:-

1. Surface spot on both sides of the newly planted pine of 100g Agras No. 1.
2. Surface spot on one side of the newly planted pine of 100g Agras No. 1.
3. Slot application on one side of the pine of 100g Agras No. 1.
4. Surface spot on both sides of the pine of 150g Super CuZnMo No. 2.

Good survival was achieved with all treatments (greater than 95%). There was no difference in height growth in response to any of the Agras treatments (Figure 1). The response to the Super CuZnMo No. 2 was initially poorer than to the Agras treatments bur had improved by the next increment period. This better long term response to Super compared to Agras is also evident in other trials. While not apparent in this trial, burying the fertilizer has given better results than a surface application in other trials.

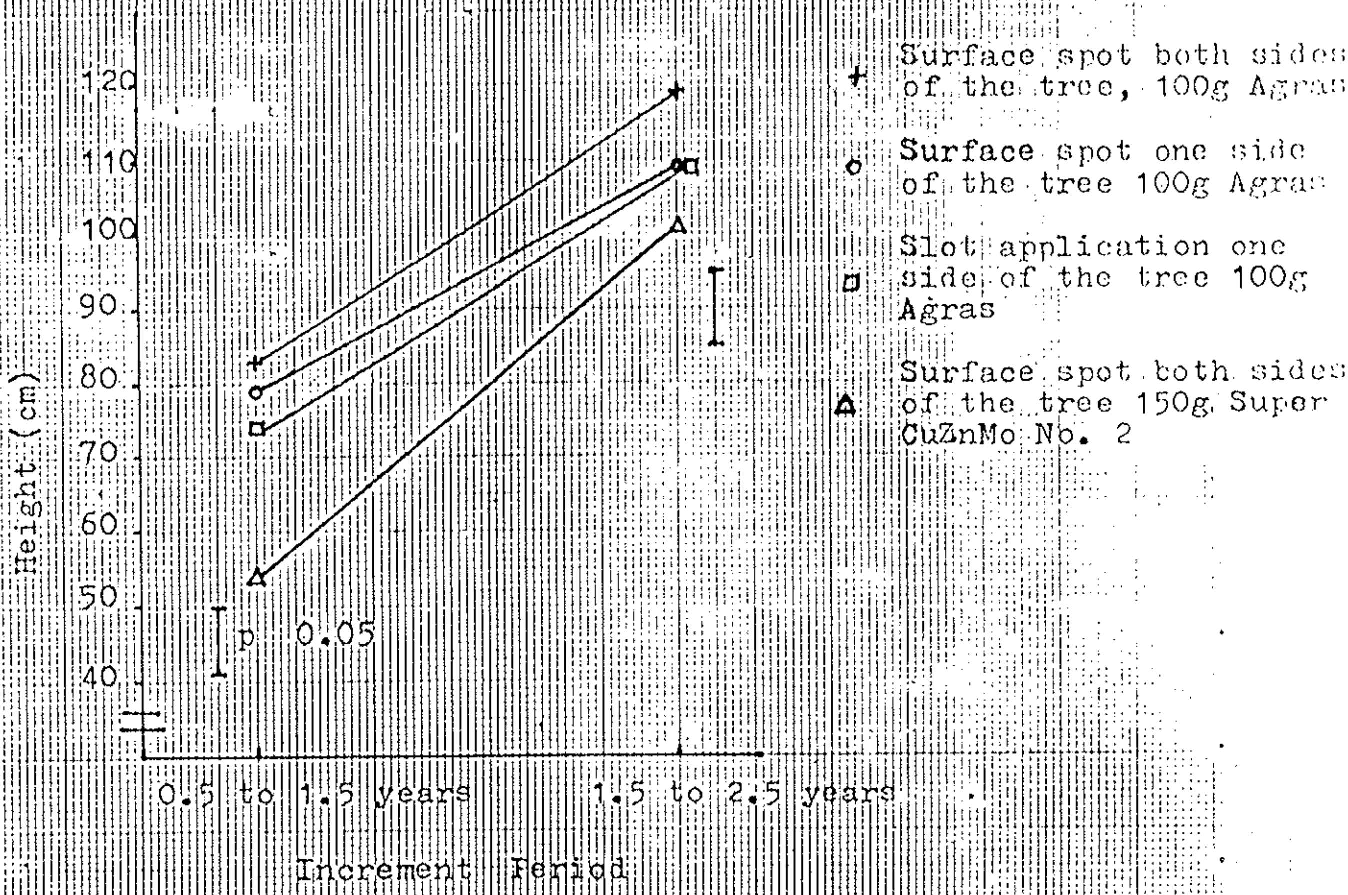


Figure: Height increment growth of *P. radiata* in response to initial applications and placement of two fertilizers

Zinc and copper requirements for *P. radiata* grown with 'Super and Clover'

File No. 244.113.12

P. radiata responds to solid applications of zinc and copper when applied with superphosphate (McGrath, 1978). The fertilizer regime used at present is to broadcast 500 kg/ha of Super CuZnMo No.2 (to establish the clover) and to place 150g Super CuZn'B' next to each pine at planting. Few deficiencies of zinc and copper have been observed with this regime.

The trial was to investigate whether zinc and copper sulphate, applied as a foliar spray would improve growth or foliar nutrient levels of the pine, when grown with the 'Super and Clover' regime. The trial was laid down in 1980 on a yellow sandy loam and a grey sandy loam. Alternating strips of sprayed and unsprayed pine were laid down. There were four strips of each treatment at each site. 10 $kgha^{-1}$ of zinc and 0.5 $kgha^{-1}$ of copper were applied 6 months after planting. 200 $kgha^{-1}$ of Super was applied when the pines were two years old. A further foliar spray of 10 $kgha^{-1}$ zinc and 0.5 $kgha^{-1}$ of copper was applied 3 months after this.

Inadequate replication precluded statistical analysis.

The foliar zinc and copper sprays had no effect on the height of the pine, at least, for 2¼ years after establishment. There was no difference in the foliar levels of N, P, Zn or Cu of 2¾ year old trees between treatments even though zinc and copper sulphate had been applied only 5 months previously. The only difference between sites was higher foliar levels of phosphorus on the yellow sandy loam.

This data suggests adequate zinc and copper are being applied to the pine at establishment and this will sustain the requirements of the pine for at least 3 years. Traces of zinc and copper in Super applied at age 2 years may also be contributing to the supply of these nutrients to the pine.

A further trial has been established to identify the roles of the broadcast and spot applications of fertilizer in providing zinc and copper to the pine.

Figure 1. Response of P. radiata to foliar sprays of zinc and copper sulphate. Foliar nutrient levels were determined for 2¾ year old trees. Height increment is from 1½ to 2½ years of age.

	Grey sandy loam		Yellow sandy loam	
	Zinc and copper sprays	No sprays	Zinc and copper sprays	No Sprays
N	1.30	1.24	1.31	1.26
P	0.18	0/18	0.23	0.24
Cu	5.71	5.00	5.35	5.67
Zn	34.32	31.32	34.81	37.89
Height (cm) Increment	85.6	91.3	95.1	95.8

Initial fertilizer to establish P. pinaster

File 244.113.1

This trial was to investigate the initial fertilizer requirements for P. pinaster. The spot fertilizer treatments were:

+ 100g/plant Agras No. 1
- 150g/plant Super
- 150g/plant Super CuZn'B'

The fertilizer was applied to the soil surface to one side of the plant. Each plot was divided, and half received 5% $ZnSO_4$ and 0.2% $CuSO_4$ foliar spray. This was applied 6 months after establishment.

Each treatment was replicated four times. This trial was established on two sites, one clovered and one un-clovered. The clovered site received 500 kg/ha Super CuZnMo No. 2 at establishment and 200 kg/ha Super two years later.

Height increment from 0.5 to 2.5 years and survival at age 2-5 years was analysed using ANOVA for a factorial design. There were no significant differences between any treatments either in the clovered or non-clovered treatments. Growth overall was greater on trees in the clovered than the non-clovered plot.

Agras gave the poorest survival in both the clovered and non-clovered treatment. Survival was better overall in the clovered plot.

Foliar sprays of zinc and copper aren't necessary when establishing P. pinaster. The need for nitrogen can't be determined from this trial. The differing amounts of phosphorus makes interpretation of the response to initial fertilizers difficult. The greater height growth on the clovered plot may be due to the large applications of phosphorus, inputs of nitrogen or a site affect.

Height (cm) (0.5 to 2.5 years)

clovered plot

150g Super CuZn'B'	176	Zn & Cu foliar sprays	161
150g Super	161	No foliar sprays	168
100g Agras No. 1	156		

Non-clovered plot

150g Super	149	Zn & Cu foliar sprays	150
100g Agras No. 1	143	No foliar sprays	140
150g Super CuZn'B'	142		

Survival (% arcsin) age 2·5 years

clovered plot

150g Super CuZn'B'	80	Zn & Cu foliar sprays	78
150g Super	80	No foliar sprays	76
100g Agras No. 1	71		

Non-clovered plot

150g Super CuZn'B'	74	Zn & Cu foliar sprays	70
150g Super	70	No foliar sprays	68
100g Agras No. 1	61		

Table: Height and survival of *P. pinaster* in response to initial fertilizer applications.

Initial fertilizer requirements for *P. taeda*

File 244.113.1

This trial was to determine the best of three fertilizers and to see whether zinc and copper foliar sprays are necessary to establish *P. taeda*.

The spot fertilizer treatments were:

- 100g/plant Agras No. 1
- 150g/plant Super
- 150g/plant Cuper CuZn'B'

The fertilizer was applied to the soil surface, to one side of the pine. The plots were divided in two and half received a 5% Zn SO_4 and 0.2% $CuSO_4$ foliar spray, 6 months after establishment.

There were 3 replicates of each treatment.

Super CuZn'B' gave the greatest height increment. The zinc and copper foliar sprays did not affect the growth of the pine. There were no differences in survival between any treatment.

Interpretation of this experiment is difficult, being complicated by a different amount of phosphorus being applied with Agras. However, foliar sprays do not appear necessary to establish *P. taeda* and 150g Super CuZn'B' is superior to 100g Agras No. 1.

Table: Height and survival of *P. taeda* in response to initial fertilizer applications.

Height (cm) 0.5 to 2.5 years

150g Super CuZn'B'	187
150g Super	171
100g Agras No. 1	131

Zinc & copper foliar sprays	164
No foliar sprays	162

Survival (% arcsin) 2.5 years

150g Super CuZn'B'	73
150g Super	65
100g Agras No. 1	59

Zinc & copper foliar sprays	62
No foliar sprays	68

Bars denote significance at 95% level

P. elliottii INITIAL FERTILISER TRIAL

W.P. File No.: 244.113.1

The trial was established to investigate the initial fertiliser requirements for Pinus elliottii. It consisted of six treatments, three of fertiliser with foliar spraying and three without. The fertiliser treatments are as follows:-

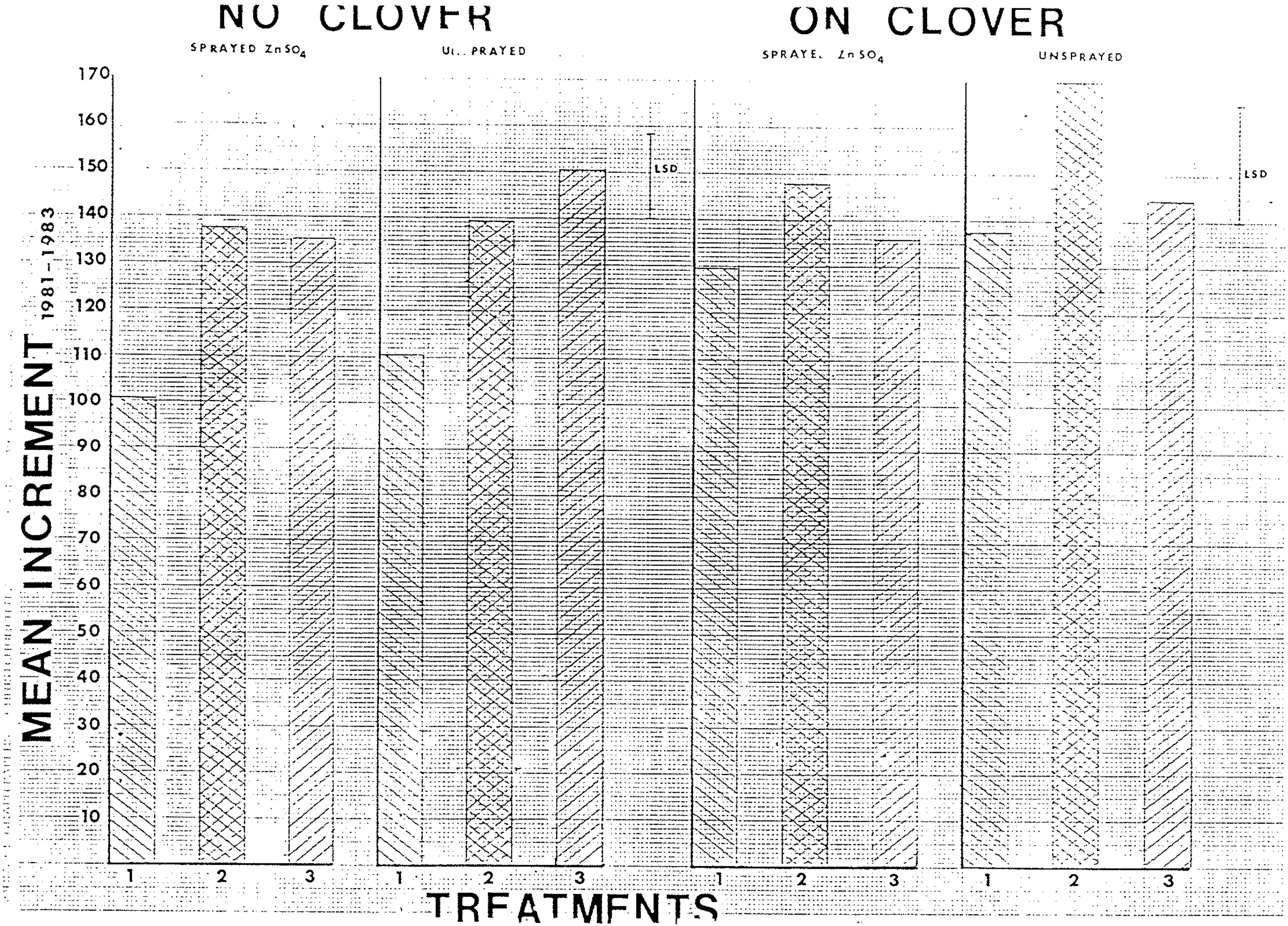
1. 100gm (Agras) 18;18
2. 150gm (Super 22%)
3. 150gm (Super Cu Zn)

Foliar sprays were 5% Zn So_4 at 10kgha^{-1} and 0.2% Cu So_4 at .5kgha^{-1}. The trial was established on a clovered area and a non clovered area, the treatments were randomized and replicated four times.

Fertiliser was placed in a heap on one side of each tree. This and the foliar spray treatments were applied by hand. Planting and fertilising took place in July 1980 and foliar spraying took place in December 1980. Height of the trees were measured annually.

The results of the trial up to 1983 have shown that there is no response to foliar spraying. The response to Super Cu Zn and Super 22% has been greater than the Agras 18:18. Although, not analysed there was a greater response to Agras 18:18 and Super 22% on clovered ground than there was on non-clovered ground.

Because there was no response to foliar spraying and the response to Super Cu Zn and Super were the same it can be assessed that there is no response to Copper and Zinc by P. elliottii.



2 GR 100 gms ER 150 gms SUP 150 gms uZn

Solid applications of zinc and copper on Sunkland P. radiata

Interim Report

W.P. 18/82 File No. 244.113.14

Recently it has been shown that where P. radiata is spot fertilized with Super CuZn'B' and clover is also established with (Super CuZnMo No.2), adequate levels of zinc and copper are achieved. This trial aims to identify the source of the zinc and copper.

The trial was in a split plot design with the major plots arranged in a randomized block layout with four replications. The treatments were;

Major plots	(a)	500 kg/ha Super CuZnMo No.2 + 12 kg/ha clover
	(b)	500 kg/ha Super CuZnMo No.2
	(c)	No broadcast applications
Sub-plots	(a)	150 g/tree Super. Surface spot application
	(b)	150 g/tree Super CuZn'B'. Surface spot application.

The experiment was laid down on a grey sand and a yellow sandy loam. Zinc levels of the soil were determined prior to treatments being applied. 10 months after establishment of the trial, nutrient levels of the soil and the foliage were determined.

The extractable levels of soil zinc were very low and were slightly higher on the yellow sandy loam (0.10 ppm) than the grey sand (0.06 ppm). The broadcast application of Super CuZnMo No.2 raised the soil levels of Zn, Cu and P as expected, there was no improvement above native levels where there was no broadcast application. There was no increase in the levels of soil nitrogen, even with clover.

Foliar levels of N, P, Zn and Cu were adequate for all treatments on both sites except for Cu on the grey sand site. There were few differences between treatments although the broadcast application appears to have marginally increased P and Zn levels above those achieved with a spot application only. Surprisingly, a spot application of Super has provided similar levels of Zn and Cu as other treatments. It is probable that deficiencies will become more apparent over the next year.

Figure Soil and Foliar nutrient levels in response to broadcast and spot applications of Super and copper and zinc.

	Foliar Nutrient Levels								**Soil** Nutrient Levels							
	Grey Sand				Yellow Sandy Loam				Grey Sand				Yellow Sandy Loam			
	N(%)	P(%)	Zn (ppm)	Cu (ppm)	N(%)	P(%)	Zn (ppm)	Cu (ppm)	N(%)	P(%) ppm	Zn (ppm)	Cu (ppm)	N(%)	P(%) ppm	Zn (ppm)	Cu (ppm)
500 kg/ha Super CuZnMo No.2 clover 150 g/tree Super	1.49	0.18	21.84	1.84 m	1.55	0.21	25.53	4.18	.052	3.55	0.38	0.31	.039	2.44	0.32	0.15
500 kg/ha Super CuZnMo No.2 clover 150 g/tree Super CuZn'B'	1.49	0.19	25.22	1.46 m	1.54	0.19	32.94	4.00	.068	2.34	0.26	0.27	.036	4.78	0.62	0.30
500 kg/ha Super CuZnMo No.2 150 g/tree Super	1.29	0.16	25.60	1.33 m	1.55	0.19	21.27	4.16	.054	4.08	0.34	0.43	.037	3.56	0.53	0.24
500 kg/ha Super CuZnMo No.2 150 g/tree Super CuZn'B'	1.32	0.16	24.10	2.26 m	1.45	0.21	25.44	5.20	.061	4.36	0.35	0.36	.041	4.10	0.53	0.26
150 g/tree Super	1.44	0.13	16.19	1.60 m	1.50	0.18	25.98	3.98	.068	0.55	0.11	0.03	.041	1.96	0.23	0.07
150 g/tree Super CuZn'B'	1.45	0.13	19.20	1.86 m	1.44	0.17	22.01	4.17	.064	0.68	0.14	0.05	.044	1.14	0.21	0.05

m = marginal level

INTER-ROW REFERTILISING

Local Experiment File No: 244.113.26

Healthy *Pinus radiata* was broadcast fertilised one year after planting with three rates of Superphosphate 22% at the following rates : 400, 800 and 1600 kg/ha.

The fertiliser was broadcast in a band covering three planted rows with the centre row of pine being measured annually for four years.

Analysis of variance of height growth over five years and annual height increment showed no significant difference between the treatments. The trial lacked a control treatment which makes it difficult to assess the value of inter-row refertilising at age one, compared with not refertilising.

TABLE 1: Total height and increment 1976 - 1981

TREATMENT	TOTAL HEIGHT 1981	INCREMENT			
		1st	2nd	3rd	4th
400 kg/ha	452	60	86	108	135
800 kg/ha	463	55	85	117	142
1600 kg/ha	491	73	93	121	136

NATIVE LEVELS OF NITROGEN AND PHOSPHORUS

W.P. 19/82 File : 244.113.29

Soil sampling of a yellow loamy sand in the Sunkland revealed the following native levels of N and P. The generally accepted limits for the growth of P. radiata are also quoted.

	Sunkland	Limits for P. radiata Growth
Total N (%)	0.035	0.07
Total P (ppm) (HCl ext.)	10.3	100
Available P (ppm) (HCO_3 ext.)	2.1	20

Obviously considerable inputs of N and P are required for the growth of P. radiata.

SUPERPHOSPHATE AND ROCK PHOSPHATE MOLLOY 14

W.P. 25/74 File No. 244.113.22

This trial was to determine the most effective source, and the optimum broadcast application rate, of phosphate, on *Pinus radiata* in the Sunklands.

