Pasture production from saltland

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Introduction

In Western Australia it has been estimated that 2.45 million ha have the potential to become salt affected (1). Currently about 315,000 ha are affected. Salinity is reported to be the single greatest threat to the environment in Victoria and threatens about 385,000 ha (2). Estimates of saltland in New South Wales total 2.2% of the State (3) and for South Australia 210,900 ha are affected (4).

Strategies developed to counteract the problem include drainage, management of recharge and control of surface water (5). To date these measures have enjoyed limited success in Western Australia, but it has been found possible to obtain grazing from saltland by planting highly salt tolerant forage plants (6). The production of shrub and grass pastures on saltland is reviewed in this paper with special reference to south Western Australia.

The saltland environment

The nature and extent of salt affected land in Australia has been reviewed in terms of mode of formation, salinity, sodicity, hydrology and Great Soil Groups (7). The extreme variability between salt affected sites has been studied in Western Australia in association with field screening studies (8). Salt affected soils range from sands to clays and include all grades between, as well as soils with and without profile development.

Soil analyses conducted on composite samples from 17 sites in agricultural areas in Western Australia (8) showed great variation between sites in saturation extract values for electrical conductivity, sodium adsorption ratio and boron, but most values exceeded acceptable levels for plants such as wheat. A summary of the data is in Table 1. All of these sites had been abandoned by farmers for normal crop and pasture species due to salinity, but all, except the most acidic, proved to be capable of supporting Puccinellia ciliata, Atriplex spp., Halosarcia spp. or Maireana brevifolia or combinations of these species.

Table 1. Ranges of chemical criteria in composite soil samples from 18 sites in south Western Australia

Depth (cm)	pH	% Cl	SAR_e	B_e (mg/L)	EC_E (mS/m)
0-7.5	3.4/10.1	0.07/1.94	18.6/46	0.2/9.7	1,100/4,530
30-60		0.14/0.64	12.3/112	0.1/12.2	

At any one salt affected site, conditions vary greatly from place to place, between depths at one place, and from time to time at the same place (9). Chloride and groundwater depth and salinity differences were reported in detail for areas planted to Atriplex spp. at Kellerberrin, Western Australia, but attempts to relate productivity to site conditions failed. Groundwater depth ranged over a 19 month period from 0.3 to 1.3 metres at any one site. Groundwater salinities were reported to range from 1,620 to 3,810 mS m^{-1} in 75 test wells in the experiment, which covered about 0.5 ha. The surface expression of this variation before the commencement of the experiment was in annual plant cover. Where the groundwater was shallowest the ground was bare and where it was deepest there was a cover of annual pasture plants. The cover of intermediate areas was patchy. The existence of a salt problem was indicated by the patchy cover and the occurrence of salt tolerant annuals such as mediterranean barley grass (Hordeum geniculatum All.), sand spurry (Spergularia rubra (L.) J. & C. Presl.) and slender ice plant (Mesembryanthemum nodiflorum L.). Despite the variability of the site, in factors that would be expected to cause differences in plant growth, bushes of five Atriplex species grew well on the site and no relationship was found between production over 19 months and site conditions.

Seasonal changes in soil salinity (10) have been shown to occur primarily in the top 0.3 m. In the surface, where plant establishment occurs, the salt content may range from around four per cent NaCl in December to about 0.1 per cent in July. The return of salt to the surface in late spring may be prevented by covering the soil with 5 cm of coarse sand.

Salt affected land is frequently located in low parts of the landscape where it is associated with the discharge of saline groundwater (5) and subject to inundation. As a result the surface soils may be waterlogged, most frequently in winter. The combination of salinity and waterlogging is especially detrimental to the growth of non-adapted plants (11). It is commonly observed that the species occurring on saline sites are limited to zones coinciding with different degrees of waterlogging, watertable depth and salinity. The different zones may be the result of only a few centrimetres difference in surface elevation.

As a result of the high sodicity of salt affected soils (8), those which have appreciable clay contents exhibit dispersion, slaking, crusting and low hydraulic conductivity. These characteristics militate against establishment (12) and result in the soils being easily eroded by water. The soil condition may be improved by applying gypsum (13). During summer some salt affected soils become powdery and are subject to wind erosion.

