# Maximising Production of *Atriplex* Species

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*Abstract*

Results of a Western Australian bio-economic model (MIDAS) suggest that increasing the productivity of forage shrubs growing on salt-affected farmland can substantially increase whole farm profitability. Agronomic experimentation has shown that such improvements in productivity are achievable by deep ripping soils to reduce subsoil compaction, adding low levels of fertiliser, planting on less saline land and choosing more appropriate genotypes.

SALTLAND revegetation in Western Australia is currently conducted using simple seeding techniques with minimal inputs of fertiliser or deep tillage. While the species most commonly sown are *Atriplex undulata* and *A. lentiformis*, the preferred species is *A. amnicola* (Malcolm and Swaan 1989). Little documented information is available for Western Australia on the annual forage yields which can be achieved, but sustainable yields of 0.8–1.0 t/ha appear reasonable (cf. Malcolm et al. 1988; Malcolm and Pol 1986; Salerian et al. 1987). In contrast, in the USA and Israel, much higher yields (12–20 t/ha) were measured from stands of *Atriplex lentiformis* and *A. nummularia* when the plants were fertilised and irrigated (Watson et al. 1987; Aronson et al. 1988).

This paper examines the economic imperative for increasing the productivity of *Atriplex* stands in Western Australia, and shows that the productivity of such stands can be increased by planting on less saline land, deep ripping soils to reduce subsoil compaction and adding low levels of fertilizer, and choosing more appropriate genotypes.

## Materials and Methods

### Economic Modelling

The bio-economic model (MIDAS) of the Department of Agriculture was run to test the hypothesis that increased production of forage shrubs on salt-affected farmland could increase whole-farm profitability (cf. Barrett-Lennard et al. 1990). The subject of this model is a typical farm in the Esperance region of Western Australia, which has 1280 ha of non-saline land, and either 50 or 400 ha of saltland. It was assumed that 300 ha of the farm were cropped each year, that the stocking rate was 6–8 sheep/ha, that the farmer received $6.00/kg for his wool and $182/t for his feed grain, and that the annual amortised cost of saltbush establishment and maintenance was $92/ha. It was also assumed that the forage had a digestibility of 55% (Malcolm et al. 1988), that all of the forage was available to be grazed, and that grazing had no effect on production in the following year.

### Agronomic Studies

*(a) Effects of salinity (Kamballup site)*

Beds were formed on a clay soil on two adjacent sites (owned by G. Pieper and R. Bairstow). The beds were made with a road grader and were about 40 cm high and 5 m apart. Each site had four replicate beds about 100 m long. The beds were deep ripped to a depth of 40 cm, and fertilised with 72 g/m row of diammonium phosphate (DAP). Nurseryraised *A. amnicola* seedlings were planted 3 m apart on the beds in June 1990. Soil salinities ($EC_e$ values) were measured in July 1990. Shoot canopy dimensions were measured after 15 months growth; canopy volumes were calculated from measurements of canopy diameter and height.

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### *(b) Effects of soil compaction and addition of fertilizer (Tammin site)*

This site had a sandy surface soil, with a traffic pan from 10 to 30 cm. The experiment had three ripping treatments: (a) a 'slot' rip treatment in which soil was disrupted to a depth of 40 cm in a band 40 cm wide; (b) an agroplough treatment in which soil was disrupted to a depth of 40 cm in a band 4.4 m wide; and (c) no rip. There were two fertilizer treatments: (a) 23 g/m row diammonium phosphate (DAP); and (b) no fertilizer. The experiment was planted on 27 September 1989. The experiment had four replicates; a replicate consisted of a row of 10 plants spaced 5 m apart. Shoot canopy dimensions were measured after 15 months growth; canopy volumes were calculated from measurements of canopy diameter and height. Forage production was estimated from the plant density (400 plants/ha) assuming that a plant of volume 1 $m^3$ produces 1.1 kg of edible biomass (E.G. Barrett-Lennard, S. Hearn and K. Velterop, unpublished data).

### *(c) Effects of genotype and plant density (Esperance site)*

Comparisons were made of the productivity of two *Atriplex* species at a range of planting densities at Esperance, Western Australia. The two species were *A. cinerea* (a vigorous prostrate shrub which forms adventitious roots when its procumbent branches touch the ground) and *A. amnicola* (an erect shrub which forms few adventitious roots). These were grown in blocks of 25 plants (in a 5 × 5 array) at densities of 2000, 1000, 500, 250 and 125 plants/ha. The experiment was planted on 7 September 1988. The growth (canopy dimensions and forage dry weight) of the central nine plants in each block was measured after 21 months.

# Results and Discussion

## Economic Modelling

Results of the model showed that saltland revegetation was highly profitable since the forage produced could be used to fill the feed gap which occurred in autumn and early winter.