The trial was designed as a ~~Latin Square~~ factorial(?) and was not replicated or randomized. Height and foliar nutrient levels were collected from 5 subplots within each treatment plot. Rock Phosphate (R.P.) and Superphosphate 22% (S22) were broadcast spread 2 years after the pines were transplanted. Application rates ranged from 0 - 400kg ha^{-1} for R.P. and from 0 - 600kg ha^{-1} for S22, with all possible combinations of these rates being applied.

Foliar P Levels In Response to Treatments

TABLE 1:

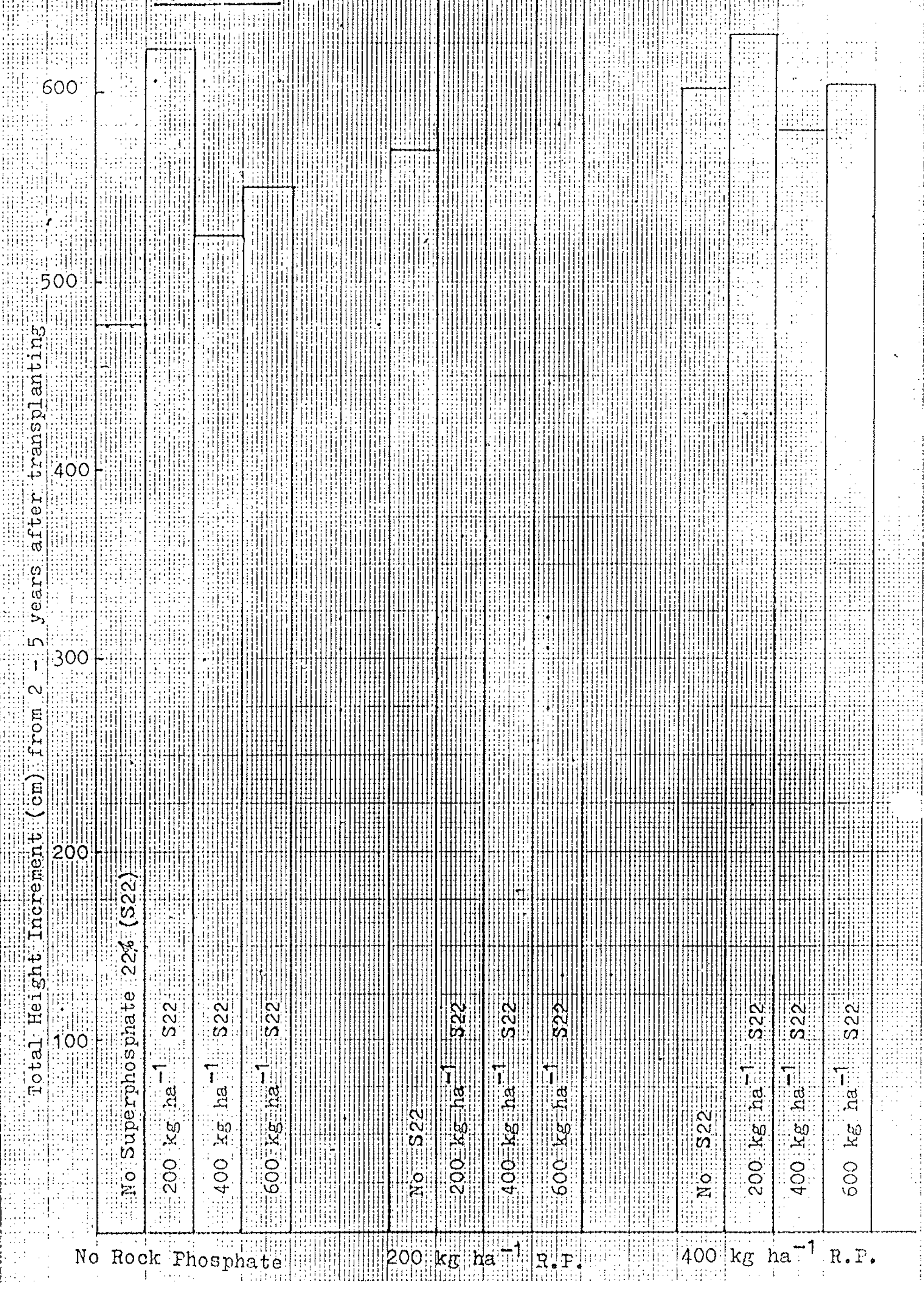
S22	R.P. (kg ha^{-1})		
(kg ha^{-1})	0	200	400
0	0.115%	0.118	0.116
200	0.128	0.139	0.171
400	0.139	0.176	0.163
600	0.164	0.189	0.189

0.140 is adequate for pine growth (WILL 1978)

Table
~~Figure~~ 1 shows that R.P. alone did not raise the foliar P. concentration to a level considered adequate for pine growth. Foliar P increased with increasing rates of S22. Figure 2 shows the height growth response following fertilizing. There is increased growth where S22 alone was applied although no clear trend is evident to indicate the optimum rate. The growth response to R.P. alone increased with rate, which is inconsistent with foliar P. concentration (Fig. 1). The best overall growth was achieved by an application of 200kg ha^{-1} R.P. with 200 - 600 kg ha^{-1} of S22.

The optimum application rate and the most effective source of P cannot be recommended, as the trends discussed may be influenced by site factors as much as by treatments. A better designed trial would be needed to answer these questions.

FIGURE 1: Effect of broadcast application of forms of phosphate on height growth for *P. radiata* in the Sunklands.



1975 ROCK PHOSPHATE - SUPERPHOSPHATE EXPERIMENT

W.P. 3/75 File No. 244.113.11

This trial was to determine the optimum pre planting broadcast level of phosphate (P) on *Pinus radiata* in the Sunklands, and to compare the effectiveness of using Superphosphate 22% (S22) or Rock Phosphate (R.P.) as the source of P.

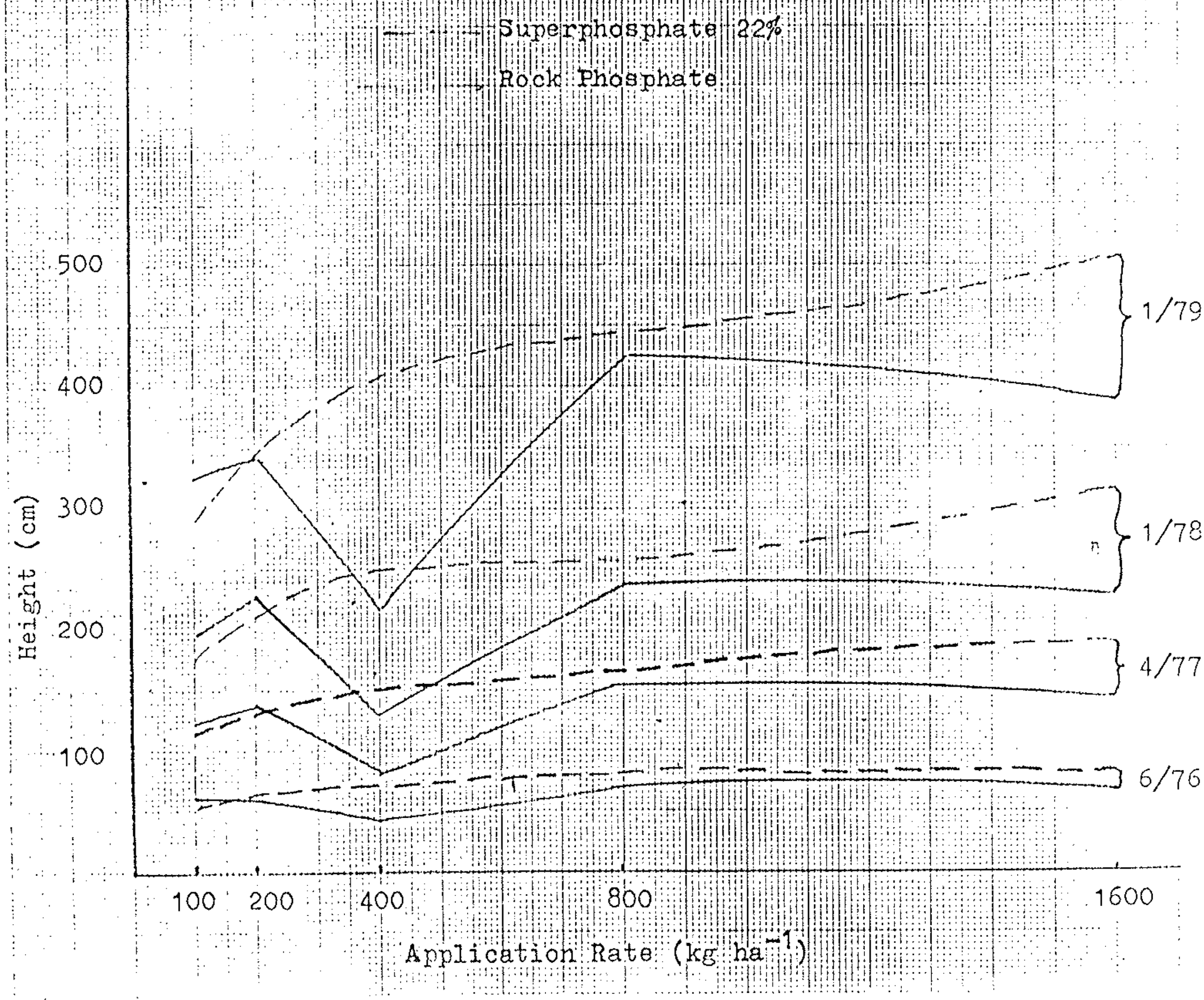
The trial was not replicated, with height and foliar nutrient levels being collected from 5 subplots within each treatment plot. 5 rates of each fertilizer, ranging from 100 to 1600 kg ha^{-1} were broadcast spread and lightly cultivated in prior to planting. Routine foliar sprays and a spot application of 120gm $tree^{-1}$ of S22 were applied to all treatments.

As the trial was unreplicated, only trends, and not statistically viable data can be gained, from the results. Figure 1 shows height versus application rate for each fertilizer.

Growth rate increases with application rate of S22. Foliar levels of P follow the same trend and are considered adequate for rates of 400kg ha^{-1} and above. For R.P. the growth response to application rate is confusing due mainly to extremely depressed growth rate at 400kg ha^{-1}. This may be due to site differences or a wrongly applied treatment. Growth was depressed at 1600kg ha^{-1}, indicating a possible toxic effect at this level. Foliar levels in response to R.P. rates of 800kg ha^{-1} and above were adequate. Below this rate levels were inadequate, but showed no obvious trends.

There appears to be a positive response to pre planting broadcast of both S22 and R.P. The optimum application rate and the most effective source of P, cannot be recommended due to inadequate trial design. Further investigation would be necessary to answer these questions.

FIGURE 1: Effect of broadcast application rate of Superphosphate 22% and Rock Phosphate on height growth of *P. radiata* growing in the Donnybrook Sunklands.



EVALUATION OF COMPOUND NP FERTILIZERS FOR THE ESTABLISHMENT OF *P. radiata*

W.P. 7/77 File No.: 244.113.18

The aim of this trial was to compare the growth of pine in response to several compound NP fertilizers on the basis of equal nitrogen or phosphorus content.

The higher rates of nitrogen lead to poor survival, even where there was an adequate balance of phosphorus (N:P of 1:2).

70 g/tree of MAP gave good growth and survival. Possible reasons for this are the correct balance of N to P and the amount of nitrogen applied would not cause mortality of the newly planted pine.

TREATMENT		N:P	HEIGHT (cm) $\frac{1}{2}$ - $2\frac{1}{2}$ YEARS	SURVIVAL (%)
300 g/tree M.A.P.	Equal N	1:2	196 abc	56b
200 g/tree D.A.P.		1:1	179 c	53b
200 g/tree Agras		1:½	189 bc	34b
400 g/tree Vigran		1:½	248 a	53b
70 g/tree M.A.P.	Equal P	1:2	226 abc	95a
80 g/tree D.A.P.		1:1	181 bc	81a

(L.S.D.'s $p < 0.05$)

TABLE; Growth and survival of *P. radiata* in response to several NP fertilizers.

Effect of Sulphur on establishment and growth of *P. radiata*

W.P. 8/77 File No. 244.113.19

This trial was established to investigate whether sulphur applied with triple super or triple super and urea would improve survival or growth of the pine.

The treatments were;

100g triple super }
200g triple super } ± 50g gypsum ± 50g Urea

This factorial trial was laid down in a randomized block design with four replications.

The application of gypsum nor the increased rate of triple super had any effect on the survival or height of the pine. Urea adversely affected both survival and height of the pine.

The extra triple super increased the foliar phosphorus levels although levels were adequate for all treatments. The addition of gypsum has had very little effect on foliar sulphur levels. The levels of copper were adequate but zinc and manganese levels were very unsatisfactory and are probably limiting growth of the pine.

There is no need to apply gypsum to *P. radiata* at establishment. Applications of Superphosphate probably provide adequate sulphur. Zinc and copper need to be applied to *P. radiata* grown in the Sunkland. Nitrogen should not be applied as urea. No more than 100 g/tree of triple super needs to be applied to establish *P. radiata*.

ATRAZINE APPLICATION TRIAL

Local Experiment File No.: 244.113.115

The aim of this trial was to determine if atrazine stimulates the growth of P. radiata under Sunkland soil conditions. Super 22% 150 g/tree and Agras 18:18 100 g/tree was applied to three plots each at planting. Atrazine (80% w/w) was applied using a pack spray in a 0.4 metre strip along the planting mound at rates of 0, 2.5 and 4 kg/ha.

The data was unable to be analysed due to lack of replication. Trends indicated that Super gave better growth than the Agras treatments and there was no response to Atrazine.

TABLE 1: Height growth and increment over 2 years (1978 - 80)

FERTILISER @ PLANTING	ATRAZINE KG/HA	MEAN HEIGHT 1980	TOTAL INCREMENT (1978 - 80)
Super 22% 150 g/tree	0	292	191
	2.5	284	180
	4	280	181
Agras 18:18 100 g/tree	0	248	156
	2.5	258	163
	4	251	159

THINNING AND FERTILIZING FOUR YEAR OLD P. radiata

File NO.: 244.113.25

Part of a four year old stand of P. radiata was thinned from 1850 sph to 850 sph. Half of each plot was then refertilized with 400 $kgha^{-1}$ of Agras No. 1. 200 crop trees per hectare were selected.

The stand was spot fertilized with Super at establishment. At age one and two years it was foliar sprayed with minor elements. 400 kg/ha of Super was applied at age 2 years.

There was a response to both thinning and fertilizing. (Table 1). The response to thinning was greater than that to fertilizing. Crop tree growth was reduced at the higher stocking. Less than 1700 sph should be established.

TABLE 1 Growth of *P. radiata* in response to thinning and fertilizing at age four years.

	D.B.H.O.B. (cm)			BA ha^{-1} (m^2ha^{-1})			D.B.H.O.B.			BA ha^{-1}		
	4 Yrs	7 Yrs	INCR	4 Yrs	7 Yrs	INCR	4 Yrs	7 Yrs	INCR	4 Yrs	7 Yrs	INCR
1700 sph 400 $kgha^{-1}$ Agras	8.34	10.8	2.5	10.83	17.75	6.9	11.2	14.3	3.1	2.0	3.3	1.0
1700 sph No Fert.	8.1	10.2	2.1	10.0	15.9	5.9	10.5	13.2	2.7	1.7	2.7	1.0
800 sph 400 $kgha^{-1}$ Agras	9.6	13.0	3.4	6.6	11.8	5.2	11.8	16.0	4.2	2.3	4.2	1.9
800 sph No Fert.	9.7	13.6	3.9	6.2	11.9	5.7	11.7	16.0	4.3	2.2	4.2	2.0

Alleviation of a manganese (?) deficiency in the Sunkland

File No. 244.113.16

In August 1978, a disorder was observed in *P. radiata* growing at Chapman's Lease. The same disorder was observed in the Cundinup 1 plot in September 1979. Agras had recently been applied to the plot.

Early visual symptoms were browning of the tips of older needles. This developed to severe necrosis of all the needles as summer approached. Foliar sampling of trees at Chapman's Lease revealed extremely low levels of manganese in unhealthy trees.

This experiment was initiated to investigate whether applications of manganese would correct the disorder. The Treatments were;

control
Foliar spray of 2.5% $MnSO_4$) $\pm$ 125 kg/ha $MnSO_4$ soil application

Each of the four treatments was applied to one plot only. The foliar sprays were applied in December 1978 and July 1979. The soil application was carried out in April 1979. Foliar samples were collected from 16 trees per plot every three months.

By the end of the study period almost all of the trees had recovered from the disorder. This recovery was not in response to applications of manganese nor were foliar levels of manganese considered adequate for some plots.

Levels of manganese varied considerably prior to any treatment being applied. There was a slight increase in manganese levels in the foliage by the end of the study period, but this could be due to seasonal fluctuations in nutrient concentrations.

This trial casts doubt upon deficiencies of manganese being the cause of the disorder. Deficiencies of manganese are generally first apparent in the younger needles. The older needles were the first to be affected at Chapman's Lease. If manganese is mobile then it may be withdrawn from foliage which is dying due to some other cause. The affected trees should be further analysed to determine whether there are deficiencies of other nutrients.

Season and site could also be influencing the occurrence of the disorder. Both plots were on a grey sand site and had been pastured for several years prior to the pine being planted. The disorder occurred in late-winter and spring in successive years.

Table: Foliar levels of manganese in response to application of $MnSO_4$. The critical level of manganese is 30ppm.

Date	Treatment			
	Control	Foliar spray	Soil application	Foliar and soil application
Sept. 1978	18.8 ± 5.7	13.4 ± 6.3	5.2 ± 5.3	18.8 ± 7.9
Feb. 1979	34.8 ± 11.8	24.1 ± 5.6	10.9 ± 3.8	28.9 ± 5.9
June 1979	30.9 ± 17.5	16.8 ± 6.0	12.0 ± 5.1	25.4 ± 6.3
Oct. 1979	29.4 ± 11.9	22.8 ± 3.4	24.0 ± 6.3	40.4 ± 7.8

REFERTILIZATION OF THREE-YEAR-OLD PINUS PINASTER IN THE SUNKLAND.

Healthy three-year-old Pinus pinaster Ait. growing on yellow sand were fertilized with four rates of an NP compound ("Agras No. 1") and one rate of superphosphate. An unfertilized control was also included. Rates of "Agras" ranged from 200 kg.ha^{-1} to 1600 kg.ha^{-1} and for superphosphate the rate was 655 kg.ha^{-1}, the latter having an available P content equivalent to 800 kg.ha^{-1} of "Agras".

Height increment of trees decreased as the rate of nitrogen increased. Plots receiving 655 kg.ha^{-1} of superphosphate and 200 kg.ha^{-1} of "Agras" grew significantl more ($p < .05$) than other treatments in the second year after treatment (Fig. 2). A remeasurement one year later showed that the differences in height increment between treatments had decreased. Diameter increments were not significantly different betwe treatments, although there was a positive correlation ($p < .05$) between tree diameter and rates of "Agras". A strong negative correlation ($p < .05$) existed between the height/diameter ratio* and rate of "Agras" (Fig 1.).