Apart from limited studies on the use of P and N fertilizer and lime on Puccinellia ciliata (14, 15), information is lacking on the use of fertilizers on salt affected soils in agricultural areas. Establishment and growth of Atriplex spp. is greatly improved on saline mine overburden at Kalgoorlie by additions of P and N (16). Phosphate is widely used for crops and pastures on non-saline agricultural soils otherwise identical to those that are salt affected and its use on salt affected soils for halophytes is currently being studied.

Climatically the agricultural saltland in Western Australia occurs in an area of Mediterranean climate ranging from about 275-750 mm annual rainfall. Summers are hot and dry, and winters cool and moist. There are occasional summer thunderstorms and in winter minimum temperatures occasionally go below zero. In the north-west of the agricultural regions (e.g. Geraldton) the rainfall is more concentrate in the winter, whereeas in the south-east (e.g. Esperance) rainfall is spread through the year. The elevation of all salt affected areas is below 500 m.

Salt tolerance versus site salinity

Site salinity is commonly expressed as the conductivity of the saturation extract of the soil (EC_e). Standards for salt tolerance may be based on the EC_e level at which a given yield reduction is caused to a specific plant. As discussed earlier, the salinity of a site may vary greatly and it is important to ensure that the EC_e level represents the growing conditions in the root zone.

Salinity levels in soils vary haphazardly from place to place across a site (17), the differences may be 20-fold or more within a few metres. As a result, conditions change from those suited to glycophytic crops to those where only halophytes will survive within a few metres (6). It is not possible to plant the saline and non-saline areas separately and farmers identify by experience the degree of affectedness beyond which cropping is unprofitable. The remaining land is capable of growing halophytic pasture species.

Attempts have been made to improve the salt tolerance of glycophytic plants for growth on saline soils but the results have been disappointing. Screening of 6,200 lines of barley only resulted in a 23% improvement in salt tolerance, and this was not reflected when the selections were tested in the field (18). By contrast, halophytes are an order of magnitude more salt tolerant than glycophytes. Moreover, the halophytic perennial pasture species in use (see later) will survive periods of extremely high salinity growing opportunistically during more favourable times. This strategy is denied annual crop and pasture plants with seasonally determined growth and development.

Selecting plants for pasture production

The considerations in the previous section lead to the conclusion that it is necesssary to look for perennial halophytic species to provide pasture production from salt affected land. Halophytic species are of high salt tolerance and other aspects of their biology or agronomy determine their selection (see Table 2). Assessment of these criteria is best done in the field on representative salt affected sites. The suitability of 15 species of shrubs to 14 salt affected sites in Western Australia was studied over 12 years (8). There were major differences between species in survival, growth habit, seedling regeneration, disease resistance and size. Bush survival was related to waterlogging events, not salinity. No one species was suited to all sites but all sites except a highly acidic one were capable of supporting shrubby halophytes. The information from the study together with general field observations was used to construct a plant selection table (Table 3) (19).

Table 2. Criteria for assessing the suitability of forage halophytes for salt affected sites*

- Survival duration
- Ability to flower and produce seeds
- Production of volunteer plants
- Growth habit relative to intended use
- Feed quality
- Recovery after grazing
- Effect of drought, frost, heat, insects, disease, waterlogging Additional qualitites e.g. soil stabilization, shelter, water use
- Productivity

* Note: Salt tolerance is important relative to glycophytes but less important between halophytes.

Table 3 - a guide to selecting salt tolerant forage plants for saltland types in the. agricultural areas of Western Australia

Saltland type and conditions			Site severity*		
			Mild	Moderate	Severe
Hillside seepage		Soil surface wet in summer	Strawberry clover,** paspalum, couch, kikuyu	Salt water couch	Salt water couch
		Soil surface dry in summer	Puccinellia, barley tall wheat grass	Puccinellia	Puccinellia
Saline valley floors	more than 375 mm annual rainfall		Puccinellia, barley tall wheat grass	Puccinellia, saltbushes***	Samphire
	less than 375 mm annual rainfall	Commonly flooded	Saltbushes, Puccinellia, barley	Saltbushes, Puccinellia, samphire	Samphire
		Seldom flooded	Barley, bluebush, Puccinellia, saltbushes	Saltbushes, bluebush, Puccinellia	Saltbushes, samphire Puccinellia
Dryland salinity	less than 375 mm annual rainfall	Never flooded	Barley, bluebush, saltbushes	Bluebush, saltbushes	Bluebush, saltbushes

* Site severity is defined in the text.
** The recommended'plant is shown underlined, others listed are also capable of reasonable growth.
*** Saltbushes are only recommended in areas with less than 500 mm annual rainfall.

