AGROFORESTRY TRIALS AT MUNDARING AND BAKERS HILL, WESTERN AUSTRALIA

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INTRODUCTION

Major problems which face owners/managers of Pinus plantations in Western Australia include drought, fire, infertile soils, an oversupply of small-sized materials, and cash flow imbalance because of the delays between establishment costs and returns from merchantable timber. To overcome some of these, a regime involving frequent and heavy thinnings has been implemented in State-owned plantations. Some combination of forestry and agriculture offers promise in these more open stands so as to reduce scrub and fire control problems, improve the fertility of the soil and return some income earlier in the rotation.

A number of co-operative research trials between the Forests Department, the Public Works Department and the CSIRO Division of Land Resources Management have been established. This article summarises preliminary results from some of this interdisciplinary research.

1. Clover and crop production under 13-15 year old Pinus radiata

13-year old P. radiata at Mundaring were thinned to 143 and 261 stems per hectare (s ha^{-1}) and pruned to 6 m in May 1975. Three cultivars of subterranean clover, Daliak, Seaton Park and Woogenellup,

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were sown in strips between the tree rows and on a control area without trees. For two years the cultivars were reasonably pure and their individual production of herbage and seed were measured. Chemical analyses of both green and dry herbage were performed. The strips were grazed in common by sheep each year and this helped transfer seed to the unsown areas in the tree rows. By the third year the cultivars were fairly well mixed and all the ground surface carried pasture.

Oats and lupins were sown on part of the experiment in 1976 and again in 1977. Trees were sampled for ring analysis, needle lengths and foliar nutrient levels, and estimates of crown cover were made. Soil moisture measurements were made during the spring and early summer of the first two years.

The clovers established without any problems and remained healthy. They were gradually invaded by volunteer pasture species as happens in purely agricultural systems but remained more clover dominant under the trees at 261 s ha^{-1} (Table 1). Daliak was not as productive as the other, later maturing cultivars. Daliak also appeared to be relatively unpalatable to the sheep when dry which may again be related to its earlier maturity, though the combination of higher fibre content, lower digestibility, and lower concentrations of P, K, S, Mg and carbohydrates, revealed by the analyses, may also have been involved. The concentrations of P, K and S were low in the dry herbage of all cultivars but no ill effects were observed in the sheep. Differences in chemical composition were small between control pastures and those under trees.

By the third growing season herbage yields had fallen under the trees to 84% of the control pasture at 143 s ha^{-1} and to 68% at

261 s ha^{-1} (Table 1). Seed yields were higher under the trees in the first year and similar to those of the control pastures in the second year. The seeds were heavier under the trees. The clovers, oats and lupins were all etiolated under the trees (50% taller under 261 s ha^{-1} than those on control plots), but this only affected the yields of clover and oats, the latter showing reduced tiller development which is often correlated with reduced yield.

The effects of pastures on tree growth rates and nutrient uptakes cannot yet be separated from those of thinning treatments but these measurements will be continued (Table 2). Basal areas of individual tree crowns increased by about 2 m^2 per year thus doubling the ground surface shaded in 4-5 years (Table 3).

During late spring, there was more moisture in the top soil under the trees. This is important in seed development, pasture growth and in keeping the pastures growing longer, but these factors only partly compensate for the reduced yields which result from shading.

Pastures were crash grazed each year during spring and early summer so that by January little herbage remained (< 500 kg ha^{-1}) and an excellent reduction in fire hazard was achieved.

2. Combining sheep grazing and softwood production, at various tree stocking rates and at two phases of the pine rotation

(a) The encouraging results of experiment 1 led to a larger experiment being established in the same locality. This had Seaton Park clover sown under 15 year old P. radiata at 70, 120 and 150 s ha^{-1}, P. pinaster at 90 s ha^{-1} and on control areas from which these pines were clear felled and removed. The trees have been pruned to 6 m.

Fences have been erected so that treatments can be individually grazed by sheep each year at rates that will fully utilize the pasture by early summer. Liveweight changes and wool growth of the sheep are being measured. Trees are being measured annually for growth rates, and at three yearly intervals for changes in form and nutrient uptakes. Dendrometers are used to monitor seasonal growth patterns.

Other areas were also thinned and pruned but left without pasture. Half of these areas have been fertilized with superphosphate at the same rates as the pasture plots. This allows assessments to be made of thinning alone, thinning + fertilizing, and thinning + fertilizing + grazing of pastures, on tree growth rates etc.