This study suggests that there is little advantage in refertilizing P.pinaster with "Agras" on yellow sands in the Sunkland. While a small increase in diameter growth can be expected after applying high rates of "Agras" (> 800 kg.ha^{-1}), the cost to do so is not warranted. The increase in tree taper that results may also be a disadvantage. It appears from this trial that superphosphate is a more cost effectiv fertilizer.

$$\text{* Height/diameter ratio} = \frac{\text{Height of tree (m)}}{\text{D.B.H.O.B. (cm)}}$$

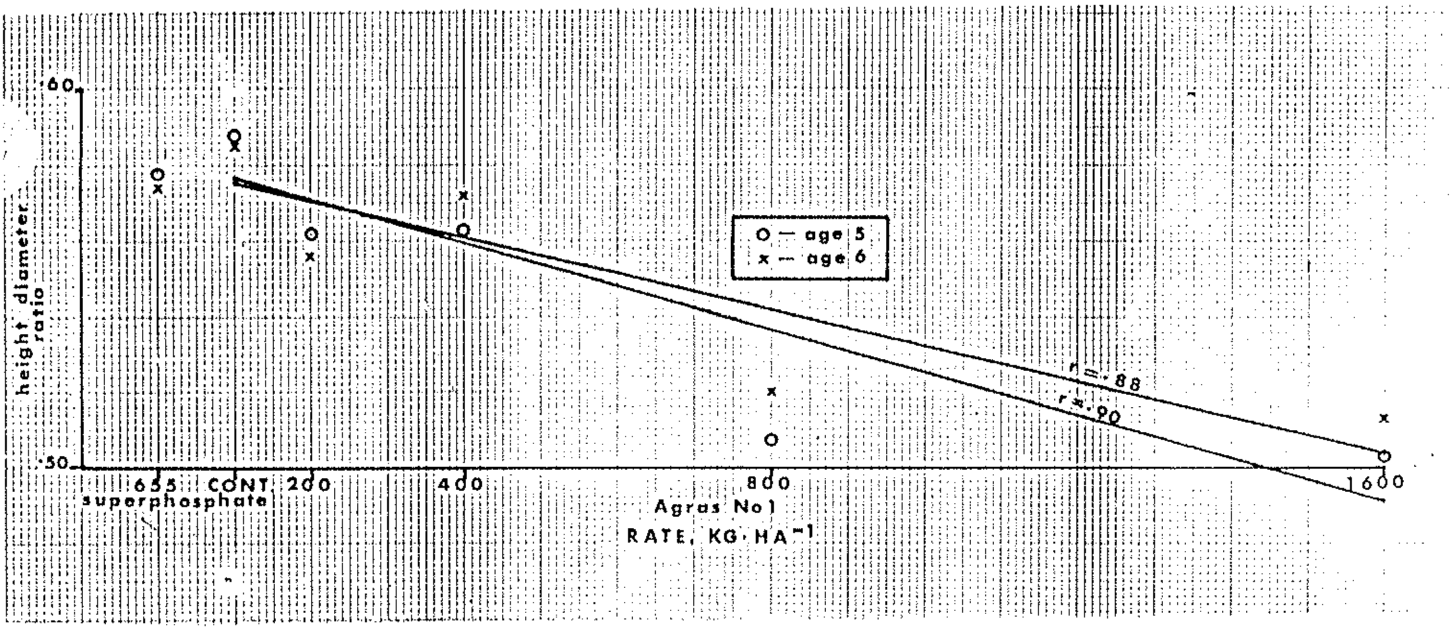


Figure 1.

Relationship between the height/diameter ratio of P. pinaster and rate of "Agras".

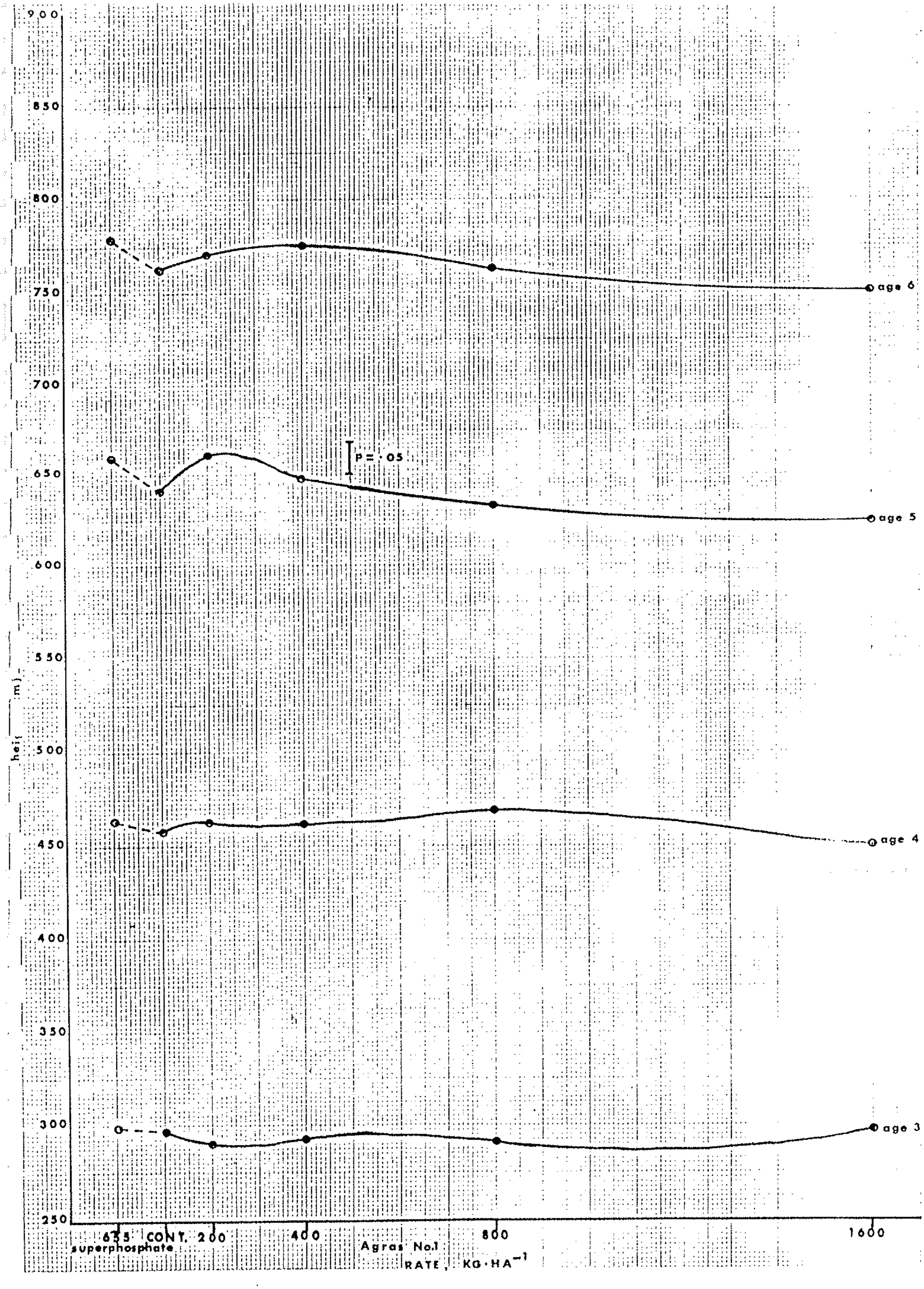

900
850
800
750
700
650
600
550
500
450
400
350
300
250
P = ·05
age 6
age 5
age 4
age 3
635 CONT. 200 400 800 1600
superphosphate
Agras No.1
RATE, KG·HA^{-1}

Figure 2.

REFERTILIZATION OF THREE-YEAR-OLD PINUS TAEDA ON THE SUNKLAND

W.P. 17/79 File No. 244.113.22(1)

Four rates of a compound NP fertilizer ("Agras No. 1") were applied to healthy three year old Pinus teada L. growing on yellow sand. The rates of "Agras" ranged from 200kg ha^{-1} to 1600kg ha^{-1} and an unfertilized control was included.

Differences in height growth between treatments were not significant although data show a trend of increase in height increment at lower rates (200 and 400kg ha^{-1}) (Figure 1). During the third year after refertilization trees fertilized with 400, 800 and 1600kg ha^{-1} "Agras" grew significantly more ($P < 0.05$) than control in terms of diameter increment (Figure 2). However there was no significant difference between treatments in terms of mean diameter (D.B.H.O.B.). There was a positive correlation ($P < 0.05$) between tree diameter and rate of "Agras". The correlation between height/diameter ratio and rate of "Agras" was negative and highly significant ($P < 0.01$).

This experiment suggests there is no value in fertilizing 3 year old P. taeda on the Sunkland. Whilst diameter increment (Figure 2) suggests that growth rate is significantly more with 400kg ha^{-1} total height and total diameter data showed that there was no significant increase in growth. Although the correlation between rate of "Agras" and height/diameter ratio is highly significant it is not possible to predict at this stage whether the effect on tree taper will be significant in milling potential.

FIGURE 1: Height growth of *P. taeda* on yellow sand on the Sunk and following refertilization at age 3 years. Four rates of a compound NP fertilizer ("Agras No. 1") were tested.

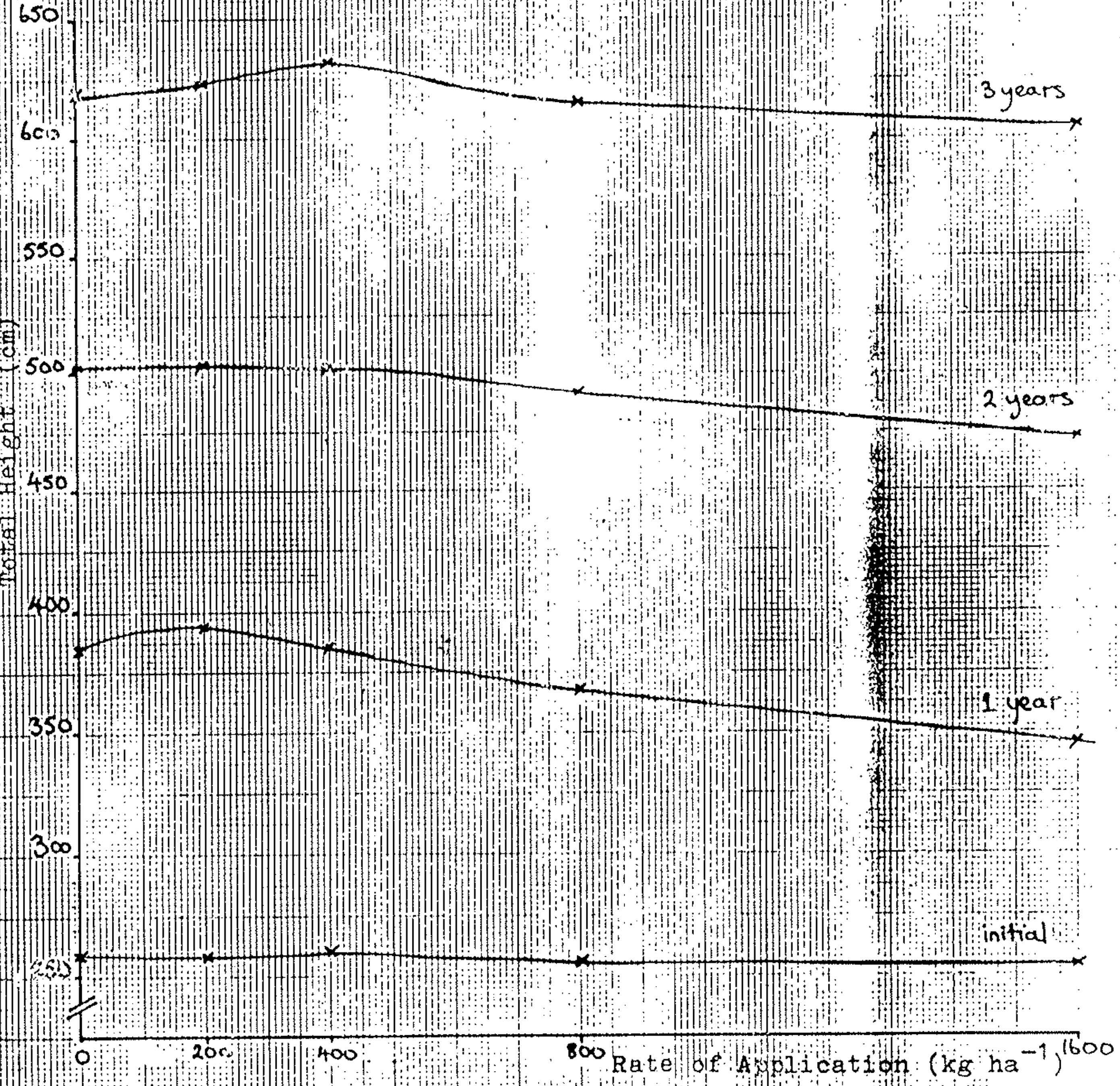
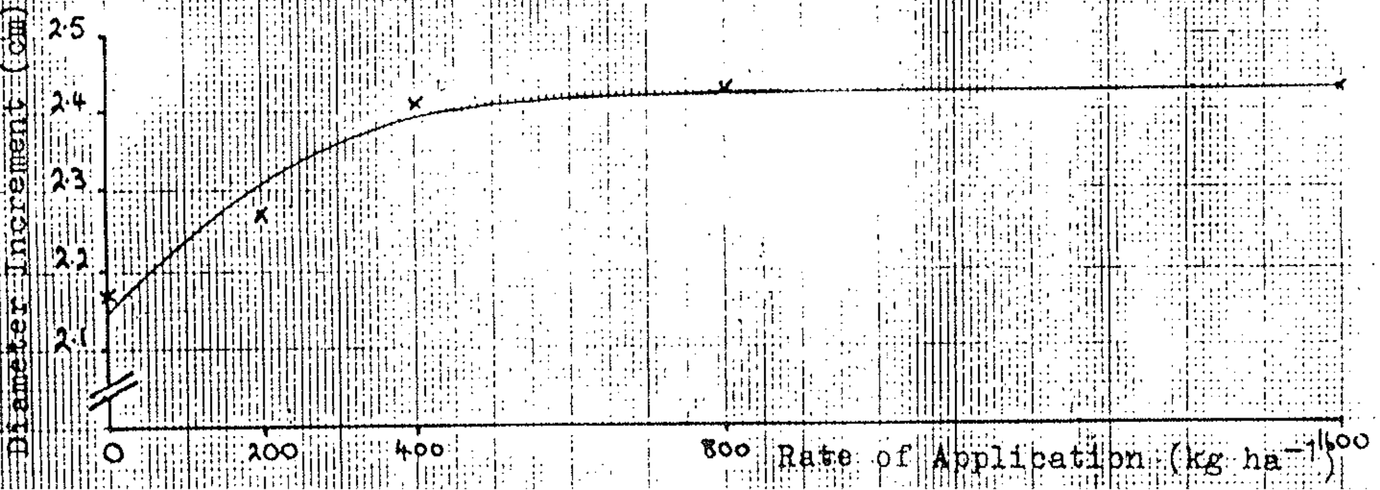


FIGURE 2: Diameter increment (cm) during the third year after fertilization for 4 rates of "Agras No. 1". Data not having the same letter are significantly different at the P 0.05 level.



REPORT

1979 LUDLOW POT TRIALS (W.P.'s 15/77, 16/77 and 17/77)

Three separate pot trials were carried out with *P. radiata* looking at optimum ratio of N:P, sources and rates of zinc and the need for zinc, copper and manganese.

METHOD:

The following method was used for all three experiments.

The soil used was a grey sandy loam from the Sunkland. Six kilograms of soil was used per pot. Four one year old *P. radiata* seedlings were planted per pot. Seedlings had been planted in a washed river sand and 'starved' for 10 weeks prior to planting.

Soil in pots was maintained at 60-75% field capacity. Twenty five weeks after the first application of nutrients the length of new growth was measured. The plants were then harvested, divided into old and new growth and dried to determine oven dry weights.

EXPERIMENT 1: Sunkland NP Pot Trial 1977 - W.P. 15/77.

The aim of this experiment was to determine the optimum ratio of N:P for *P. radiata* growth on Sunkland grey sandy loam.

The design of the experiment was randomized block with a factorial arrangement of 4 phosphate rates and 3 nitrogen rates. The 12 treatments were replicated 3 times. Details of treatments are shown in Table 1.

TABLE 1

Treatment No.	Treatment	Amount of N and P (kg/ha equivalents)	Ratio N:P
1	$N_0 + P_0$	0 : 0	–
2	$N_1 + P_0$	9 : 0	–
3	$N_2 + P_0$	72 : 0	–
4	$N_0 + P_1$	0 : 18	–
5	$N_1 + P_1$	9 : 18	1 : 2
6	$N_2 + P_1$	72 : 18	4 : 1
7	$N_0 + P_2$	0 : 72	–
8	$N_1 + P_2$	9 : 72	1 : 8
9	$N_2 + P_2$	72 : 72	1 : 1
10	$N_0 + P_3$	0 : 180	–
11	$N_1 + P_3$	9 : 180	1 : 20
12	$N_2 + P_3$	72 : 180	1 : 2.5

RESULTS:

The only significant finding (at P = 0.05 level) was that N_2P_2, N_2P_3 and N_2P_1 are better than the control in terms of both height growth and oven dry weight of new growth (Table 2).

TABLE 2 Height of new growth in cm and oven dry weight of new growth (g) of *P. radiata* seedlings at termination of experiment.

	P_0		P_1		P_2		P_3	
N_0	14.5	(9.9)	19.0	(11.0)	13.3	(9.8)	17.7	(11.2)
N_1	14.8	(9.3)	19.7	(12.9)	21.5	(10.8)	21.5	(14.1)
N_2	17.6	(13.0)	20.8	(15.8)	24.2	(14.8)	24.4	(18.8)

Although there are no other significant findings the data does indicate an NP interaction. When N and P are combined the growth is better than either N or P on its own. For example whilst P alone (N_0P_2) produced 9.8g in O.D.W. and N alone (N_2P_0) produced 13.0g the combination of the two (N_2P_2) produced growth of 14.8g (Table 2).

Other trends are;

1. The best growth was achieved with the higher N rates rather than the highest P rates.
2. With zero N there was little response to increasing rates of P.
3. With zero P there was a response to increasing rates of N.
4. Increasing rates of N whilst keeping P constant produced a better response than keeping N constant and increasing rates of P. The growth increase from N_2P_0, through N_2P_1 to N_2P_2 for example, was 1.8g O.D.W. whereas increasing the N rate while P remained constant (N_0P_2, N_1P_2, N_2P_2) produced a 5.0g O.D.W. growth.

DISCUSSION:

The most significant finding was that the highest rates of N and P produced the best growth. There was no significant difference in growth of the top three fertiliser treatments - N_2P_3, N_2P_2 and N_2P_1.

../4

On a per hectare basis N_2P_2 contained 72kg N and 18kg of P. 18kg of P is equivalent to 200kg of Super which is the current rate of refertilisation every second year for pine on clover on the sunklands. A similar tie with field rates exists with N. A study of nitrogen build-up in the soil by clover under P. radiata (W.P. 17/80) showed that over six years the average annual N input at the No. 7 Road plot was 66kg/ha/yr. The rate of N in the treatments that produced the best growth in this trial was 72kg/ha. These figures show that the rates that produced the best growth in the pot trial broadly correspond with the rates of the current field regime for pine on clover on the Sunkland. The range of rates tested in this experiment do not allow the optimum levels of N and P to be determined ~~however~~, a wider range of rates would need to be tested.

Unfortunately the differences between treatments are not large enough to determine the best ratio of N:P. Furthermore the ratios tested are rather discontinuous and make interpretation difficult. The experiment would have been improved by starting at an N:P ratio of 1:1 at about optimum rates and varying the ratios up and down from there.

There are trends that suggest that N may be more limiting than P. Increasing rates of P produced little response with zero N while with zero P there was a response to increasing rates of N. Further evidence is the better growth response to increasing N rates with P constant than to increasing P with N constant. These observations are not consistent with the findings of Waring (1971) who showed that increasing rates of N, (with zero P), depressed growth. Our result may be attributable to an unknown source of P or results being not significant.

EXPERIMENT 2: Minor Element Pot Trial No. 1 - W.P. 16/77

The native levels of zinc in Sunkland soils are so low that if zinc is not applied within a few months of planting, *P. radiata* seedlings will not grow. The practise of spraying each pine with a solution of zinc sulphate has been generally successful but further work is required to refine the technique.

This pot trial aimed to determine whether zinc sulphate is as effective a zinc oxide and what rate of zinc is optimum for growth of *P. radiata* during establishment on Sunkland soil.

RESULTS:

Table 3 presents mean oven dry weights of new growth for all rates and forms of zinc. There are no significant differences between any of the treatments.

TABLE 3

Treatment		Rate of Zinc		Mean Oven dry weight of new growth (g)
No.	Form of Zinc	g/pot	kg/ha	
1	Zn O	0	0	16.4
2	0.1M solution	0.006	2.5	18.0
3		0.012	5	17.7
4		0.027	10	15.2
5		0.042	15	13.1
6		0.083	30	16.4
7	Anhydrous	0	0	14.3
8	$ZnSO_4$	0.006	4.7	16.2
9	0.05M sol.	0.012	9.45	18.2
10		0.027	21.05	19.1
11		0.042	32.67	16.7
12	0.01M sol.	0.083	64.40	16.7

../6

DISCUSSION:

The fact that growth of pine seedlings in control pots was not different from treated pots suggests that there may have been contamination of zinc. A small but known source were the fungicides (Ridomil and Benlate) which were applied on three occasions. Ridomil contains 20ppm, which would have contributed about 20 micrograms of zinc to each pot. Such an amount is very small being 300 times lower than the lowest treatment rate. Therefore it is likely that there were other unknown sources of zinc.