Other species (e.g. Atriplex cinerea) have subsequently been tested and found to have promise. To determine the suitability of new species relative to those in use it has been necessary to devise standardized shrub testing procedures (20). It is currently recommended that shrubs under test are raised in a nursery, planted into representative field sites as single plant plots on a 4 x 4 m spacing, randomized and replicated 20 times. The sites are characterized and data on the criteria in Table 2 are collected. A data base is currently being developed to handle information on site characteristics and species performance.

Homoclimes have not been found to be a reliable guide to species performance (8), possibly because of the importance of run-on and groundwater at saline sites. The opportunistic growth of perennial shrubs and their ability to survive are factors in widening their site adaptation.

Grasses have also been found to be useful for pasture production on saltland. Paspalum vaginatum (21), Puccinellia ciliata (22) and Elytrygia (Agropyron) elongatum were introduced to Western Australia before the 1960s. The first two are in widespread use but the use of E. elongatum was discouraged for many years due to its possible role as a host for wheat rust. The original P. ciliata Introduction was compared with new collections from North Africa, Turkey and Iran (23) at the same sites used for shrub selection studies (8) but no superior types were identified (author's unpublished data). Other genera, not widely tested in Western Australia (Aeluropus, Diplachne and Sporobolus) are under study in eastern Australia (B. Myers, personal communication, 1988).

On areas of saltland planted many years ago it is common to find P. ciliata growing in association with halophytic shrubs either between bushes or under the canopy. No research has been undertaken to determine whether the bushes and shrubs compete.

Many saltland areas include sections suited to different species. For example, the lowest sections may be highly saline and frequently waterlogged and suited only to the growth of Haloscarcia spp.; up-slope where waterlogging is less frequent Atriplex spp. may be well adapted; still further up-slope where waterlogging is absent or occurs only for a few days after heavy rain, Maireana brevifolia will grow (8).

Recent research (24) has shown differences in waterlogging tolerance between Atriplex spp. The work followed field observations by the author in which A. amnicola survived waterlogging events to which A. bunburyana and A. paludosa succumbed. Research is currently directed to identifying plant criteria which indicate tolerance to waterlogging and using them to screen a range of species and ecotypes. This work may shift the use of Atriplex spp. into higher rainfall zones and wetter sections of present sites. Replacement of Halosarcia with Atriplex is beneficial for grazing because of its lower salt content and higher palatability.

To be suitable for pasture production plants must be sufficiently productive. For grasses such as P. ciliata, standard methods of pasture research (e.g. quadrat cuts) may be used to assess the yield of a sward. For measurement of production from natural shrub stands, methods have been devised in range management studies. To determine the yield of planted shrubs it is necessary to plant the bushes at an appropriate spacing. Spacing has been found to be a major factor determining the yield of individual bushes in a stand (9). Ash free yields from 0.5 to 2 t ha-1 were obtained from five Atriplex spp. in a single cut after 20 months' growth on saltland at Kellerberrin. For a small species (A. vesicaria) maximum yield per hectare was obtained at 1 x 1 m spacing, but for a large species (A. amnicola) the yield was the same from 1 x 2 to 3 x 3 m spacing, indicating that bush yield was limited by interbush competition. Due to the high salt content of the leaves (26-39 per cent ash) yields of Atriplex spp. (and other halophytic shrubs) should be expressed on an ash free basis.

Halophytic shrubs as feed for sheep

The feed quality of material eaten from shrubs by sheep varies with the proportion of leaf and twig in the diet. leaves have an in vitro digestibility of 66-74 per cent (but are high in ash), while twigs up to 5 mm diameter have an in vitro digestibility of 32-39 per cent (with an ash content of 6-11%) (9). As sheep browse a shrub they remove the leafiest materials first and eventually eat sticks if allowed to continue without alternative feed. Studies on the effect of this diet change on the performance of sheep are lacking.