About 5 plants dm^{-2} established from the initial sowing in June 1977 and these made satisfactory growth considering the low rainfall in that season. Yields of clover herbage ranged from 2500-4500 kg ha^{-1} and seed yields were high on the P radiata plots. On the drier and less fertile soils of the P. pinaster site herbage yields were only 1200-1500 kg ha^{-1} and seed yields were also reduced. The P. radiata pastures were grazed down to about the level of the P. pinaster pastures after the end of the growing season.

In 1978 the pastures regenerated well producing 800-1400 kg ha^{-1} by the end of June, sufficient to allow sheep grazing to commence. Our aim of maintaining similar grazing pressure (hence also similar liveweights) on all plots was achieved by adjusting sheep numbers per plot to pasture availability as estimated periodically (Figure 1). The mean liveweights of the sheep increased from 39 kg in June to 53 kg in December (Figure 2). By January most flocks were losing weight and there was only around 500 kg ha^{-1} of herbage left, so the sheep were removed. From the number of sheep days of grazing per

treatment we calculated the approximate carrying capacities, for the whole year, to be 10, 9, 7 and 6 sheep ha^{-1} on the P. radiata (0, 70, 120 and 150 trees ha^{-1} respectively) and 7 and 6 sheep ha^{-1} on the 0 and 90 trees ha^{-1} treatments of P. pinaster.

The sheep grazing part of this experiment will continue for a few years and the tree growth measurements somewhat longer. From the carrying capacities of the pastures and the estimated timber yields it will be possible to make economic comparisons of the pine and pasture combinations used.

(b) Another experiment required the planting of 24 ha of pines and 3 ha of eucalypts on old pasture land and this was completed in July 1978. The design of this experiment allows several objectives to be met. The first is to compare the effects of planting density (0, 380, 760, or 1140 trees ha^{-1}) of P. radiata on tree growth rate and form, and on pasture production. The second compares the effects of P. radiata, P. pinaster and Eucalyptus camaldulensis each at 760 trees ha^{-1} on pasture growth and composition. The third will measure the effects on tree growth and pasture production of varying row spacings, planting pattern, time and severity of pruning and methods of treating trash, all with P. radiata planted at 760 trees ha^{-1}. The pastures will not be grazed until 1980 so that damage to the trees by livestock can be avoided. Twelve piezometric wells have been drilled to bedrock so that changes in groundwater and salt levels may be monitored as the trees developed. A further twelve shallow wells monitor perched groundwater tables. No results are available at this stage.

3. Management problems with young trees in pasture and crop situations

When tree seedlings are planted into old pasture land it is essential to protect them from competition for light, moisture and nutrients until their roots and foliage extend beyond those of the competing plants. It is therefore necessary to spot or strip spray with weedicide for at least the first season. This leaves most of the area available for the growing of pastures or crops.

Grazing the pasture between young trees is risky because, once they start, stock usually eat not only the leaves but much of the stem, and permanent damage or tree deaths occur. Stock usually start damaging the trees when the pasture is only partly utilised.

(a) Palatability investigations

At CSIRO's Yalanbee Experiment Station, Bakers Hill, the palatability of several tree species in a range of pasture conditions is being investigated. The species used so far are P. radiata, P. pinaster, E camaldulensis, E. robusta, E. maculata, E. citriodora and E. globulus.

When potted trees ranging in height from 30 to 150 cm were placed in dry pastures sheep quickly started eating them, and caused heavy losses especially if the pastures were of low quality and dominated by grass or erodium (wild geranium). In good quality pastures of clover much less damage was done, and in a highly palatable capeweed dominant pasture very few trees were eaten or damaged. The pines, E. camaldulensis and E. robusta were much more attractive to the sheep than E. citriodora or E. globulus. Fresh growth was preferred if the leaves were within reach, and sometimes bark was nibbled on trees whose leaves were not eaten. The pines were killed or rendered useless for timber

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production in these experiments, but most of the eucalypts recovered well, though with changed form. This may not be crucial if the trees are primarily grown for shelter, erosion control or for amelioration of waterlogged or saline conditions.

(b) Cropping between rows of tree seedlings

If the land is arable, hay production and cropping between tree rows are alternatives to grazing. CSIRO workers have investigated the effects of oat crops, on the survival and early growth rates of several tree species (P. radiata, P. pinaster, E. camaldulensis, E. robusta, E. maculata, E. citriodora and E. globulus) planted in rows 6 m apart. In 1976 the effects of crops sown to within 45 and 90 cm of the tree rows were compared with those where no crop was sown. In 1977 the trial was repeated using only P. radiata, E. robusta, E. camaldulensis and E. wandoo. Each year both trees and crops were planted in June and the crops harvested to 20 cm by a header at the end of November.