EXPERIMENT 3: Minor Element Pot Trial No. 2 - W.P. 17/77

The native levels of zinc, copper and manganese in Sunkland soils are low and some, if not all three elements, need to be applied to P. radiata to ensure satisfactory growth. This pot trial aims to determine if additions of all three elements are necessary for growth of P. radiata on a Donnybrook Sunkland grey sandy loam.

RESULTS:

Table 4 presents mean oven dry weights of new growth for all treatments. There are no significant differences between any of the treatments.

TABLE 4

Treatment				Mean Oven Dry weight of new growth (g)
No.	Copper	Manganese	Zinc	
1	-	-	-	12.8
2	-	-	+	10.7
3	-	+	-	10.0
4	-	+	+	10.4
5	+	-	-	12.0
6	+	-	+	10.1
7	+	+	-	11.2
8	+	+	+	7.5

DISCUSSION:

Growth of seedlings in the control pots was better than all other treatments (not significantly better however). Equally unexpected was the growth of treatment 8 (all elements applied) where growth weights were lower (not significantly) than all other treatments. These trends and the lack of significant findings suggest that as with Experiment 2 there may have been an unknown source of minor elements.

Richard Moore

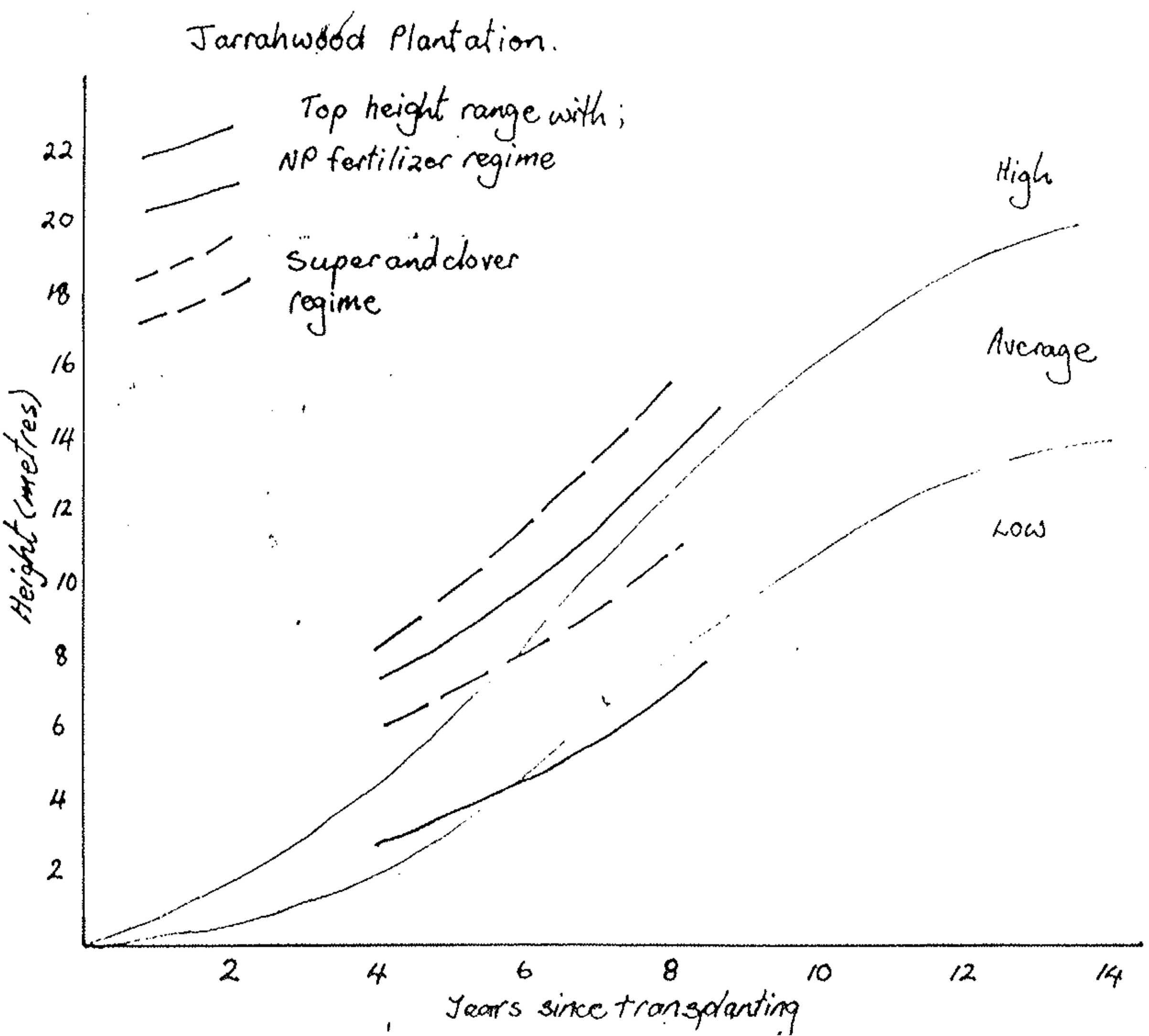
December 1981

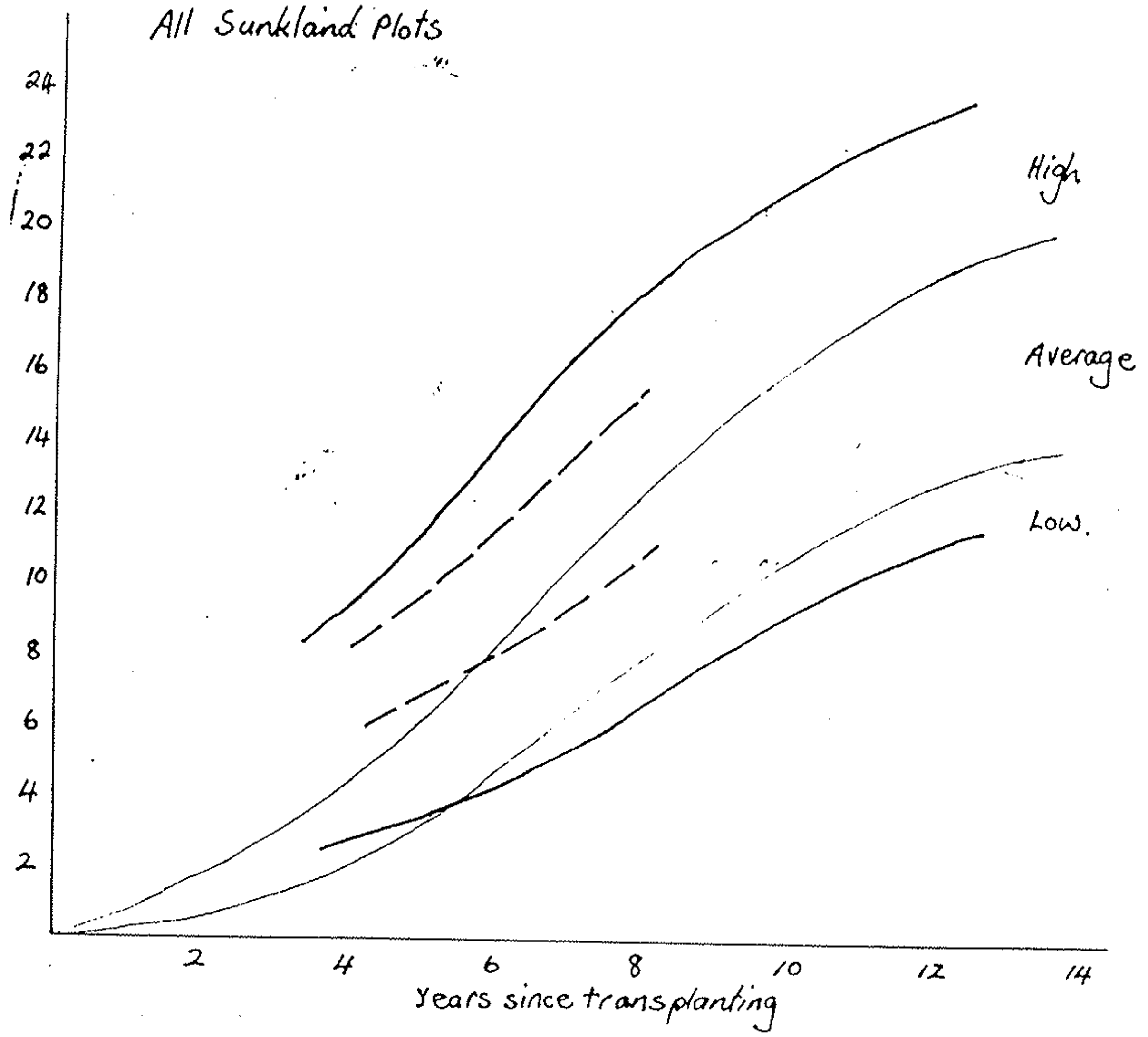
Growth rates of P. radiata under different nutrition regimes

Early in the life of the Sunklands project, P. radiata was established and refertilized using "Agras No. 1", an inorganic nitrogen and phosphorus fertilizer. The generally poor growth in response to refertilizing with this fertilizer prompted the adoption of a 'super and clover' regime.

A comparison of top height data of P. radiata in plots and older plantation in the Sunkland shows that to age 8 years the 'Super and Clover' regime will result in a stand of average to high quality, while the Agras regime will produce a stand of only average quality.

The potential for maintaining growth of the pine will be greater with the 'Super and Clover' regime due to the higher soil levels of N, P, and Cu which are achieved than with the 'Agras' regime.





All Sunkland Plots
24
22
20
18
16
14
12
10
8
6
4
2
2
4
6
8
10
12
14
Years since transplanting
High
Average
Low.

CHEMICAL CONTROL OF EPICORMIC SHOOTS ON FOUR YEAR OLD *Pinus radiata*

W.P. 39/82 File No.: 249.2

The aim of this trial was to compare six chemicals and to determine the optimum rate for controlling young (< 10cm) epicormic shoots during spring. Rates were determined from an earlier pilot trial. The trial was laid out on a 4 year old clovered Pinus radiata stand. The following chemicals and rates were applied:-

Trade Name	Chemical	Rates (mls/l)
1. "Reglone"	diquat	3, 6, 12
2. "Gram oxone"	paraquat	3, 6, 12
3. "Daconate 8"	800 g/l M.S.M.A.	6, 12,24
4. "Brominil"	200 g/l bromoxynil	12, 24, 48
5. "Amitrol Plus Herbicide"	250 g/l Amitrol + 220 g/l Ammonium thiocyanate	50, 100, 200
6. "Roundup"	glyphosate	20, 40, 80

A control treatment was also included. "Agral 60" (wetting agent) was added to treatments 1, 2 and 5 at 1 teaspoon/litre.

Treatments were randomly allocated according to epicormic stem coverage and given a 0 - 4 rating, where 0 = 20% and 4 = 80% stem cover. Prior to spraying, all trees where form pruned; all branches were removed up to a point where the stem diameter equalled 10cm. Above this point, forks, steeply angled or large branches were removed. Large retained branches were also tip-pruned when considered necessary. Treatments were applied with a "Solo" hand sprayer and the epicormics sprayed to run-off, to a height of approximately 2.1 metres.

The trial was assessed 3 weeks and again 6 months following spraying. Tree height and diameter were measured prior to spraying and at the 6 month assessment.

Interim results indicate that "Reglone" and "Gramoxone" at all rates show 100% kill to epicormics. "Daconate 8" at 24 ml/l shows 80% kill, whilst "Amitrol Plus" has given 90% kill at 100 and 200 ml/l. Other treatments show moderate results.

Measurement trends indicate that "Gramoxone" has caused height and diameter increment loss.

Field observations indicate chemical translocation effects at the medium and high rates of "Amitrol Plus". "Roundup", at the high rate, also shows some translocation effects.

CHEMICAL CONTROL OF EPICORMICS IN *P. radiata*

Local Experiment File No.: 249

The aim of this pilot trial was to screen and compare six different herbicides in controlling advanced epicormic shoots on 8 year old *P. radiata*. Manufacturers recommendations for controlling broadleaved weeds were used as a guide for application rates. The following chemicals and rates were applied:-

Trade Name	Chemical	Rate (ml/l)
1. "Reglone"	diquat	6
2. "Gramoxone"	paraquat	6
3. "Triquat"	paraquat + diquat (2:1)	8
4. "Brominil"	200 g/l bromoxynil	6
5. "Amitrol Plus"	250 g/l Amitrol + 220 g/l Ammonium thyocyanate	100
6. "Roundup"	glyphosate	

"Agral 60" (wetting agent) was added at 1 teaspoon/litre to all treatments except 4 and 6.

All trees were assessed and rated according to the intensity of epicormic development. Treatments were randomly allocated within groups from a ranked list. Treatments were applied in June using a "Solo" hand sprayer and the epicormic shoots were sprayed to run-off.

The trial was assessed 3 weeks, 3 months and 13 months after spraying, using a linear scale where 0 = no effect and 5 = dead.

The results indicated that "Reglone", "Gramoxone", "Triquat" and "Amitrol Plus" will kill epicormics using the above rates. "Brominil" and "Roundup" had very little effect.

Another trial using these chemicals and 3 rates was implemented following early results gained from this experiment. (see W.P. 39/82)

1980 EPICORMIC STUDY IN THE CENTRAL REGION

Local Project

A preliminary assessment of the incidence of epicormics in the Central Region was carried out in December, 1980. The study covered the following Divisions in Pinus radiata plantations that were planted from 1968 - 1975: Harvey, Collie, Nannup, Kirup and Busselton.

During the study, each compartment was given a 0 - 5 visual severity rating where 0 = severe or > 80% of the compartment was affected by epicormics and 5 = slight or < 20% of compartment was affected by epicormics.

This study indicated that:-

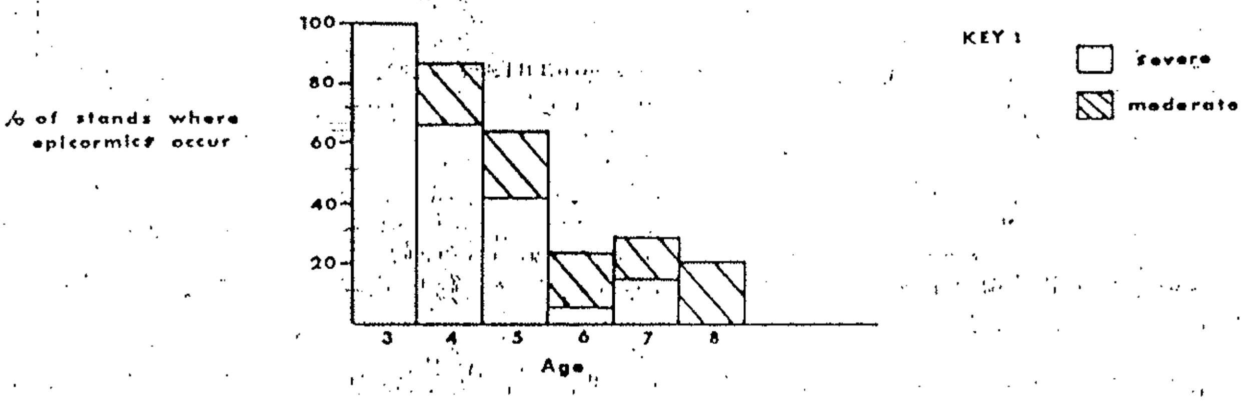
1. There were 1402 ha affected by severe epicormics in the Busselton, Kirup and Nannup Divisions.
2. Ex-pasture plantation sites possess a greater tendency to develop epicormic shoots and larger or heavier branches than ex-native bush sites (see Table 1). This may be due to high nitrogen/phosphorus levels in pastured soils.
3. There is a decline in the severity of epicormic shooting with increasing age of plantations at pruning (see figure 1).
4. The current silvicultural treatments to Fuel Reduced Buffer plantations act as a stimuli in the development of epicormic shoots.
5. Silvicultural techniques can be used to control epicormics. This can be achieved by avoiding early thinning and pruning. Pruning during autumn or winter also reduces the incidence of epicormics.

TABLE 1 : Site difference on compartments from 1968 - 1975 plantings.

SEVERITY RATING	EX-BUSH	EX-PASTURE
Severe > 60%	31%	69%
Moderate 20 - 60%	43%	57%
Slight < 20%	34%	60%

Figures were taken from Kirup, Nannup and Busselton Divisions.

FIGURE 1 : Age at pruning compared with severity of epicormics.



SUMMARY DATA: NON-COMMERCIAL THINNING TRIAL - W.P. 30/83

JARRAHWOOD COMPARTMENT 5 (P.79) DATA AT AGE 4.7, 5.6, YEARS

TREATMENT	P/N	DBHOB 3/83	DBHOB 2/84	DBHOB Incr. 83/84	Basal Area / HECTARE 3/83	Basal Area / HECTARE 2/84	BA/ha Incr 83/84	CURRENT STOCKING PLOT	CURRENT STOCKING HECTARE
250 S.P.H.	8	8.49	13.55	5.06	1.51	3.75	2.24	19	257
	11	9.14	13.75	4.61	1.70	3.82	2.12	20	256
	16	7.41	11.59	4.18	1.26	2.92	1.66	21	253
	17	9.53	13.96	4.43	1.90	4.01	2.11	17	258
	20	9.37	13.13	3.76	1.82	3.53	1.71	17	258
MEAN		8.79	13.20	4.41	1.64	3.61	1.97	19	256
500 S.P.H.	1	8.98	12.53	3.55	3.36	6.42	3.06	36	507
	4	6.84	10.43	3.59	2.24	4.88	2.64	32	492
	12	9.44	13.37	3.93	3.74	7.42	3.68	36	514
	15	7.82	11.91	4.09	2.73	6.08	3.35	28	500
	18	7.62	11.14	3.52	2.63	5.27	2.64	35	493
MEAN		8.15	11.88	3.73	2.93	6.01	3.08	33	501
750 S.P.H.	2	7.72	11.33	3.61	4.04	8.18	4.14	52	754
	6	6.22	9.96	3.74	2.70	6.58	3.88	52	743
	7	7.74	11.45	3.71	3.93	8.34	4.41	52	754
	9	5.54	8.81	3.27	2.27	5.30	3.03	51	750
	13	8.00	11.60	3.60	4.32	8.63	4.31	51	750
MEAN		7.04	10.63	3.59	3.45	7.41	3.96	52	750
1000 S.P.H.	3	8.47	11.81	3.34	6.30	11.74	5.44	61	1000
	5	5.53	8.78	3.25	2.91	6.85	3.94	64	941
	10	7.04	10.32	3.28	4.52	9.28	4.76	69	1000
	14	6.56	10.21	3.65	3.84	8.60	4.76	60	923
	19	6.56	9.92	3.36	3.60	7.57	3.97	66	868
MEAN		6.83	10.21	3.38	4.23	8.81	4.58	64	946
750 S.P.H. (OFF CLOVER)	21	9.12	12.07	2.95	5.09	8.58	3.49	61	726

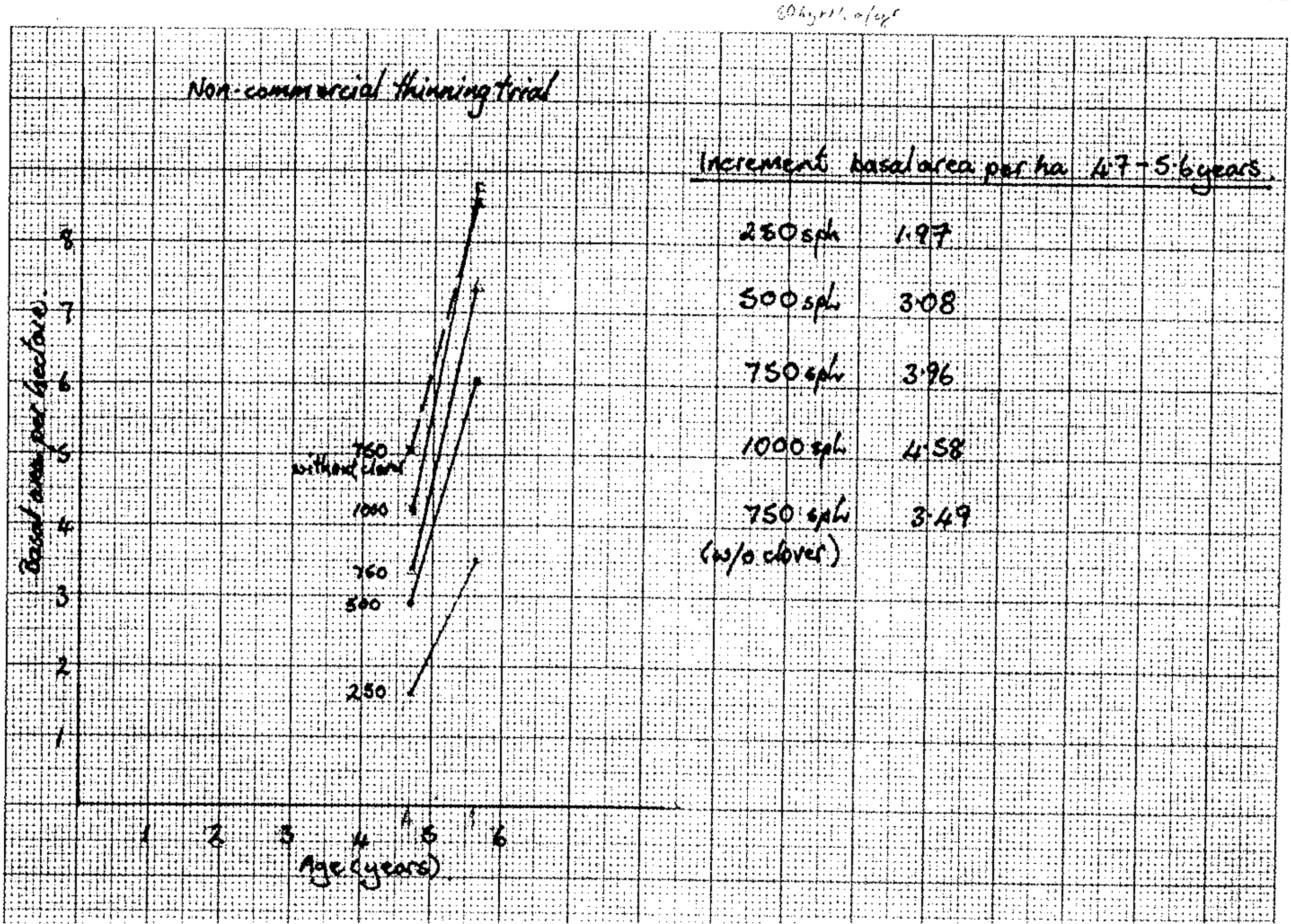
8/8/84

Table Growth of P. radiata, and soil nutrient levels, at the time of non-commercial thinning, 3½ years after establishment.