Intake of shrub feed may be limited by palatability (20). Even within a species, Ward observed that sheep stripped plants of an ecotype of A. cinerea from Geraldton but refused to eat adjacent bushes of an ecotype from Rottnest even though they were losing weight.

Intake and digestibility of Halosarcia pergranulata by pen-fed sheep were markedly increased by washing the material to reduce its salt content (25).

The ultimate test of a pasture is to conduct grazing experiments and observe the effects on the pasture and the animal. In a review of studies on grazing or pen feeding of chenopod shrubs it was concluded that they are more likely to be useful under extreme or unreliable conditions (26). In Western Australia the most critical period for sheep feed supply is autumn and early winter. At this time of year, annual pastures are at their poorest in quantity and quality, stubbles have deteriorated and sheep must be hand-fed until rain brings pasture growth. Chenopod shrubs in late autumn carry ripe seeds and their growth rate slows (20). The quality data discussed above refer to samples obtained in autumn. Substituting shrub pastures for hand feeding allows the farmer to save on hand feeding materials and labour, and to defer grazing on pastures which germinate after rain. Many other benefits are claimed for saltland revegetation with perennial halophytes (see list in Table 4).

Table 4. Benefits from saltland revegetation with halophyte forages

- Seed production and sales Water use to lower groundwater Erosion control (wind and water) Improved annual cover
- Improved aesthetics
- Development of a diverse ecosystem Increased farm value
- Shelter for sheep
- Cleaner wool
- Deferred use of other pasture after opening rain
- Savings on hand feeding (materials and labour)
- Better autumn sheep nutrition
- Labour saving at seeding time

The economic benefits of halophytic shrub pastures have been studied (27) using linear programming models and data from grazing experiments (28). For a variety of scenarios it was found that for wheatbelt farms expenditures ranging from $88 to $319 per hectare (1986 prices) were economically justified for establishing Atriplex spp. pastures. The benefits accounted for were increased sheep numbers, less grain feeding and reduced cropping on soils with the lowest opportunity cost for growing pastures. Accounting for all benefits listed in Table 4 would increase the attractiveness of shrub pastures.

The grazing studies on which the economic analysis are based (28) were conducted on field plots of shrubs grazed with small groups of sheep in autumn-winter. Body weight was the only criterion used to determine when to remove the sheep. There is an urgent need for studies to determine the effect of the shrub pastures on other aspects of animal production e.g. wool and meat production, lactation, lambing and weaning.

Halophytic shrubs subjected to grazing (28) or hand pruning (20) vary greatly in their ability to recover. A. paludosa bushes succumb to intense autumn grazing but regenerate well from seed if given protection. A. lentiformis and A. undulata recover from intense grazing and produce new seedlings if only grazed in late autumn and early winter, but their production is reduced by successive years of intense autumn-winter grazing. A. amnicola continues to recover well despite successive years of intense autumn-winter grazing and provides seedling regeneration as well. These studies were conducted in 0.16 ha plots and it is important to develop management methods that maintain vigorous shrub pastures at a paddock scale.

Establishment of halophyte pastures

Paspalum vaginatum is established vegetatively, and Puccinellia ciliata and Elytrygia elongatum are sown from seed using standard farm machinery and techniques.

Shrub pastures are established by using the niche seeding technique (29), encouraging natural seedling regeneration (M. brevifolia and H. pergranulata) (30) or by using seedlings. The second method is the cheapest but does not work for the recommended Atriplex spp. Niche seeding is used on a routine basis by commercial contract operators to sow thousands of hectares on private farms each year. In some situations niche seeding is unreliable and seedling planting using bare-rooted seedlings is being investigated as a method of reducing cost and improving reliability.

Establishment is hindered by many factors (31). Research is being targetted at improving site characterization so that species selection, site preparation, planting/seeding methods and pest control can be more effectively prescribed. Major factors causing problems are salinity, waterlogging, poor soil structure, weeds and insects. Innovations to overcome these problems include improved niche design, raised planting positions, gypsum, mulch, bitumen emulsion and pesticides. Alternatively the planting of seedlings can be used to avoid many of the difficulties.

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