The results emphasised the importance of the correct choice of species, of site and of planting stock in tree survival and early growth. However, there was also evidence that crops grown within half a metre of young trees will probably be detrimental to the trees. Tree survival was always less where crops had been grown within this distance and although there were small growth advantages in spring to seedlings sheltered by crops these disappeared within four months after crop removal.

E. camaldulensis, E. robusta and E. wandoo showed considerable promise for this area and P. radiata which is not usually recommended in this rainfall zone has continued to make good growth into early 1979.

E. robusta showed definite site preferences, being least affected by waterlogging in 1976 and most affected by early drying out of one block in 1977.

The oat crops were not affected by the tree seedlings and yields depended solely on the proportion of land on which the crops were grown, in our case 70% or 85%.

(c) Use of repellants to deter consumption of young trees in pastures

CSIRO workers are continuing investigations into the use of chemical repellants to deter consumptions. In one trial two repellants (Ziram and AA Protect) gave two weeks of protection to pines in August, allowing pasture around the trees to be crash grazed with only minor consumption of foliage. Ziram also gave effective protection to pines on other occasions and was partly effective on a range of eucalypts. It was least effective on species which are very palatable to sheep such as acacia and casuarina.

4. The effects of trees on downslope agricultural productivity and water tables

Blocks of 100 trees of E. wandoo were planted in old pasture land in 1977, to compare the effects of landscape position and size of tree blocks on the composition and productivity of pastures downslope. Blocks of E. wandoo, E. camaldulensis, P. radiata and P. pinaster were also planted in lower slope positions to compare the effect of species. In each tree block one shallow and one piezometric well has been installed so that groundwater level and salinity changes can be monitored. The trees have established and are growing well but changes in water levels and productivity have not yet occurred.

5. Other studies

In addition to the work reported here, aspects of agroforestry are also under study in other parts of Western Australia. These include experiments on the Sunklands (Forests Department, Department of Agriculture) which concentrate primarily on the nutritional/mycorrhizal aspects of the system as well as tree form, health and productivity. In the Wellington catchment; Forests, Agriculture, P.W.D. and CSIRO are involved in several trials which concentrate primarily on the salinity problem. Various forms of clearing and of reforestation strategies are being evaluated. Some of this work has been extended to Brookton in a 400 mm rainfall zone by the Department of Agriculture. The main contacts for further data on these trials are as follows:

Sunklands	Dr. F. McKinnell, Mr. P. Kimber (Forests)
Wellington	Mr. D. Spriggins (Forests), Mr. A. Sprivulis (Agriculture, Mr. I. Loh (P.W.D.) Dr. A. Peck (CSIRO).
Brookton	Mr. R. Pepper (Agriculture)

6. Further reading

Anderson, G.W. and Batini, F.E. (1979). "Clover and crop production under 13-15 year old Pinus radiata". Aust. J. Exp. Agric. Anim. Husb. ~~(in press)~~. , 1979 , 19 : 362 - 368

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McKinnell, F.H. (1979). "Silviculture of Pinus radiata in an agroforestry management system". Forest Dept. of W.A. Research Paper No. 51.

"Agro-forestry - a new kind of farming" (1978) in Rural Research No. 99.

"Integrating Agriculture and Forestry" (1978). CSIRO Division of Land Resources Management, Perth, W.A.

Table 1. Yields and percentage clover of pastures sown under 13 year old P. radiata at two densities and in the open (kg ha^{-1}). (Percentage clover in brackets.)

Tree Density trees ha^{-1}	Oct. 1975	Aug. 1976	Nov. 1976	Nov. 1977	Oct. 1978
0	1750 (70)	3170	2630 (58)	4800 (56)	5500 (20)
143	1910 (95)	2200	1840 (78)	4050 (72)	4880 (60)
261	1800 (95)	2600	1980 (83)	3300 (78)	4420 (80)

Table 2. Growth data from three densities of P. radiata

Stocking s ha^{-1}	DUB inc/yr cm	BAUB inc/yr	VOL inc/yr	
			m^3 to 6cm top diam.	m^3 to 23cm top diam.
126	1.36	0.64	6.0	5.5
213	1.01	0.74	7.25	5.5
316	0.86	1.01	10.25	7.5

Table 3. Basal area of P. radiata crowns (m^2 per tree)

Tree Density	July 1975	Sept 1976	Aug 1977	July 1978
143	9.4	12.2	14.7	16.5
261	9.6	12.6	14.6	15.9

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