Stems per ha	DBHOB(cm)	BA ha^{-1}	Height(m)
250	8.79	1.64	5.66
500	8.15	2.93	5.22
750	7.06	3.45	4.76
1000	6.83	4.23	4.68
750 non-clovered	9.12	5.09	6.07

Soil nutrient levels

		Org. Carbon (%)	Total Nitrogen (%)	Available Phosphoru (ppm)
Clovered plots	Min	0.59	0.024	2.03
	Max	1.64	0.073	9.99
	Mean	0.91	0.045	5.67
Non-clovered plot	Mean	0.49	0.027	7.83



Sunkland Thinning Trial

W.P. 21/78 File No. 242.16

This trial was established to investigate the effect of intensity of early non-commercial thinning on timber production of the stand , especially sawlogs. The effect of wide initial spacing on branch development was also to be studied.

The trial area was planted in 1972 at 2.7 x 2.1m spacing (1760 sph). The stand was thinned at age 6 years to the following densities:

1. 1700 sph
2. 1150 sph
3. 650 sph
4. 400 sph
5. 250 sph

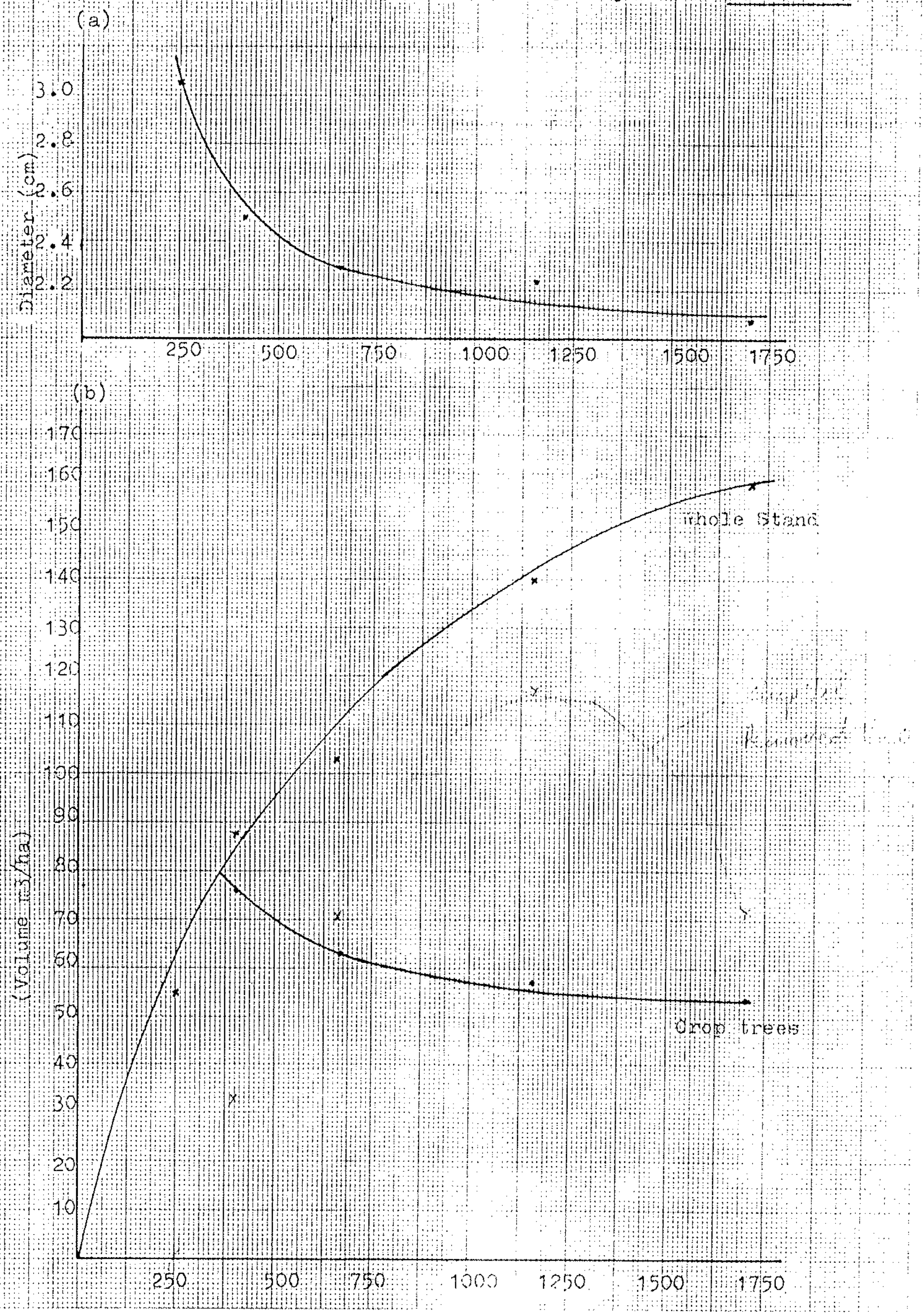
Diameters of the branches in the 2 to 5m bole section were measured on five trees at age 9 years. 350 sph were high pruned in the same year and volumes were calculated the following year.

There was an increase in branch diameters at the lower stockings. Branches were dead, or greatly suppressed at 1700 sph.

Total volume increased with higher stockings. However, average diameter of the stand decreased as did volume of the 350 sph selected as crop trees. There was 25% greater volume on the crop trees at a stocking of 350 sph than at 1150 sph.

Experience from New Zealand (Radiata Pine Task Force) shows that economic returns from a regime involving NCT to a final crop are greater than for a multi-thinning regime. Increases in branch growth resulting from early thinning are not significant as they are more than compensated for by increased stem growth.

Fig. Branch (a) and stress growth (b) of 9-10 year old *P. radiata*



THINNING - WIND STABILITY STUDY

W.P. 6/83 File No.: 251.1

This trial was to see whether thinning 12 year old P. radiata in the Donnybrook Sunkland to various densities would affect the growth and wind firmness of the trees.

The stand was thinned from 1100sph to 500, 350, or 200sph. There were six replicates of each treatment in a randomized block design. An average of $85m^3\ ha^{-1}$ was removed from the plot, making the thinning a viable commercial operation. The trial was located on a deep grey sand. Some wind lean occurred prior to thinning.

In November 1982, nine months after thinning there had been a small increase in the amount of windlean but this did not appear to be related to stand density. Damage was concentrated in a few plots.

Individual trees were growing faster in diameter at the lower stand densities but basal area was being accumulated faster at the higher stand densities.

This trial suggests little wind damage will occur following commercial thinning of P. radiata in the Sunkland. The chance of damage will vary, however, according to individual circumstances.

TABLE 1: Growth and stability of 12.5 year old P. radiata following thinning to various densities in the Donnybrook Sunkland. The trees were assessed 9 months after thinning.

	D.B.H.O.B. (cm) increment		B.A.O.B. (m^2ha^{-1}) increment		Δ in leaning trees (%)
200 sph	23.07	1.24a	8.05	0.67a	4.7
350 sph	21.70	1.02ab	13.14	1.21b	12.2
500 sph	21.91	0.93b	19.13	1.63c	8.2
	$p < 0.05$		$p < 0.05$		

WIND DAMAGE IN THE SUNKLAND

W.P. 1/81 File No.: 25.1

Wind damage has occurred in several of the older plots in the Sunkland (Table 1). This has generally followed thinning. Windthrow i very uncommon, having only occurred in one older P. pinaster plot. Windlean is the more common occurrence.

It has been observed that the trees became windfirm again two to three years after thinning.

TABLE 1: Wind damage of pine in the Sunkland

Age (years)	Thinning History	Area Affected	Windthrow (%)	> 5° lean (%)	HT (m)	(m : cm) HT : Dia
P. radiata						
8½	Thinned from 1700sph to 650sph 2½ years previously.	Windward edge of plot.	0	20	9.0	0.6
9½		Windward edge of plot	0	27	16.6	0.9
9½	Thinned from 1700 to 750sph at age 4 years and to 500sph at age 8 years. Very wet in winter.	Windward edge of plot	0	27	11.0	0.6
6½	Thinned from 1100sph to 400sph the previous year. Site is wet in winter.	~1 ha of plantation	0	17	8.8	0.7
P. pinaster						
5½	Unthinned, standing at 1100sph	~½ ha of plantation	0	30	7.3	0.6
19½	Thinned from 1700sph to 750sph at age 9 years and to 250sph at age 19 years.	~2 ha of plantation along a drainage line.	37	63	16.7	0.7

ESTABLISHMENT OF PINE WITH PASTURE

File No.: 264.45

The No. 7 Road plot was the earliest plot established in the Sunkland with the 'Super and clover' regime.

The native forest was cleared, windrowed and burnt in the summer of 1972/73. The plot was then disc ploughed using a 2 - 4 metre Connor Shea plough. The area was left fallow till 1974 due to heavy winter rains.

The area was ploughed again in the spring of 1974. 400 kg/ha of Super Cu Zn 'B' and 200 kg/ha of Super were applied with 10 kg/ha of Mount Barker sub clover and 5kg/ha of Wimmera rye grass. The plot was refertilized with 200 kg/ha of Super in 1975, 1977 and 1981.

The plot was not mounded and the P. radiata was planted by Quick wood planting machine. Half the plot was planted in 1975, the remainder in 1976.

Fertilizer and weed control for establishing P. radiata into pasture
The area of P. radiata planted in 1975 was divided into four plots to test whether fertilizer and weed control was necessary for establishment. 150 g/tree of Super was applied with and without a spot Vorox spray. An untreated control was included.

	CONTROL		150 g/tree SUPER	
	Height (cm)	Survival (%)	Height (cm)	Survival (%)
Control	53.5	66	47.3	57.5
Spot Vorox	68.7	81	72.9	88

TABLE 1: Survival and growth of P. radiata in response to fertilizer and weedicide applications when established with pasture in the Sunkland.

Control of competition from pasture dramatically improved growth and survival of the pine. The spot application of fertilizer marginally improved growth of the pine. The broadcast application of Super may have provided sufficient phosphate to the pine.

First thinning of pine stands grown with Super and clover

W.P. 7/83 File 264.47

Currently, high quality radiata pine stands are being thinned at approximately 12 years to obtain two 5.4m logs per tree. There may be disadvantages in following this regime in the Sunkland. There is a risk of wind damage following thinning, clover is shaded out of the plantation for six to eight years and growth will not be concentrated on the crop trees.

Possible means of carrying out a thinning before age 12 years would be to accept a single 5.4m length per tree or extract 2.7m lengths.

Eight plots, each 25 x 40m were laid out in No. 7 Road plot 350 crop trees per hectare were selected from 900 sph at age 6 years and pruned to 5 metres. The remaining trees were assessed to determine the volume of either 2.7 or 5.4m logs obtainable if the stand were thinned. Extraction tracks were not worked. The stand was assessed at age 6.3 and 7.7 years.

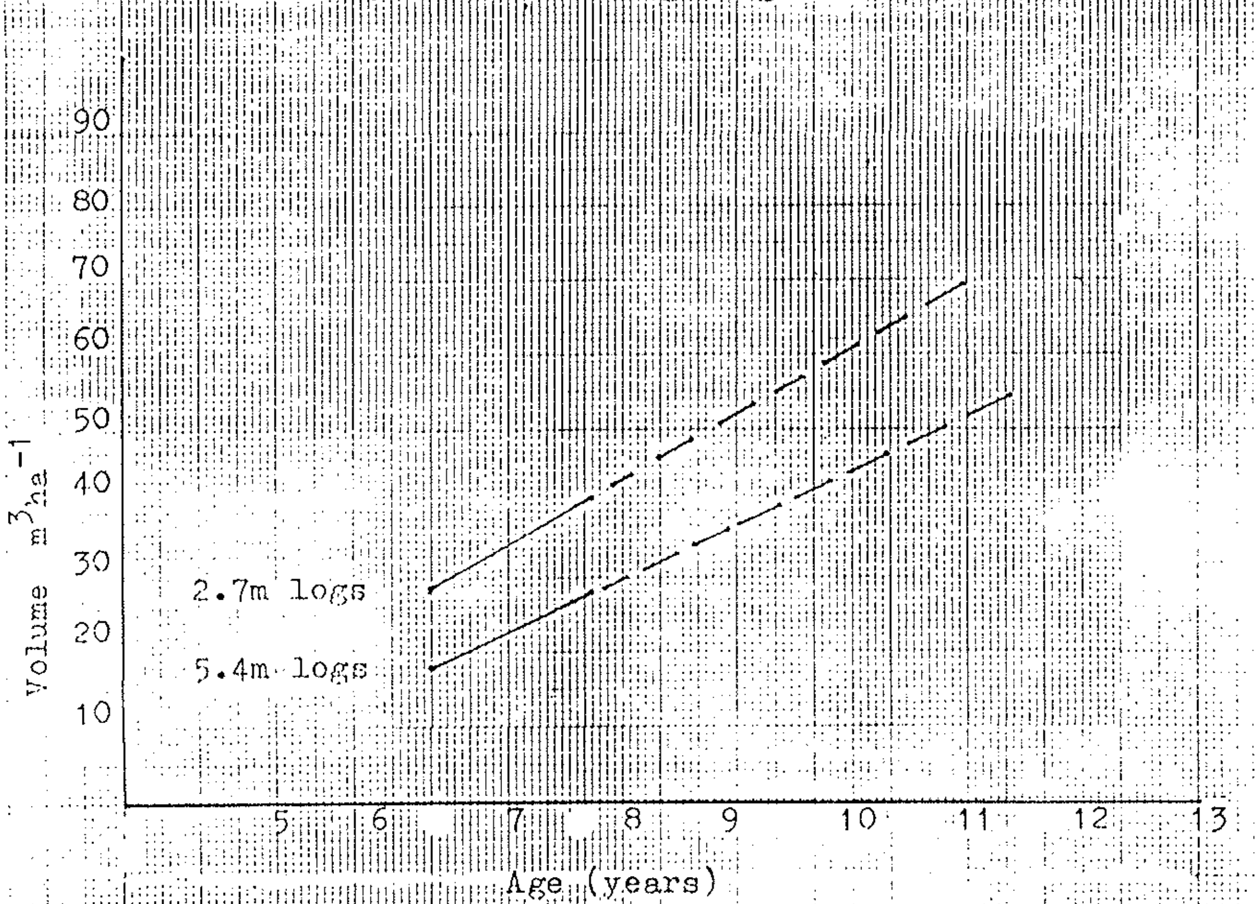
At age 7.7 years by extracting 2.7m lengths rather than 5.4m lengths the volume of thinnings was increased by 42% and would allow thinnings to be carried out two years earlier. Over the 1½ year period between assessments the volume of thinnings increased by 11.5 m^3ha^{-1}. 90% of this increase was in the 5.4m log class. As only an average of 34 trees ha^{-1} (3.4 m^3ha^{-1}) moved from the 2.7 to 5.4m log class most of this increase was due to an increase in the radial growth of individual logs.

Trees destined to be thinned were increasing in diameter much faster than the crop trees. In fact, as a result of selective high pruning of the crop trees there was a loss of 25% of potential diameter increment (Fig. 2). This trend was also reflected in basal area (Fig. 3).

At age 7.7 years the average height of the stand was 13.8 metres, making this a high quality stand. Theoretically then, a commercial thinning could be carried out at age 12 years.

However with the adoption of smaller, more efficient logging equipment earlier thinning, extracting either a single 5.4m length per tree or 2.7m lengths, could be carried out. This would give a more wind stable stand with greater volume production on the crop trees.

Fig. 1 Volume productions from thinning 560 sph extracting either 5.4m or 2.7m log lengths.



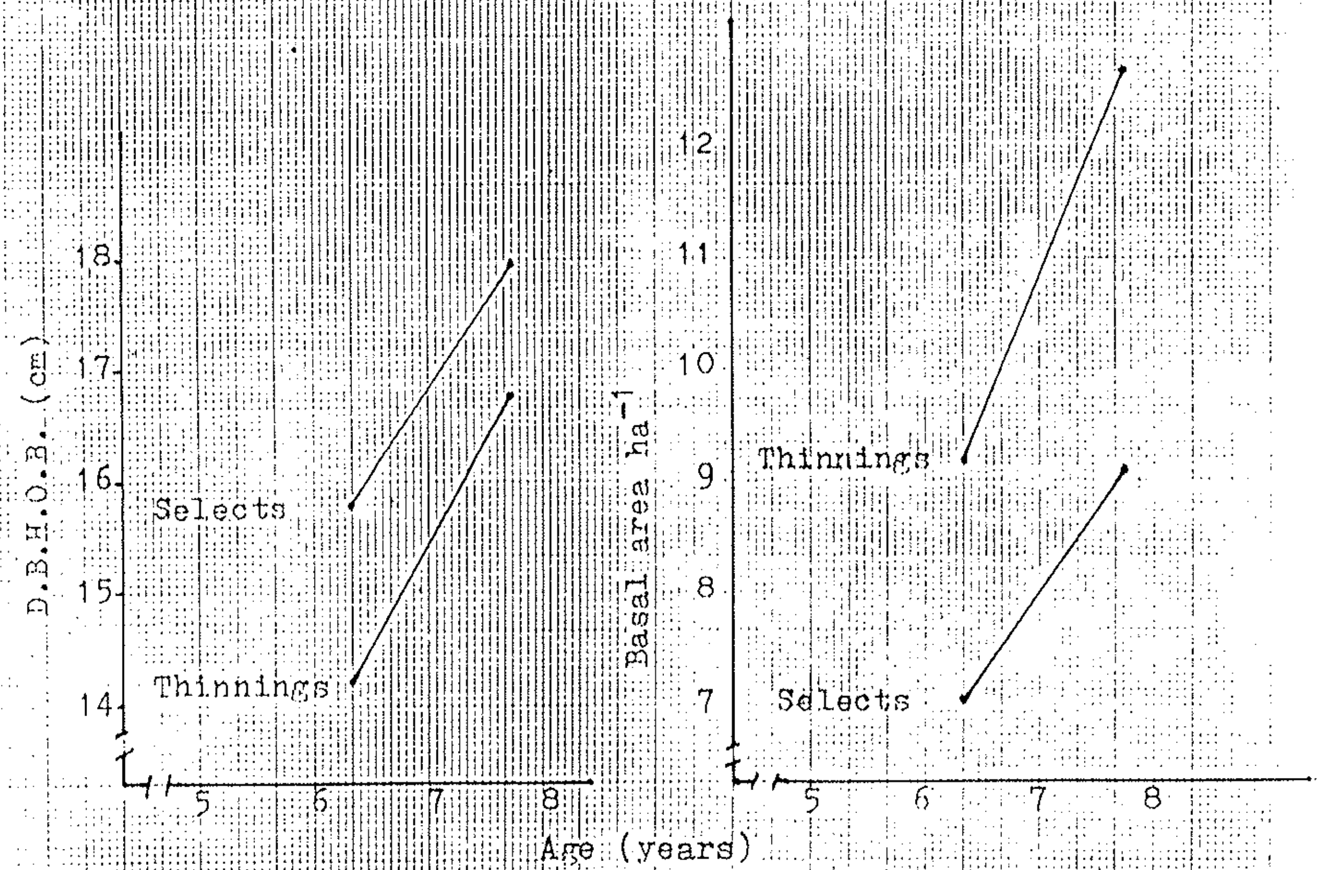


Fig. 2 & 3 Diameter and basal area growth of selects and thinnings. The select were high pruned to 5m at age 6 years.

