Chapter 9
Saltland pastures

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Saltland pastures
Ed Barrett-Lennard and Geoff Moore

In Western Australia there are between 1.0 and 1.2 million hectares of severely salinised land and between 2.8 and 4.4 million hectares of land with a high risk of secondary salinity. Saltland pastures have been planted and grazed in WA since at least the late 19th century and their use has been promoted actively since the 1940s.

About half of WA’s saltland is suited to various kinds of saltland pasture. The remainder is too saline and should be fenced to allow it to revegetate naturally with samphire (Halosarcia species) and salt- and waterlogging-tolerant trees like swamp sheoak (Casuarina obesa).

The key saltland pasture types are:

- halophytic shrubs, especially river saltbush (Atriplex amnicola), old man saltbush (A. nummularia), wavy-leaf saltbush (A. undulata) and small leaf bluebush (Maireana brevifolia)
- halophytic perennial grasses, especially puccinellia (Puccinellia ciliata) and tall wheat grass (Thinopyrum ponticum)
- mildly salt and waterlogging tolerant annual legumes such as balansa clover (Trifolium michelianum), Persian clover (Trifolium resupinatum) and burr medic (Medicago polymorpha) and more tolerant annual grasses such as annual ryegrass (Lolium rigidum).

This chapter focuses on the halophytic shrubs and perennial grasses that are currently available. The CRC for Plant-based Management of Dryland Salinity is currently developing new, improved fodder species for revegetating saltland.

A recent survey of old trial sites has demonstrated that long-term, sustainable, productive reclamation of saltland is achievable in many areas in the WA wheatbelt using a combination of halophytic shrubs and understorey plants.

Many plantings of halophytic shrubs in the wheatbelt remain productive after 40-50 years so must have reached equilibrium in terms of their salt and water balance.

Salinity, waterlogging and inundation
Saltland is not all equally productive. Saltland plants occur in a range of ecological zones of differing productivity created by variations in the severity of salinity, waterlogging and inundation. Waterlogging and inundation are different stresses, although they may occur in close proximity.

Salinity
Saline soils affect the growth of plants mainly because of high concentrations of dissolved sodium and chloride ions in the soil. They may also contain significant concentrations of magnesium, sulphate, carbonate, bicarbonate and boron. The salts in WA soils are commonly in similar proportions to the salt in seawater with sodium chloride making up about 75%. In saline soils sodium and magnesium replace calcium to varying degrees in the exchange complex on the clay and cause the soils to be dispersive and poorly structured.

Salinity can affect plants in a number of ways:

- Salinity makes it difficult for the roots to take up water due to the decreased osmotic potential. Plants may have difficulty withdrawing water from what appear to be moist soils.
- A build-up of salt in the leaves, especially old leaves, can lead to necrosis. The overall
effect on the plant depends on the rate of new growth compared with the rate of leaf necrosis.

- High sodium and chloride concentrations in the soil can affect the uptake of other nutrients, e.g. potassium, magnesium, nitrogen and phosphorus, which are essential for plant growth.

The most common way of assessing the salinity of a soil is to extract the salt in water and measure its electrical conductivity (EC). Salt solutions are conductive because of the electrical charges on the ions. For most practical purposes, the conductivity of soil extracts is proportional to their salt concentration. The electrical conductivity of soil extracts is most commonly reported in deci-siemens per metre (abbreviated dS/m). In the past, micro (µ) siemens per centimetre (µS/cm) or parts per million (ppm) were used. Conversions for sodium chloride solutions can be made between units on the basis that:

\[ 1 \text{ dS/m} = 1,000 \, \mu \text{S/cm} = 584 \, \text{ppm}. \]

Plants can be divided broadly into three groups according to their growth response to salinity (Figure 9.1).

(a) Halophytes (‘salt plants’). Halophytes actually grow faster in mildly saline soils than non-saline soils, but have reduced growth at high salt concentrations. River saltbush (*Atriplex amnicola*) is a typical example; it has a 10% increase in shoot dry weight at 5 dS/m (a salt concentration equivalent to about ~9% of seawater), a 50% decrease in growth at 40 dS/m (equivalent to ~70% of seawater), and is still alive at 75 dS/m (equivalent to ~140% of seawater).

(b) Salt-tolerant non-halophytes. These plants will grow at low salt concentrations, but have decreased growth at higher concentrations. Barley is a typical example; it has a 50% reduction in shoot growth at 13 dS/m (equivalent to ~20% of seawater).

(c) Salt sensitive non-halophytes. The growth of these plants is sensitive to even low concentrations of salt. Beans (*Phaseolus vulgaris*) are typical, with a 50% decrease in growth at salt concentrations of 5 dS/m (equivalent to ~9% of seawater).

Waterlogging

Waterlogging refers to the saturation of the root zone by excess water. This inhibits gaseous exchange between the soil and atmosphere, leading to a dramatic decrease in the concentration of oxygen in the soil and an accumulation of ethylene.
and various products of anaerobic metabolism such as carbon dioxide and ethanol. Roots normally require oxygen for the optimal production of energy from sugars. Waterlogging therefore causes: (i) an immediate decline in root growth followed by a subsequent decline in shoot growth; (ii) rapid death of root tips followed by the death of previously developed roots; and (iii) decreased activity of all processes associated with active ion transport across membranes (such as the uptake of inorganic nutrients).