Sensitivity analyses were done for three levels of forage production (1, 2 and 5 t/ha/year) for a farm with either 50 or 400 ha of saltland. With forage yields of only 1 t/ha, the value of revegetating an additional hectare of saltland with saltbush was $28 (Table 1). The value of revegetating an additional hectare of saltland increased four-fold when forage production was increased to 2 t/ha, and increased five-fold to 18-fold when production was increased to 5 t/ha (Table 1). Interestingly, at the highest level of production, the value of revegetating saltland was higher when the area of saltland was 50 rather than 400 ha (Table 1). This was because once the autumn feed gap was filled, there was no further advantage to producing more forage from saltland.

**Table 1.** Effects of increases in productivity on the marginal value ($/ha) of saltland revegetation for a typical farm in the Esperance area.

| Area of saltland (ha) | Productivity (t/ha/year) | | |
|---|---|---|---|
| | 1 | 2 | 5 |
| 50 | 28 | 153 | 537 |
| 400 | 28 | 153 | 167 |

## Agronomic Studies

### *(a) Effects of salinity*

Although little can be done to influence soil salinity in most dryland situations, it is important to know how salinity affects growth since it can assist in siting plantations at productive locations.

Studies of the growth rates of river saltbush (*A. amnicola*) in saline nutrient solutions (Aslam et al. 1986) have shown maximum growth occurs at 50 mol/$m^3$, with a halving of growth at 400 mol/$m^3$ NaCl. Evidence from the field also supports the contention that growth is affected by salinity.

Large differences in productivity of *A. amnicola* were obtained on clay soils at two adjacent sites at Kamballup, Western Australia. On the northern (Pieper) site, salinity levels in the upper 15 cm of the soil were 68% less, and plant productivity (determined from volume measurements) was 370% higher than on the southern (Bairstow) site (Fig. 1). The elevation of the beds, and the deep ripping and application of fertilizer all suggested that the differences in growth between these two sites were not due to waterlogging, soil compaction, or inadequate N or P.

### *(b) Effects of soil compaction and addition of fertilizer*

After 15 months growth, plants grown without deep ripping or application of DAP had a volume of only 0.95 $m^3$ (Table 2). The deep ripping and DAP treatments significantly ($P < 0.01$) increased shoot volumes. The 'slot' rip treatment disrupted about 10% of the traffic pan, and caused a 40% increase in average plant volume. In contrast, the agroplough disrupted about 90% of the traffic pan, and caused a 130% increase in average plant volume (Table 2). With each ripping treatment, DAP increased plant volumes by 13–58% (0.28–0.55 $m^3$) (Table 2).

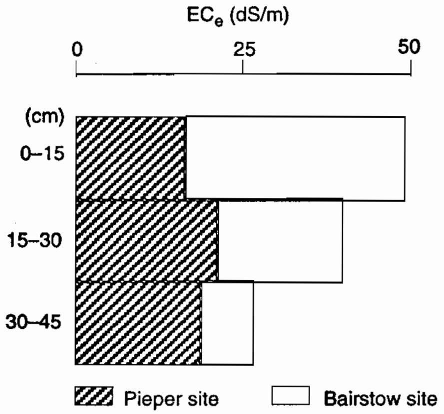

**Fig. 1.** Salinity profiles on clay soils at two adjacent sites (properties of R. Bairstow and G. Pieper) at Kamballup, Western Australia (E.G. Barrett-Lennard and K. Velterop, unpublished data). The volumes of the sites at 11 months were 1.43 m$^3$ (Pieper site) and 0.30 m$^3$ (Bairstow site).

**Table 2.** Effects of three ripping and two fertilizer treatments on the productivity of *A. amnicola* at Tammin, Western Australia (unpublished data of E.G. Barrett-Lennard and K. Velterop).

| Treatment | Plant volume (m$^3$) | Estimated forage (t/ha) |
|---|---|---|
| No rip | 0.95 | 0.42 |
| No rip + DAP | 1.50 | 0.66 |
| 'Slot' rip | 1.35 | 0.59 |
| 'Slot' rip + DAP | 1.83 | 0.81 |
| Agroplough | 2.18 | 0.96 |
| Agroplough + DAP | 2.46 | 1.08 |

### *(c) Effects of genotype and plant spacing*

At close plant spacings (2.2 m × 2.2 m; 2000 plants/ha), *A. cinerea* produced 3.8 t/ha dry forage, which was 46% more than *A. amnicola* (Fig. 2). Measurements of shoot canopy diameters showed that *A. cinerea* plants were sufficiently wide-spreading to cover all the soil surface; in contrast, the canopies of *A. amnicola* covered only 47% of the soil (Fig. 3). At the widest plant spacings used in the trial (8.9 m × 8.9 m; 125 plants/ha), *A. cinerea* plants produced 1.68 t/ha dry forage, which was 180% more than *A. amnicola* at the same spacing, and similar to the productivity of *A. amnicola* at 1000 plants/ha (Fig. 2). At 125 plants/ha the percentage of soil covered by the shoot canopy was 49% for *A. cinerea*, but only 9% for *A. amnicola* (Fig. 3).