CHEMICAL THINNING - AN ALTERNATIVE IN AGROFORESTRY?

Local Experiment File No. 264.22

The trial was to assess chemicals to determine if any are suitable for culling unwanted trees in an agroforestry regime.

Hatchets were used to notch each tree at waist height, with notches placed 8cm apart around the trunk. 2 mls of test chemical was placed in each notch. Treatment was applied in late summer to approximately 100 trees for each chemical. The trial was not replicated.

TABLE 1 shows the chemicals used and their efficacy rating 1 year after treatment.

TABLE 1

where 0 = no effect
1 = <50% crown reduction
2 = >50% crown reduction
3 = tree dead

CHEMICAL	0	1	2	3	2&3
Roundup ($360gl^{-1}$ Glyphosphate)	0	0	37	63	100
Banex ($200gl^{-1}$ Dicamba, amine salt)	0	36	63	1	64
Ustilan ($700gkg^{-1}$ Ethidimuron)	96%	4	0	0	0
Banex + Roundup	0	3	72	25	97
Daconate ($800gl^{-1}$ M.S.M.A.)	0	73	27	0	27
Dicamba (VEL 4092 ester salt)	0	70	30	0	30

Roundup showed the best results, with all trees being either severely affected or killed. Banex plus Roundup severely affected health, but deaths were much lower. Ustilan was ineffective.

Future work should test rates of Roundup and study application techniques and costs.

FOLIAR NUTRIENT LEVELS WITH TWO FERTILIZER STRATEGIES IN THE SUNKLAND

File No.: 264.45

The foliar nutrient levels of *P. radiata* grown under an NP fertilizer regime and grown with Super and clover were compared.

The Super and clover treated plots received 500kg/ha of SuperCuZnMo No. 2 at the time of clover establishment. They were then refertilized with 200kg/ha of Super approximately every two years. The pine received a spot application of 150 g/tree of Super CuZn'B' at planting.

The NP regime consisted of 100 g/tree Agras No. 1 at planting and 400kg/ha of Agras No. 1 at age 3 years. The trees received a copper, manganese and zinc foliar spray in the first year after planting.

		N	P	K	CU	Mn	Zn
No. 7 Road - 4 years	Super and Clover	1.25M	0.25	0.90	6.8	54	36
	NP fertilizers	1.49M	0.14M	-	4.0M	44	21
No. 6 Road - 6 years	Super and Clover	1.47M	0.24	-	7.3	36	44
	NP fertilizers	1.40M	0.19	-	5.6	86	40

M = Marginal level.

TABLE: Foliar nutrient levels of *P. radiata* grown with two nutrition regimes in the Donnybrook Sunkland.

In both regimes foliar nitrogen is marginal, while phosphorus is adequate in the Super and clover regime but not always with the NP fertilizer regime. Copper and zinc appear to be more available with with the Super and clover regime.

Foliar analysis is known to have many pitfalls and so this data should be treated with caution.

FORESTS DEPARTMENT OF WESTERN AUSTRALIA

REPRINT NO. 18

Reprinted, with permission, from Project-Group 202, Proceedings of Oslo meeting June 1976. IUFRO.

Sawlog Silviculture in Western Australian Pine Plantations

by

F. H. McKinnell.

SAWLOG SILVICULTURE IN WEST AUSTRALIAN PINE PLANTATIONS

by

F.H. McKINNELL
(Forests Department, Busselton, Western Australia,6280)

Paper presented to XVI IUFRO Congress, Oslo, Norway, 1976.

ABSTRACT

Silvicultural regimes at present used in Western Australia are described. The aim of the regimes is to produce high quality sawlogs in the shortest possible time, the two species involved - Pinus radiata and Pinus pinaster being grown on rotations of 30 and 40 years respectively. Techniques used are wide initial spacing, strictly timed pruning schedules and heavy thinning to concentrate the growth potential of the site on to the final crop trees. The implications of the regimes for wood quality, tree growth and land use are discussed.

INTRODUCTION

The bulk of the sawn timber used in Western Australia comes from the native hardwood forests of jarrah (Eucalyptus marginata Sm.) and karri (E.diversicolor F. Muell). These forests are, however, very limited in extent and are unable to meet the demands made upon them. Although the growth rate of karri is quite rapid (8-10 m^3/ha/year), that of jarrah, which provides by far the greatest proportion of the yield, is disappointingly slow (about 1 m^3/ha/year).

For a number of reasons, both economic and social, it is desired to maintain the existing level of sawlog yield in W.A. In order to do this it will be necessary to progressively replace about half the native hardwood yield of 1,000,000 m^3 a year with Pinus radiata and P.pinaster grown on relatively short rotations of 30 and 40 years respectively.

The situation is now becoming urgent, in that it now appears necessary to provide for an annual pine sawlog yield of 500,000 m^3 by the year 2000. Most plantings of exotic pines in W.A. date from the mid-1950's, but significant areas were not planted until the inauguration of a Federal-State agreement in 1965 which provided long term loans for pine planting.

The current silvicultural regime applied to pine plantations is therefore a rather radical one which aims to produce sawlogs in the shortest practicable time. It is recognized that such an approach to silviculture sacrifices a significant percentage (probably about 12 per cent) of the potential total volume production, but this sacrifice is considered more apparent than real, since the loss is entirely in the small log sizes which present severe marketing problems.

On purely economic grounds "sawlog silviculture" can be shown to be much more profitable than conservative regimes which aim at maximum volume production (see, for example Fenton 1972a) so long as there is a reasonable log price: size gradient. In Western Australia this is the case now and the gradient can be expected to increase in the future as log supplies become more keenly sought after.

There is a further very important advantage to the current silvicultural regime under W.A. conditions. The climate is a typical Mediterranean type with a long summer drought. The lack of summer rain, at its best, is the factor most limiting to tree growth and, at its worst, is responsible for severe drought death when stands are allowed to become overstocked. This regime, which maintains the crop at a low stocking throughout the rotation, avoids such problems. Since greater water availability means a longer growing season for the crop there is a positive growth response in terms of individual tree diameter. Since the trees grow longer during the period of latewood formation it is probable there will be no serious reduction in wood density as a consequence of the more rapid growth.

SILVICULTURAL REGIMES

The regimes in current use for the two species concerned are briefly as follows:

Year	P.radiata	P.pinaster
0	Plant 1100/ha (3.5 x 2.5m)	Plant 1100/ha
5	Low prune all stems to 2.1m	-
6	-	Low prune all stems to 2.1m
7	High prune 125/ha crop trees to 4.5m	-
8	-	High prune 125/ha crop trees to 4.5m
11-12	First commercial thinning to leave 250/ha	-
14-15	-	First commercial thinning to 250/ha
18	Second commercial thinning to leave 125/ha	-
25	-	Second commercial thinning to leave 100/ha
30	Clear fell	-
40	-	Clear fell

As yet no stands have been grown on a full rotation on these regimes but the following yield are expected on the basis of thinning research trials:

	P.radiata	Output	P.pinaster	Output
1st thinning	100m³/ha	chipwood, fence posts	53m³/ha	chipwood
2nd thinning	50m³/ha	chipwood	30m³/ha	chipwood
	90m³/ha	sawlogs 20 cm s.e.d.	26m³/ha	sawlogs 20 cm s.e.d.
Clear felling	70m³/ha	chipwood	50m³/ha	chipwood
	280m³/ha	sawlogs 20 cm s.e.d.	120m³/ha	sawlogs

The aim in each case is to produce a final crop tree of 55 cm DBHOB, and the evidence from inventory data and research indicate that this will be achieved. To illustrate the growth trends, Figure 1 presents the standing basal area data from age 6 to 15 for an experiment comparing three approaches to thinning, namely a sawlog regime, a multi-thinning long rotation regime, and a pulpwood (no thinning at all) regime. The three stands are compared on the basis of the largest 250 stems per hectare, which in the case of the sawlog regime is all stems at age 15.

Up to the age of 8 years there was essentially no difference between the three regimes, but from that age onward the sawlog stand growth trend commenced to diverge from the others. After the thinning at age 11, the divergence became dramatic. It will be seen that the sawlog regime will produce a most useful yield of moderately large sawlogs at age 18, a sawlog yield which will be roughly twice that of the multi-thinning regime at the same age. Average piece size will also be larger, an important factor in the economics of harvesting (Chandler, 1969).

DISCUSSION

The first question which might be asked is whether the wood so produced will not be of inferior quality due to its fast growth, on the one hand, and the possibility of larger branch size in the unpruned part of the tree, on the other. To the first point, the answer is a qualified no. The effect of rate of growth on wood quality has been the subject of great debate in the literature, but it is now generally agreed that growth rate per se does not significantly reduce intrinsic wood quality. However, since a fast grown tree of a given size will contain a greater proportion of juvenile wood, the overall tree density (and therefore wood quality) will be somewhat lower. This is not seen as a problem in W.A. since the observed range of P.radiata wood density of 440-480kg/m^3 (on a weighted whole tree basis) is considered satisfactory. The newly-developed high temperature seasoning techniques (Christensen, 1970) will overcome the stability problems associated with the presence of juvenile wood.

The probable development of larger limbs on the lower bole as a result of wide spacing is eliminated in the final crop trees by high pruning. Above the pruned zone it is accepted there is likely to be some reduction in wood quality due to increased knot size, but at least there will be fewer dry, loose knots. The problem is more acute in P.pinaster, so acute, in fact, that consideration is being given to high pruning all 250 stems/ha to remain after the first commercial thinning. New hydraulic pruning shears under development are expected to make this operation no more expensive than the former 125 sph operation by hand held pole saw.

On the whole, it is expected wood quality may be slightly reduced under this extreme sawlog regime, compared with that produced by a more conservative multi-thinning regime, but the reduction is expected to be of an order of magnitude less than that due to natural variation observed in pines growing on different soil types.

An important aspect to this silvicultural regime is the reduced proportion of the yield in small sized logs (that is, logs smaller than 20cm s.e.d.). In W.A. these have always presented a marketing problem and this situation is unlikely to change significantly.

The essence of the current regime is the maintenance of a low stocking of the pine in all stages of the rotation. The stocking is so low, in fact, that the crop does not fully occupy the site for a large proportion of the rotation. There are two important practical implications of this which have a large bearing on land use in W.A.

Firstly, sawlog plantations do not intercept as much rainfall as more conservatively thinned plantations would. This means there is greater recharge of soil moisture (Butcher & Havel, 1975) and therefore potentially greater water yield. Since most of the P.pinaster resource is planted over a major water resource a workable compromise between wood and water production is vital.

Secondly, the low tree stocking enables the maintenance of either a grass or shrub understorey, depending on the situation. In the former case there is scope for the integration of livestock grazing and plantation silviculture with consequent reduction in fire hazard, beneficial effects on tree nutrition and financial returns from agistment fees. The economic aspects of this have been extensively studied in New Zealand (e.g. Fenton, 1972b). Improvement in tree nutrition results from accession of stock manure, the periodic phosphate fertiliser required to maintain the pasture, fixation of atmospheric nitrogen by legume pasture plants and faster nutrient recycling due to trampling of needle litter. This technique has now reached the operational stage in plantations established on former farmland sites in Western Australia.

On sites where the understorey vegetation is native herbs and shrubs which have been allowed to regenerate after clearing for pine establishment, grazing may sometimes be feasible (McKinnell, 1974). However, if the understorey does not compete seriously with the tree crop for water and nutrients, they provide a habitat and food source for native fauna, thus increasing the conservation value of the plantation areas.

REFERENCES

Butcher, T.B. & Havel, J.J. 1975. Influence of Moisture Relationships on Thinning Practice. Paper presented to meeting of I.U.F.R.O. Division 4, Melbourne, April 1975.

Chandler, W.G. 1969. Pine Plantations - A Private Enterprise Investment.Aust. Timb. J. 34 (12): 200-207.

Christensen, F.J. 1970. Breakthrough in Drying Softwoods. For.Prod. News. CSIRO 377: 3-4.

Fenton, R. 1972a. Radiata Pine Afforestation Studies. N.Z. J. For. Sci., 2(3): 378-388.

Fenton, R. 1972b. Economics of Radiata Pine for Sawlog Production N.Z. J. For. Sci., 2(3): 313-347.

McKinnell, F.H. 1974. Control of Weeds in Radiata Pine Plantations by Sheep Grazing. Aust. For. Res. 6(4):1-4.

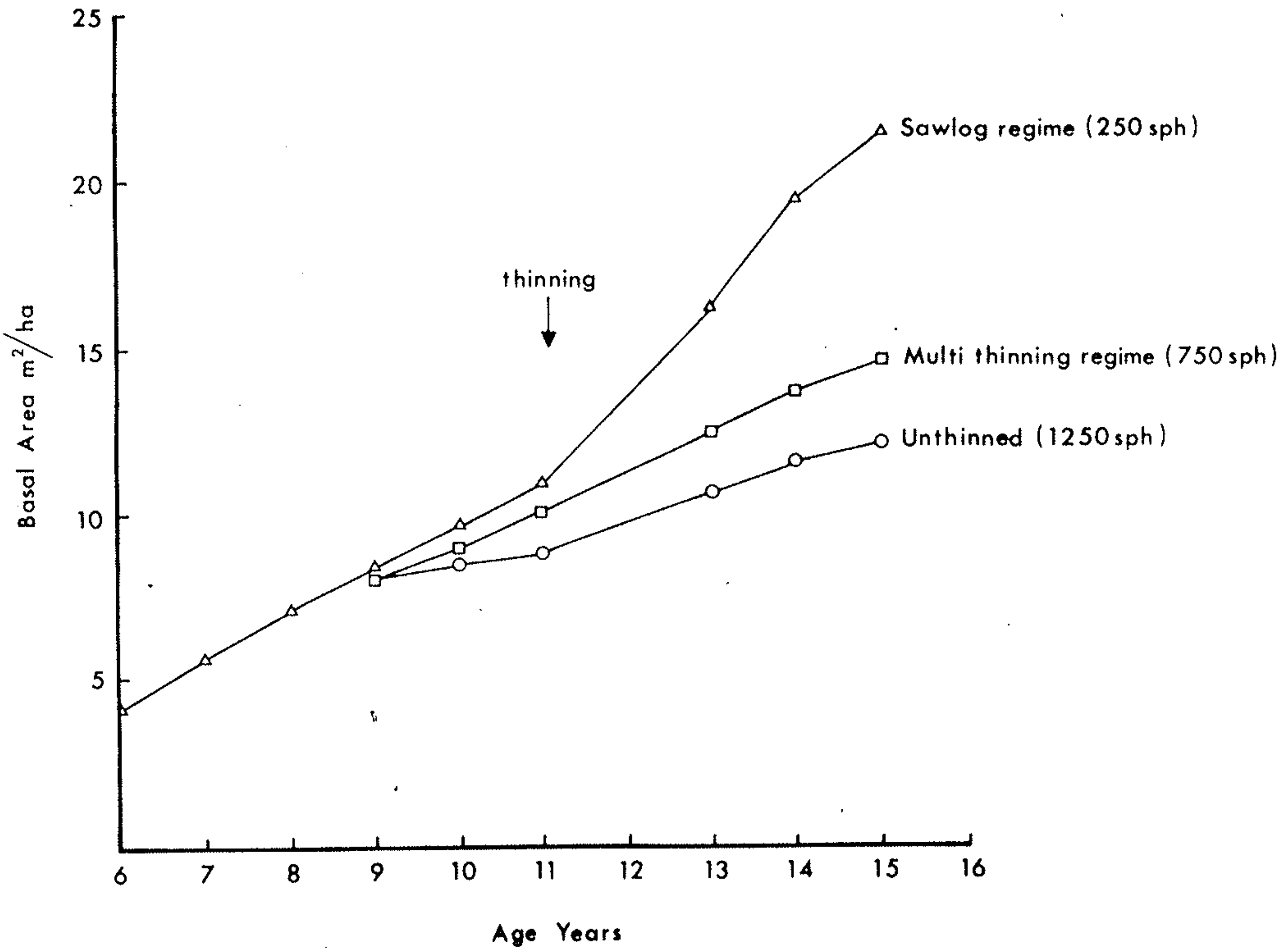


FIG. 1: Basal Area Largest 250 SPH

LEGUME TRIALS IN WESTERN AUSTRALIAN PINE PLANTATIONS

A.B. Hatch

SUMMARY

The combination of pines and a legume understorey provides a rapid means of increasing the soil nitrogen status, and accumulation of 350 kg ha^{-1} of nitrogen have been recorded in some young W.A. pine plantations.

The preliminary data indicates that much of the increased soil nitrogen is held in the humic acid fraction of the soil.

INTRODUCTION

The combination of conifers and a legume understorey is a recent development in plantation forestry and many aspects of this work are still in the experimental stage. Some important aspects of this integration of agriculture and forestry have been discussed at a workshop organised by the C.S.I.R.O. Division of Land Resources Management (Howes & Rummery, Eds., 1977). Another general review of this subject has been given by McKinnell & Batini (1978).

As this workshop is devoted to the nitrogen economy of forest ecosystems I do not propose to discuss the economic aspects of this form of forestry, but I would like to indicate how agro-forestry can increase the amount of nitrogen in a plantation ecosystem.

EXPERIMENTAL

Composite surface soil (0-10 cm) samples were collected from three agroforestry trials in the Busselton Forest Division, 200 km S.S.W. of Perth. The areas were a series of paired plots, one half being the agroforestry trial and the adjacent area receiving normal plantation establishment treatment. The soils of these areas have been described by Smith (1951) and belong to the Mungite Soil Series. The experimental areas consist of widely spaced P. radiata with a sward of subterranean clover as a ground cover.

The fertiliser treatments for the two plots were:

(a) clover pasture; at establishment 500 $kg.ha^{-1}$ of super., copper, zinc, B. (8.4% P, 10.2% S, 0.33% Cu and 0.3% Zn) followed by an annual dressing of 100 $kg.ha^{-1}$ of the above fertiliser.

(b) routine plantation; 100 g/tree at planting of Agras No 1, (17.5% N, 7.6% P and 16.0% S) followed by a broadcast application at 3 years of 400 $kg.ha^{-1}$ of the Agras fertilizer. In addition, the young pines received a copper, manganese and zinc sulphate spray during the first year in the field.

The soil samples were analysed by standard laboratory procedures to estimate the build up of the soil organic matter by the clover sward.

RESULTS

The analytical data for the three areas is shown in Table 1. Statistical analysis of the organic carbon and nitrogen data showed that only the main effects due to the locality and clover were significant (Appendix 1).

These soils have a mean bulk density of 1600 $kg.ha^{-1}$ and using this figure it is a simple calculation to show that the nitrogen accumulation in the first 10cm of the three clover plots has amounted to:

Chapman Lease	352 $kg.ha^{-1}$
No. 6 Road	432 $kg.ha^{-1}$
No. 7 Road	400 $kg.ha^{-1}$

In an attempt to determine if there is a change in the form of the soil nitrogen under the clover sward, two nitrogen availability indices were examined. These were extracted with (1) dilute sulphuric acid (Purvis & Leo, 1961) and (2) the sulphuric acid potassium permanganate extractant suggested by Stanford & Smith (1978). The results are shown in Table 2 and this data indicate that there is some evidence of a decline in the percentage of nitrogen extracted by these reagents under the clover.

TABLE 1

Jarrahwood Agroforestry Trials

Effect of Clover on Surface Soil Properties

Location	No. of years under pasture	Clover	pH	T.S.S. %	O.C. %	N %	P - ppm Total	Bray	Olsen	CEC m.e.%
Chapman Lease	10	+	5.44	0.004	1.35	0.082	38	18	6.5	6.89
		-	5.52	0.003	1.43	0.060	6	0.6	1.0	8.84
No. 6 Road Agroforestry plot	5	+	6.30	0.006	1.32	0.066	67	12	1.5	9.36
		-	5.94	0.004	0.79	0.039	17	1.3	0.1	7.66
No. 7 Road Agroforestry plot	6	+	5.72	0.003	1.12	0.051	29	13	2.2	
		-	6.02	0.002	0.57	0.026	7	1.0	0.2	

TABLE 2

Jarrahwood Agroforestry Trials
Nitrogen Availability Indices

Location	Clover	Purvis & Leo N ppm	Purvis & Leo Percent of Total N.	Stanford & Smith N ppm	Stanford & Smith Percent of Total N
Chapman Lease	+	59	7.2	36	4.4
	-	58	9.7	48	8.0
No. 6 Road	+	42	6.3	34	5.1
	-	45	11.6	41	10.6
No. 7 Road	+	67	13.1	49	9.6
	-	53	20.2	22	8.4
Means (all areas)	+		8.9		6.4
	-		13.8		9.0

Hydrolysis of the soil nitrogen by 6N hydrochloric acid showed very little difference in the percentage of nitrogen extracted by this method, viz:

ie Hydrolysable N doesn't represent available N

Clover	Percent of Total N Extracted by 6N HCl Hydrolysis
+	67.2
-	70.2

Similarly, the amino acids released by this hydrolysis were very similar in both sets of soils:

Clover	Percent of Total N Extracted as amino acid nitrogen
+	68.0
-	68.2

Possibly N is accumulated as humic acid

Extraction of the soil organic nitrogen by alkaline sodium pyrophosphate (Kononova, 1966) showed marked differences between the two sets of soils. The percentage of nitrogen extracted was similar for both, but it was clearly evident that the proportion of humic acid nitrogen was much higher under the clover (Table 3)..

TABLE 3

Jarrahwood Agroforestry Trials
Organic Nitrogen Fractionation

Clover	Percentage of total N extracted by alkaline pryophosphate	Humic acid N as percentage of total N
+	43.0	14.1
-	43.0	8.1

DISCUSSION

It is evident that an agroforestry regime can cause a rapid (5 years) build up of soil nitrogen at a site and this technique could provide an important nutrient addition to some of our impoverished plantation soils.

This accumulation of nitrogen by legumes is not new work, as our colleagues in agriculture have used this technique to maintain and improve soil fertility for many years.

There is insufficient data at present to be able to comment definitely on the changes in the nature of the soil nitrogen, but the change in humic acid nitrogen is worthy of further investigation.

Moore (unpublished data) has indicated that P. radiata growing on clover trials at Jarrahwood appear much healthier and more vigorous than trees growing on non-clover areas and foliar nitrogen levels from one of these trials support this observation. This particular trial after 5 years under clover showed a foliar nitrogen level of 1.59% nitrogen, which is more than adequate for satisfactory pine growth.

Its one way pushing N input.

There are of course, silvicultural problems associated with this plantation management technique and trials covering these aspects are currently being investigated.

REFERENCES

Howes, K.M.W. and Rummery, R.A., Eds - (1978) - Integrating agriculture and forestry. CSIRO Division of Land Resources Management, Perth.

Kononova, M.M. (1966). Soil Organic Matter. Pergamon Press.

McKinnell, F.H. and Batini, F. (1978) Agroforestry trials in the south-west. Forest Focus No. 20., Forests Department, Western Australia.

Purvis, E.R. and Leo, M.W.M. (1961). Rapid procedure for estimating potentially available soil nitrogen under greenhouse conditions. Jour. Ag. and Food Chem., 9:15.

Smith, R. (1951) - Soils of Margaret and Lower Blackwood Rivers, W.A. Bull. 262, Comm. Sci. & Industr. Res. Org., Australia.

Stanford, G. and Smith, S.J. (1978) - Oxidative Release of Potentially Mineralizable Soil Nitrogen by Acid Permanganate Extraction. Soil Sci. 16(4) 210-218.

APPENDIX I

Effect of Clover on Soil Properties
Analyses of Variance

Organic Carbon

Source	df	S S	M S	V R	
Localities	2	1.2098	0.6049	5.43	*
Clover	1	0.6600	0.6600	5.93	*
Remainder	20	2.2266	0.1113		
Total	23	4.0964			

Nitrogen

Localities	2	0.004117	0.002059	15.25	***
Clover	1	0.003675	0.003675	27.22	***
Remainder	20	0.002705	0.000135		
Total	23	0.010497			

CLOVER CULTIVAR TRIAL

W.P. 13/79 File No. 268.12

This trial was to determine the optimum cultivars of clover to establish in the Sunkland.

Six subterranean clovers and two perennial clovers were established over an area of 1 hectare each some of the cultivars were also tested as mixtures. The site was ploughed, 20kg/ha of seed was sowen and 500kg/ha of Super Cu Zn Mo No. 2 was broadcast. P. radiata was then planted on mounds through the trial.

Soil samples collected at the end of the first growing season showed there were very low levels of nitrogen and phosphorus (FIGURE 1). The biomass of the clover was assessed at the end of the first two growing seasons. Trikkala, Larissa, Seaton Park and Mt Barker performed well. Esperance performed only moderately. The perennial clovers (Strawberry and New Zealand White) did not persist. However the mixture of Esperance and New Zealand White, which was planted on a wetter site, performed well. There was little scrub regrowth in the trial area.

Trikkala and Larissa are cultivars which will perform well in the Sunkland. Mt Barker and Esperance are other possibilities, although the former does have a high oestrogen level. On drier sites Seaton Park, or some other quick maturing varieties, could be used. The perennial clovers will grow well in the wetter sites, providing useful grazing during the summer months. A dense sward of clover appears to restrict the regrowth of scrub, as could grazing.

FIGURE 1 Growth of various cultivars of clover in the Donnybrook Sunklands.

CULTIVAR	BIOMASS (kg/ha)		SOIL NUTRIENT LEVELS SEASON 1	
	Season 1	Season 2	N(%)	P(ppm)
Mount Barker	6681	5690	.059	14
Larissa	3564	6710	.053	20
Trikkala & Larissa	3145	6970	.041	13
Trikkala	3480	5520	.043	28
Esperance	2846	4760	.037	29
Strawberry	353	1690	.031	12
N.Z. White	-	880	.030	10
Control	-	0	.081	30
Seaton Park	4541	5670	.028	49
Clare	3855	5670	.044	15
Dinninup	2777	6100	.052	15
Trikkala-Strawberry	988	4720	.046	7
Larissa-N.Z. White	2822	5460	.043	15
Esperance-N.Z. White	5998	5920	.049	9
Esperance-Strawberry	2059	5100	.028	19

CLOVER SHADE TOLERANCE EXPERIMENT

Research Working Plan 6/79

Report

INTRODUCTION:

Trial plots of pine on clover, established in 1974, indicate that such an association could help to remedy some of the nutrient disorders. Consequently there has been a dramatic change to broadscale planting of pine on clover. The question that is being asked is how will the current clover cultivars perform in the shady conditions of a pine plantation.
In this experiment seven clover cultivars were grown under different shade intensities to answer the question:
Are some clover cultivars more shade tolerant than others?

METHOD:

Treatments:

Seven clover cultivars were tested:-

1. Seaton Park
2. Trikkala
3. Dinninup
4. Esperance
5. Clare
6. Mt Barker
7. Larisa

The clover types were grown under four shade intensities:-
0, 50%, 70%and 95% shade.

Experimental Design:

Three clover plants were established per plot and for each shade intensity treatment there were four replications.

Harvesting Procedure

The whole tops were harvested once the plants had flowered, set seed and were clearly beginning to brown off. The tops were oven dried and weighed.

RESULTS:

Table 1 shows the mean dry matter (grams) for the seven clover cultivars at 3 shade intensities.

Table 1. The effects of shading on clover biomass production (grams).

../2

Clover Cultivar	Percentage Shade		
	0%	60%	95%
Seaton Park	35.5	18.4	5.6
Trikkala	27.1	12.3	2.3
Dinninup	24.2	18.8	3.8
Esperance	36.1	18.6	2.7
Clare	26.1	20.8	3.8
Mt Barker	32.3	18.1	1.9
Larisa	34.8	20.0	3.5

Biomass production declined for each cultivar with increasing shade intensity. Figure 1, based on the mean value for all cultivars, illustrates this decline.

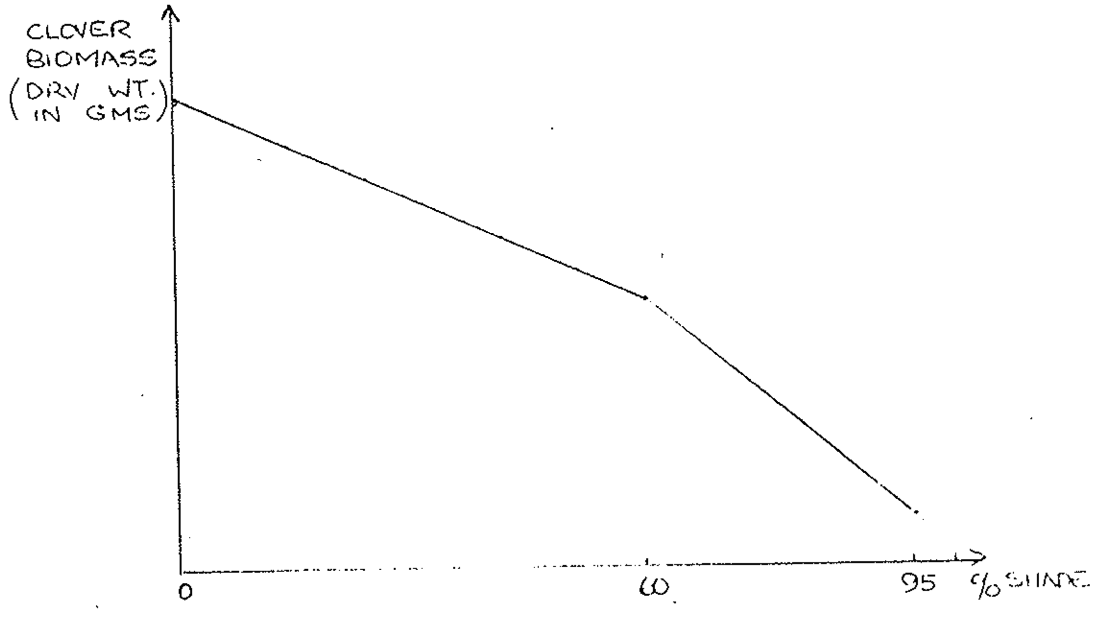


Figure 1. Clover biomass at three shade intensities.

DISCUSSION: The results show that none of the clover cultivars were any more tolerant of shade than any other in terms of biomass production. Growth of all cultivars declined with increasing shade. The data suggests that the rate of decline increases as the shade intensity increases (Figure 1). Therefore in selecting from the commercially available clover cultivars for broadscale use on the sunklands, characteristics such as resistance to scorch and suitability to the site should be considered.as none of the types are more tolerant of shade than any other.

It is interesting to examine the expected inputs of N from clover pasture growing in the shade of a pine plantation. Sixty kilograms per hectare (60kg/ha) is a conservative estimate of the amount of N produced by a clover pasture each year (Dept. of Ag. pers. comm.). The current fertilizer regime of 400kg Agras/ha every 3 years is equivalent to applying 24kg of actual N per year. These rough calculations suggest that clover pasture should produce considerably more N (and in a more continuous supply) than is currently being added in fertilizers. Perhaps, therefore sufficient nitrogen will be produced even under moderately shady conditions, when, as this trial has shown, clover growth is reduced.

A factor which may be important in pastured forests is the effect of shading on seed yield. W. Collins (1978) reports in a study with clover cultivars used in W.A. that seed yields declined 50% with a 50% reduction in daylight. Such a drop in seed yields could be a major cause in the decline of pasture under forests. For maximum nutritional benefit it may be desirable to have a clover sward beneath the pines on the sunklands throughout the rotation. Therefore further clover shade tolerance studies are recommended. The following aspects should be investigated:-

1. The possibility of finding shade tolerant varieties of clover from the gene pool.

2. The decline in seed yield with increasing shade.

SUMMARY:

1. Seven clover cultivars were grown under four shade intensities.

2. Shading reduced growth of all cultivars. None of the cultivars were any more shade tolerant than any other cultivar.

REFERENCES:

W.J. Collins, R.C. Rossiter and A. Romos Monreal (1978) The influence of shading on seed yield in subterranean clover. Aust. Jour. Agric. Res., 29, 1167-75.

A.D.F.O.

Richard Moore

THE EFFECT OF A PERCHED WATER TABLE ON P. RADIATA ROOT FORM

H. Chevis

W.A. Forests Dept,
Busselton.

Windthrow of *Pinus radiata* D. Don has occurred in the Sunklands Plantations. Observations suggest windthrow can occur once the stand has reached a top height of 10-12 metres. The sites on which the problem is most prevalent are moisture gaining, the soil texture being sandy loam or heavier. Perched water tables are known to occur on many of these sites during the winter months.

Restricted vertical drainage has been shown to impede root development of Scots Pine (*Pinus sylvestris* L.) and lead to tree instability (Faulkner and Malcolm, 1972).

The present studies were carried out to test the hypothesis that perched water on some sunklands sites was restricting vertical root development of *P. radiata*.

Methods

Two lines of 15 shallow bores, each bore 20 metres apart were established running across the contour and parallel to the planting mounds on two typical soil types within the plantation. Water tables were monitored at least weekly through 1980. Rainfall was monitored at two points in the survey area. The soil profile at each site was described.

The bores exhibiting highest and lowest water levels on each line were selected and the roots of five trees representative of the stands at the four sites were excavated using a water jet.

Maximum root depth was determined as was lateral root spread in four quadrats centred on the cardinal compass points. Major lateral roots were measured along their length to where their diameter fell below 1 centimetre.

Results

Figures 1-4 illustrate soil profile, depth to the water table through the year and a root system considered representative of each site. Rainfall data is illustrated in Figure 2. Table 1 shows crown and root parameters for the trees at each site. Roots were present in zones subject to perched water presence on all of the site studied. Root penetration was greater on both lines at the site with less pronounced perched water table. Vertical root development differed markedly between lines both in depth of rooting and number of vertical roots.

At the sites on line 1, commonly two or three vertical roots were present with some sinkers occurring on laterals at the better drained site. Rarely was more than one vertical root present at the sites on line 2.

There was much greater depth to an impeding layer on line 1 than line 2. Also, heavier textured layers were present over the impeding layer on line 2 than line 1.

../3

Lateral root spread was uniform in all quadrats except at site (i) line 1, where there was restricted development in the east and west quadrats. The planting mound was in a north-south orientation.

Discussion

The data show that vertical root development is not excluded by the presence of perched water, but prolonged presence may be restricting the number and depth of tap and sinker roots.

Soil physical factors seem to be important in determining the soil depth available to root penetration. On the sites studied there was little root growth through a gravelly or concreted layer. Soils of sandy clay and clay texture could also be restricting root development.

There appeared to be restricted lateral root development away from the planting mound on one site. This site (site 1:1) was subject to prolonged presence of perched water. This factor could promote instability on very wet sites or sites with greatly impeded drainage.

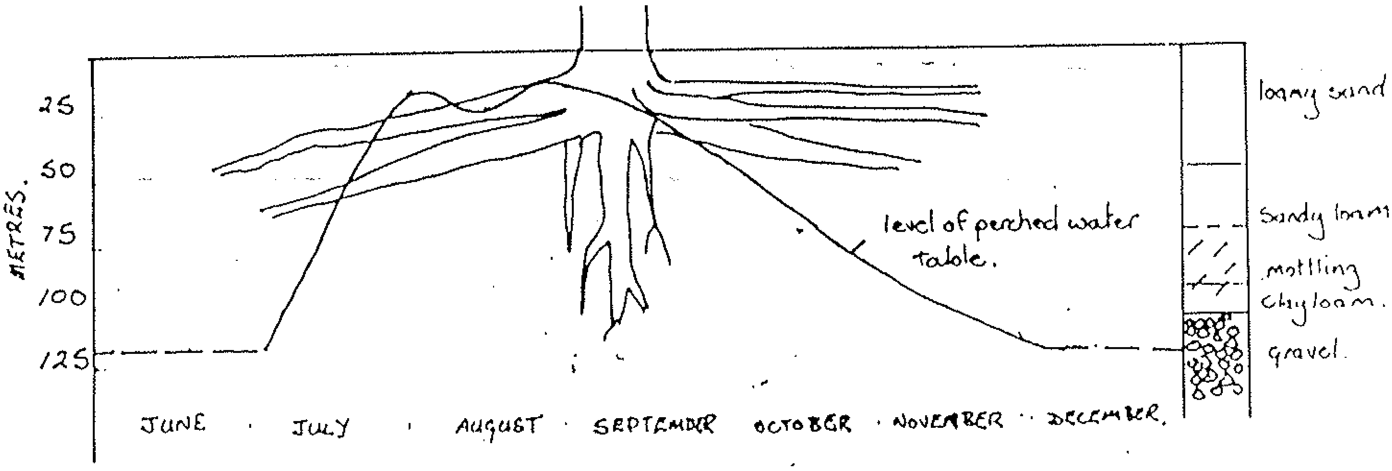
Reference

M.E. Faulkner and D.C. Malcolm (1972) Soil physical factors affecting root marphology and stability of Sctos Pine on upland heaths. Forestry Vol. 45 (1) p23-36.

TABLE 1 Crown and root parameters for 5½ year old P. radiata on sour Sunklands sites.

Site	No. sampled	DBHOB (cm)	Ht (m)	Crown Width (m)	Max. Root Depth (cm)		Nature of roots	Length of laterals in four quadrats (cm) (down to 1cm diam.)							
					$\bar{x}$	Range		North	No.	South	No.	East	No.	West	No.
Bore line 1; (i)	5	10.40	7.00	2.03	116	92-125	Two, occassionally three major vertical roots.	104	4	116	6	57	4	60	4
(ii)	5	14.65	9.94	3.38	135	85-170	Two, often three vertical roots + sinkers off laterals.	93	7	101	5	90	8	91	5
Bore line 2; (i)	5	8.04	6.03	2.21	75	60-92	Normally one major vertical root only.	85	4	96	2	72	6	113	3
(ii)	5	7.45	5.87	1.54	89	65-110	Normally one major vertical root only.	122	5	70	5	84	3	67	4

Figure 5.
The effect of soil physical factors and perched water on the root growth of P. radiata



INOCULATION TRIALS

W.P. 11/80 File No.: 443.222.1

Deaths of P. radiata in the Sunkland occur in a random fashion through the plantation. This raises the question of whether the healthy trees are exhibiting a tolerance to P. cinnamomi infection or whether there is a random distribution of inoculum in the soil.

This trial was to see whether it was possible to artificially inoculate P. radiata in the field. Four plots of 25 trees were inoculated at each of three sites. These were one year old pine on clovered and non-clovered sites in Jarrahwood and 28 year old pine at Willcocks. Four control plots were also laid out at each site.

Eight pine plugs, inoculated with P. cinnamomi were placed in the soil around the base of the trees in the inoculated plots. Also at each site two trees were selected adjacent to the plots to be saturated in inoculum. Plugs were recovered at regular intervals from around these trees to determine the viability of the inoculum.

The inoculum declined rapidly at all sites, especially under the older pine. No deaths of pine occurred over the two years the trials were monitored. Inoculation did not result in a depression of growth of the pine (Table 1). In fact, at one site, pine in the inoculated plot grew better than in the uninoculated plots.

There are several possibilities for the lack of response in this trial. As the trials were set up in established pine, the proportion of the population which is highly susceptible to infection may have already succumbed. Alternatively the pine plugs may not have been a viable infection source.

TABLE 1 : Growth of *P. radiata* after attempted inoculation with *P. cinnamomi*.

1 Year Old Pine	Height (cm) 3 years	Increment (cm) 1 - 3 years	
Clovered Site : Inoculated	432.6	375.1	N.S.
Control	433.4	373.6	
Non-Clovered Site : Inoculated	396.9	329.4	$p < 0.0$
Control	346.8	289.4	
28 Year Old Pine	**Basal Area (cm) 30 years**	**Increment (cm) 28 - 30 years**	
Inoculated	1.20	0.14	N.S.
Control	1.33	0.14	

REPORT: SOIL MOISTURE/TEMPERATURE EXPERIMENT - MOLLOY 10

WP 13/75

Since initiation of P. radiata plantings in the sunklands there has been an awareness of the potential of Phytophthora cinnamomi to cause P. radiata mortalities. In young plantation environmental conditions may be very conducive to sporulation and spread of P.C. For the production of sporangia, and infection, a soil temperature in excess of 15°C is required. Roth and Kuhlman (1964) postulated two soil moisture thresholds affecting pathogenesis; soil saturation, which stimulates sporulation, and field capacity which allows spore migration and possibly aids infection. Movement of zoospores in the soil water is considered to be the primary means by which new infections are established. Therefore, for the establishment of new infections soil moisture levels in excess of field capacity and soil temperatures greater than 15°C are required.