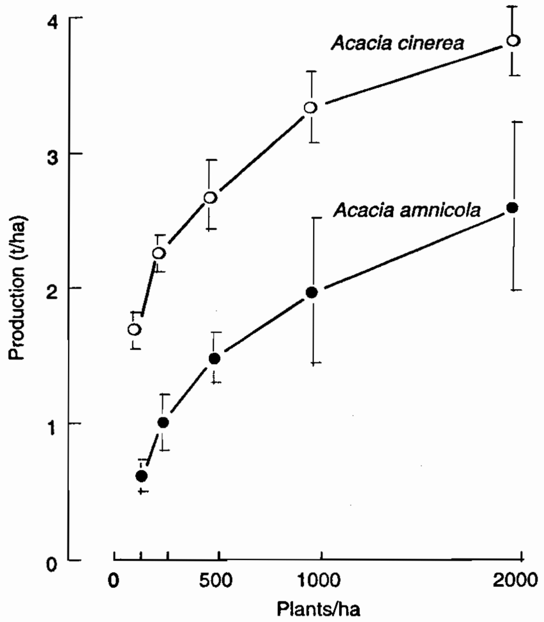

**Fig. 2.** Effects of plant spacing on forage production (t/ha dry matter) by *Acacia cinerea* and *A. amnicola* on a saline duplex soil at Esperance, Western Australia. Values are the means of four replicates, each replicate being the mean of 9 plants. Bars are standard errors (E.G. Barrett-Lennard and K. Velterop, unpublished data).

## Discussion

The trials described here suggest that simple agronomic manipulations can improve the productivity of saltland, and that such improvements will increase farm profitability. In particular the results suggest the following.

1. *Costs of planting can be reduced by avoiding the most saline locations.*

These have far lower productivity than more moderately saline sites.

2. *On responsive soils, the benefits of deep ripping and fertilizer application outweigh the costs.*

At Tammin, the costs of establishing nursery-raised seedlings was about $150/ha ($120/ha for seedlings, $30/ha for planting). The use of the agroplough and the application of fertilizer increased the total cost of revegetation by about 20% ($30–40/ha), but these treatments increased forage production by 160% (Table 2).

3. *There can be considerable benefits to using improved genotypes.*

The results of the genotype comparison trial suggest two strategies for increasing the profitability of saltland revegetation.

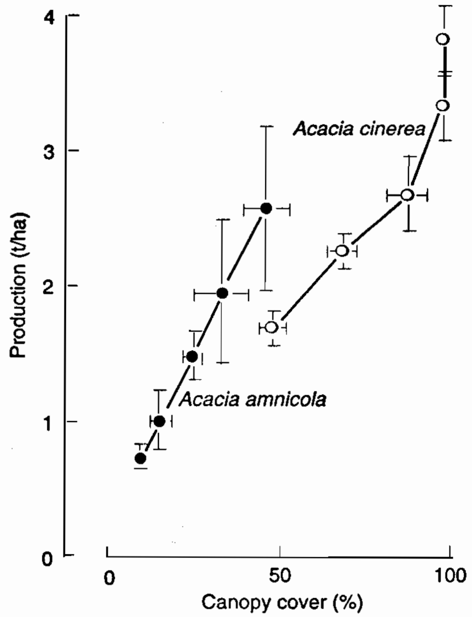

**Fig. 3.** Relationship between projected canopy cover (% soil surface covered) and forage production (t/ha dry matter) by two forage shrubs growing on a saline duplex soil at Esperance, Western Australia. Projected canopy cover was calculated from measurements of plant diameter. Values are means of four replicates as for Figure 2. Bars are standard errors (E.G. Barrett-Lennard, S. Hearn and K. Velterop, unpublished data).

(a) Reduce planting densities (and hence costs of establishment) without decreasing yields.

The data of Figure 2 suggest that the substitution of *Atriplex amnicola* at 1000 plants/ha by *A. cinerea* at 125 plants/ha would have no adverse effect on yield, but would reduce costs of establishment from about $330/ha to $70/ha (calculated assuming that nursery-raised seedlings cost $0.30 each, and that land preparation costs $30/ha).

(b) Maintain planting densities but increase yields.

The data of Figure 2 suggest that at 1000 plants/ha, the additional yields due to the substitution of *Atriplex amnicola* by *A. cinerea* would increase the value of saltland by about $150/ha (interpolated from Table 1) (calculated assuming the costs of establishment used in Table 1).

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