This experiment was conducted over a 17 month period to test the hypothesis that environmental conditions in young P. radiata plantation are more favourable to P.C. zoospore activity than in the original native forest.

Method

Two sites were selected, both on moist mid-lower slope positions;

- 2 year old P. radiata plot standing at 1700 stems per hectare.
- mature jarrah/marri forest.

Two sampling points were established at each site. At each point, one fibreglass electrical resistance probe (measuring temperature and moisture) was established at 5, 20, 50 and 90cm depths.

Resistance readings were recorded once per week.

Results

Temperature probe resistance readings were converted to °C.

The resistance reading approximating field capacity was determined and the period when resistances were less than this base figure was calculated.

The soil moisture and temperature regimes over the 17 months on the two sites are illustrated in figures 1 and 2. The shaded sections indicate when both soil moisture and temperature were suitable for infection.

../2

Soil moisture. The period during which soil moisture was at, or above field capacity was longer, at all depths, in the young plantation than the native forest. The longer periods were mainly due to an extension of wet soil conditions later in the season; e.g. at 20cm depth in 1974, field capacity was reached only 15 days earlier in the pine than the native forest but extended 84 days longer.

The most noticeable differences in soil moisture conditions between the two treatments were at shallow depths. At 5cm depth, in 1974 optimum soil moisture conditions in the native forest existed for only 20% of the time as those in the pine, whereas at 90cm depth they existed for 85%.

Optimum soil moisture conditions extended further into spring/summer in 1973 than in 1974. From the rainfall data (Fig. 3) it can be seen that higher spring rains occurred in 1973, although the annual rainfall was higher in 1974.

Temperature. Data for the native forest, at 5cm depth, was only available from November 1973 to April 1974.

There did not seem to be the same differences between sites in regard to temperature as there was for soil moisture. On both sites, and at all depths, soil temperatures were depressed below 15°C in early May. 15°C was exceeded again between 6 and 7½ months later, the only noticeable variation between sites being at 90cm depth, where there was a log of 1 month in the native forest.

Periods of possible P.C. zoospore activity. Conditions were suitable for zoospore activity at all depths on the pine site during spring 1973 but only at 50 and 90cm depth in 1974. Only at 90cm depth during spring 1973 were conditions suitable on the native forest site. The more suitable conditions for zoospore activity experienced in 1973 than 1974 could be due to the heavier spring rains experienced in the former.

Discussion

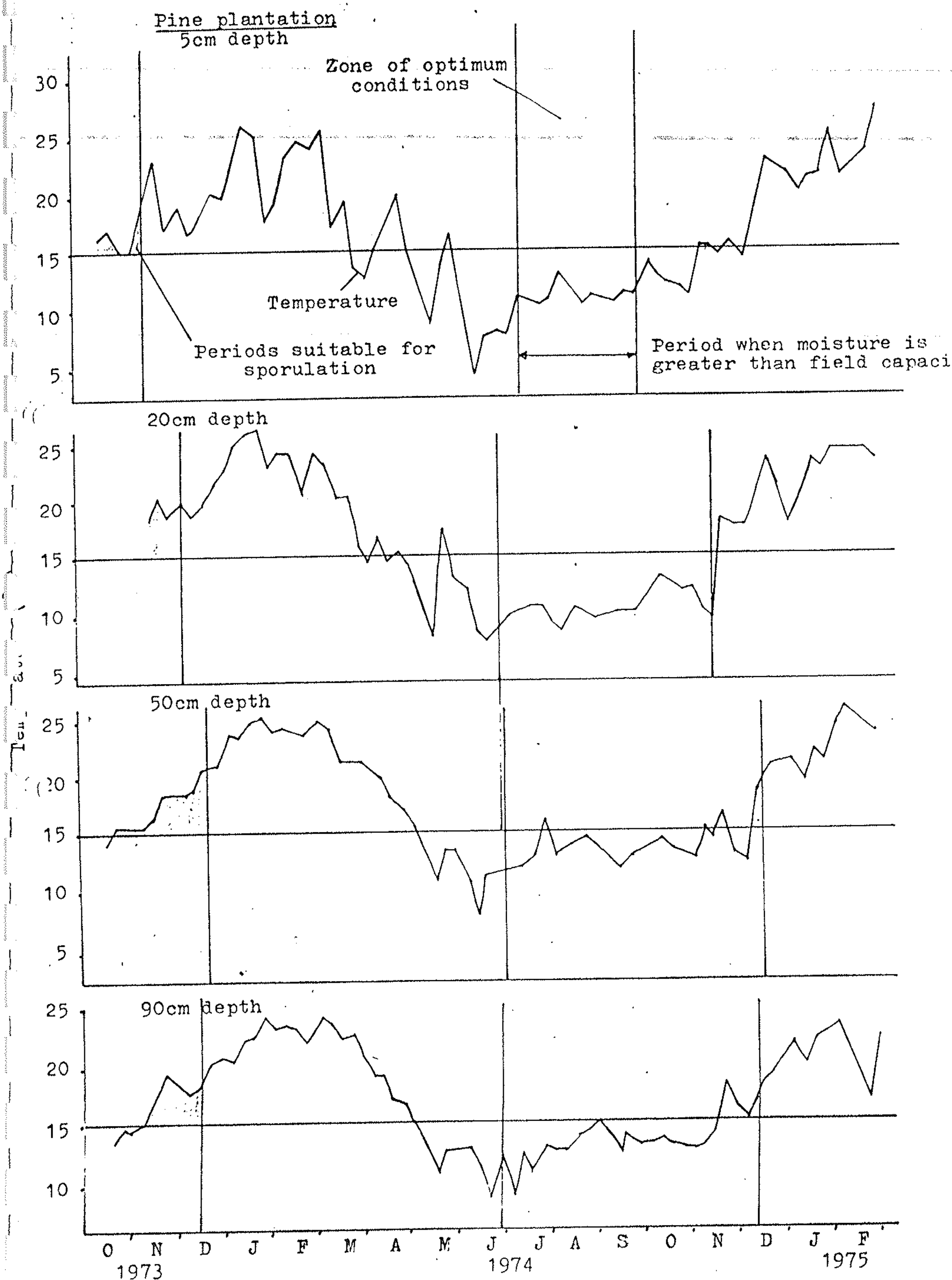
In young *P. radiata* plantation environmental conditions seem to be more favourable for P.C. zoospore activity, than in the original native forest. Soil moisture seemed to be the primary factor, being influenced strongly by rainfall and canopy. Temperature between years, sites and depths (excluding 5cm, data being lacking) was quite uniform.

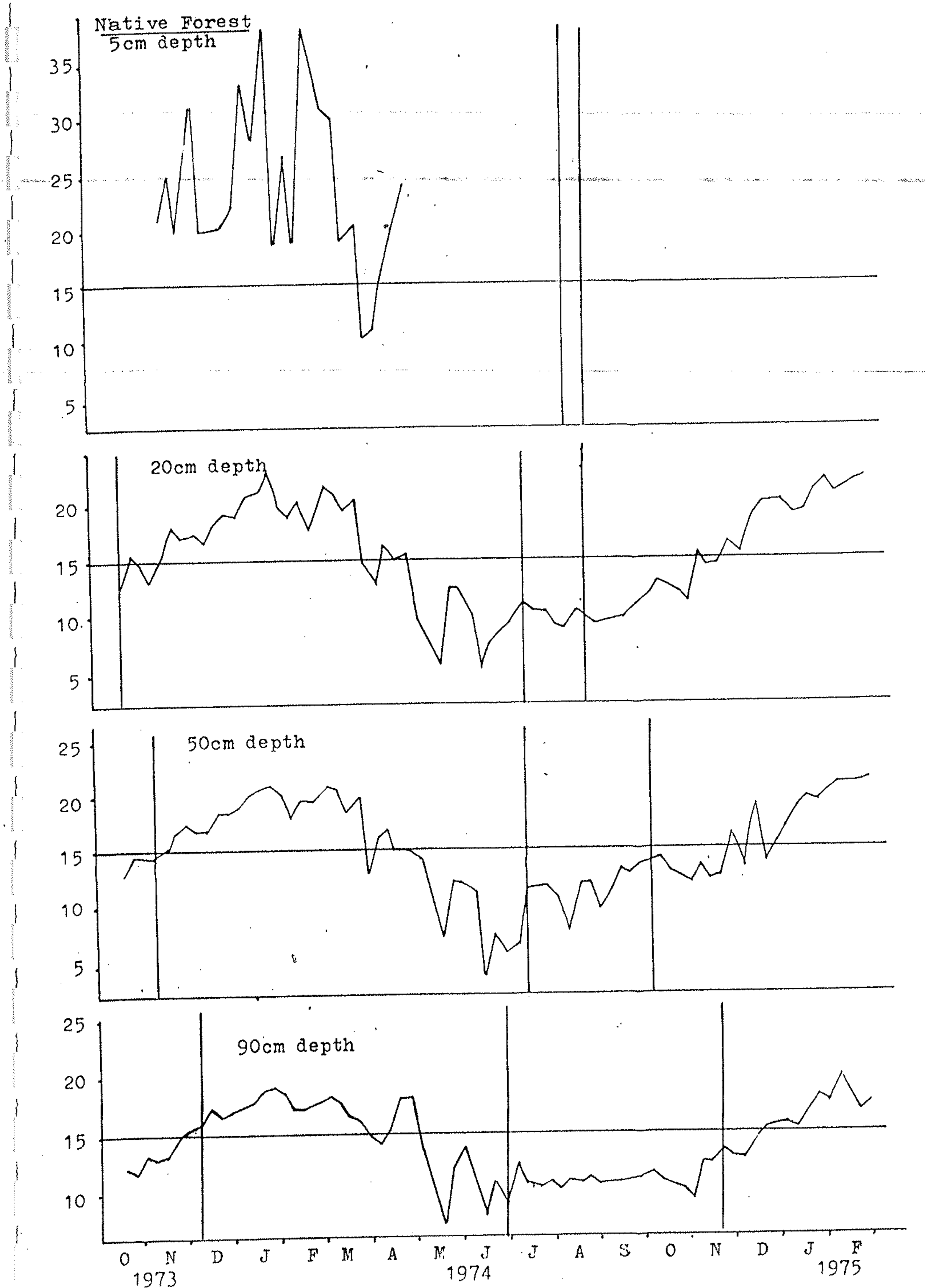
The implication is that late spring rains present a threat to young *P. radiata* plantations through their influence over the period of P.C. zoospore activity.

References

Roth L.F. and Kuhlman E.G. (1966) Phytophthora cinnamomi, an unlikely threat to Douglas-fir forestry. For. Sci. 12 147-159.

Fig. Environmental conditions affecting sporulation of P. cinnamomi in native forest and recently established pine plantation.





Native Forest
5cm depth
20cm depth
50cm depth
90cm depth
35
30
25
20
15
10
5
O N D J F M A M J J A S O N D J F
1973
1974
1975

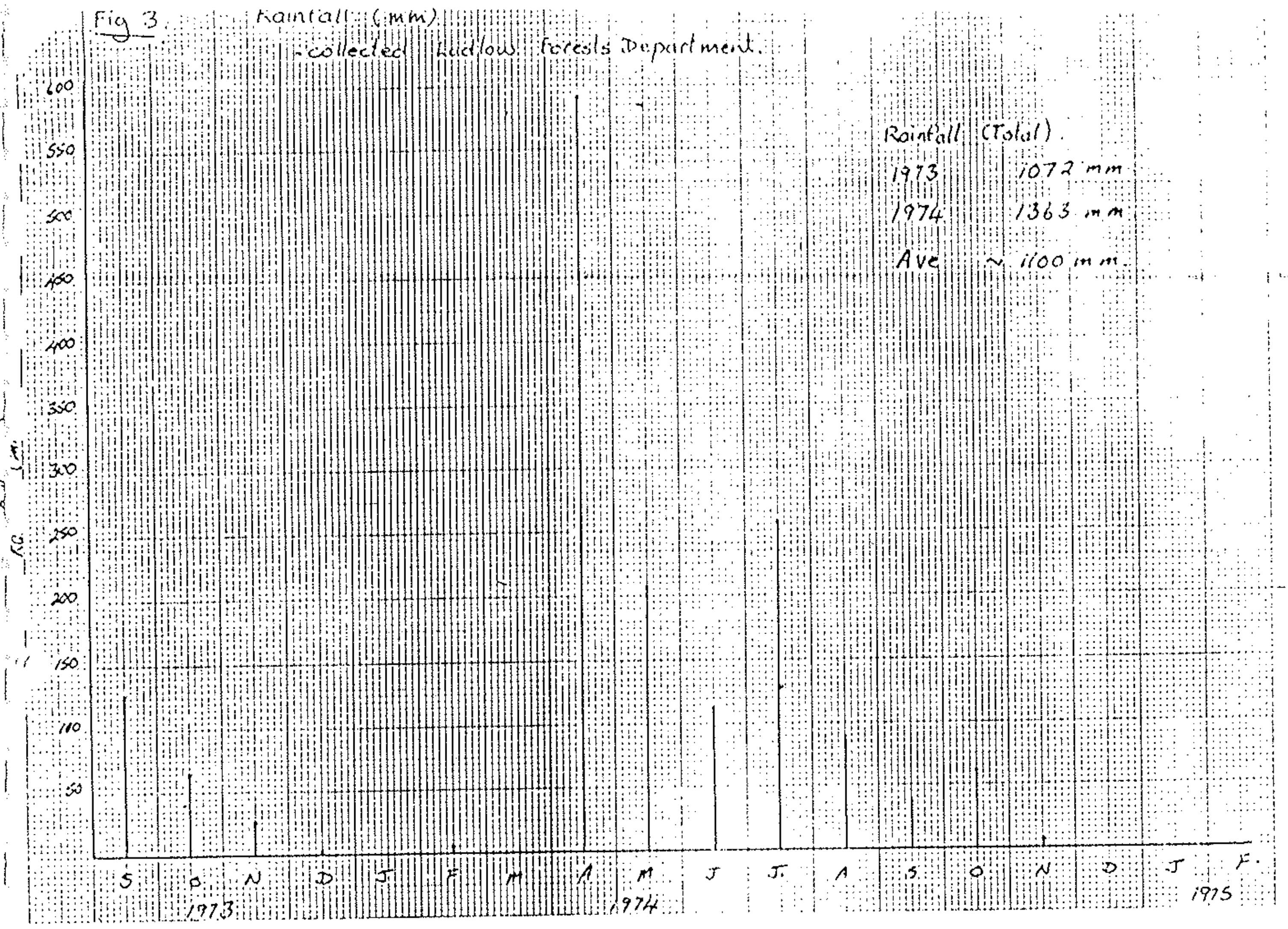


Fig 3.
Rainfall (mm)
- collected Ludlow Forests Department.
Rainfall (Total).
1973 1072 mm
1974 1363 mm
Ave ~ 1100 mm.
600
550
500
450
400
350
300
250
200
150
110
50
S
O
N
D
J
F
M
A
M
J
J.
A
S
O
N
D
J
F.
1973
1974
1975

THE OCCURRENCE OF PINE DEATHS, ASSOCIATED WITH PHYTOPHTHORA spp., ON SOILS IN THE DONNYBROOK SUNKLAND

Summary

Areas of the Donnybrook Sunkland in Western Australia are being converted from native forest to *Pinus radiata* plantation. Some of the native forest is affected by jarrah dieback, caused by *Phytophthora* spp.

Decline of the native forest, and number of deaths of *P. radiata* were compared between soil types. Mortalities of both *P. radiata* and jarrah were greatest on the silty loams along the valley floors. A similarly high number of deaths of *P. radiata* occurred on the leached loamy sands. This was not matched by a high incidence of decline in the native forest.

The leached loamy sands are one of the major soil types being planted to *P. radiata*. Measures to reduce the impact of *Phytophthora* on *Pinus radiata* should be concentrated on this soil type where jarrah dieback is known to have occurred.

SOIL TYPE	1	2	3	4	5	7
Area (ha)	4.0	10.5	10.2	25.5	15.9	4.3
Deaths/ha	0.2	0. 9	1.1	2.3	2.0	2.3

Difference between rates: x^2 = ~~11.07 (p < 0.05)~~

TABLE 2 : The distribution of deaths of P. radiata with soil type on areas affected by jarrah dieback in a Sunkland plantation. The pines were planted in 1974 and 1976 and the deaths were recorded in 1980 and 1981.

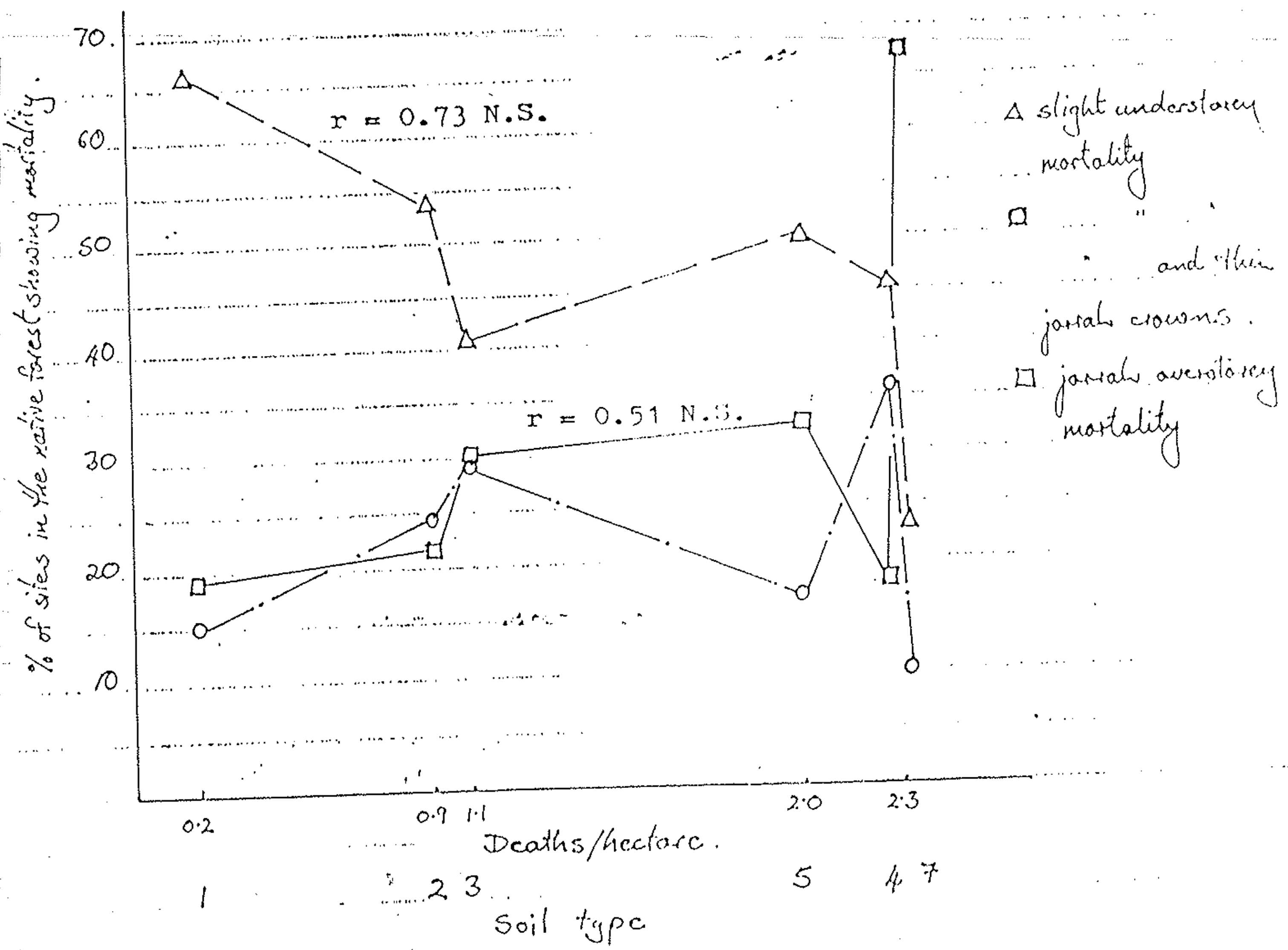


FIGURE 1: The occurrence of pine deaths and mortality in the native forest with soil type in the Sunkland. In the survey of the native forest only sites where mortality was evident, were considered.