Most importantly, under saline conditions, waterlogging causes plants to increase their rate of salt uptake, increasing the concentrations of salt in the shoots and jeopardising growth and survival.

Much of WA’s saltland is also subject to waterlogging because of the presence of shallow groundwater and/or shallow duplex soils with impermeable clay subsoils. The importance of waterlogging is often underestimated, since it is usually not visible at the soil surface and can be ephemeral.

Waterlogging varies in duration and intensity (depth to watertable) and can have a more adverse effect on plants when they are growing actively. For instance, cereals are more tolerant of waterlogging in mid-winter when temperatures and transpiration rates are low than in mid- to late-spring when temperatures and transpiration rates are higher.

For saltland pastures, one of the keys to profitability is to grow the right plant in the right place. Waterlogging will affect the growth of all but the most tolerant plants on saltland. The matrix in Figure 9.2 shows where different plants have a competitive advantage in soils of increasing salinity and waterlogging.
Inundation
Inundation refers to water ponding on the soil surface. The effect on plants is severe because inundated leaves cannot photosynthesise and few plants survive if they are completely submerged. Flooding is similar, but refers to water flowing outside its usual channel, such as a river or a small drainage line.

As salinity in valley floors increases because of shallow watertables, inundation and flooding will become more severe. In effect, less rainfall can infiltrate into the soil, so more becomes available for run-off. Even brief periods of inundation appear to be highly damaging to plants and the environment. There is only limited anecdotal evidence of the tolerance of different plants to inundation. One mechanism by which plants avoid inundation is to grow quickly so that total immersion in water is avoided.

Implications for drainage
Understanding the interactions between waterlogging, inundation and salinity can help with the debate about design criteria for drainage.

The level of drainage required to decrease soil salinity can be substantial. Depending on soil texture and rainfall the watertable may need to be drawn-down to ‘critical depths’, e.g. greater than 2 m from the surface. However, studies of the interaction between waterlogging and salinity show that substantial improvements in plant growth can be possible with even slight decreases in waterlogging. These kinds of changes may be achievable with relatively cheap structures that improve the control of surface water, for example, grade banks that intercept surface water run-off further up the landscape and redirect it away from low lying waterlogged areas and surface drains like W-drains or raised beds. Such measures should be used to alleviate surface waterlogging before saltland pastures are established. Further lowering of the watertable may then be possible through the use of shallow groundwater by these salt-tolerant plants.

Developing a revegetation strategy
Saltland is usually highly variable spatially, especially in terms of the degree of salinity and waterlogging. As a result, evaluating a site’s potential for revegetation options may not be straightforward. For example, a site with moderate salinity in summer may also be subject to prolonged waterlogging in winter. The combination of waterlogging and salinity may adversely affect plant establishment, depending on the degree of leaching in early winter (which in turn is related to the soil texture). As discussed previously, reducing waterlogging (e.g. raised beds, W-drains, surface drains) will often increase the revegetation options. Figure 9.3 outlines the steps in developing a revegetation strategy for saltland.
9.1 Halophytic shrubs

The benefits of growing halophytic shrubs include:

- increased production on moderately salt-affected and waterlogged land
- high protein forage available to meet the ‘autumn feed gap’ and provides a source of vitamin E
- increased evapotranspiration, so recharge and saline groundwater are used. This makes productive use of as much water as possible and can lower the watertable, so that understorey species of higher productivity and nutritive value can be grown
- sequestration of CO$_2$
- control of wind and water erosion
- shelter for stock in severe weather conditions
- reduced shedding of water, salt, soil and nutrients
- improved sustainability in the long-term
- increased biodiversity and improved wildlife habitat.

The importance of mixtures

Good animal production requires fodders that contain high concentrations of metabolisable energy, moderate to high concentrations of crude protein, adequate vitamin levels and relatively low concentrations of salt. In general, saltbushes have a reasonable metabolisable energy concentration when expressed as a proportion of the organic material in the plant. They also have high crude protein, vitamin E and high salt concentrations.239, 285

High salt concentration is a major limitation to feed intake, as grazing animals are unable to eat sufficient saltbush to grow. Animals grazed on pastures containing saltbush alone will gain weight briefly (due to additional fluid retention), but will not thrive in the longer-term.268, 416

Saltbush leaf on its own is at best a maintenance diet for sheep.

The key to the use of saltbush fodder is to mix it with feeds with complementary characteristics such as stubble. The potential of this approach is clear from a pen-feeding trial in which sheep were fed diets of 100% low quality hay (dry matter digestibility 57%), 100% leaves of wavy-leaf saltbush, or a 50:50 mixture of hay and saltbush (Figure 9.4a, b)418. Sheep fed the saltbush or the hay alone had low feed intakes and lost liveweight. However, when saltbush leaf was mixed with hay, feed intake doubled and the sheep gained liveweight at about 70 g/day (Figure 9.4).

Achieving mixtures in the field

The field strategies required to optimise mixed saltland pasture diets are the subject of research in the Sustainable Grazing on Saline Lands (SGSL) initiative. Nevertheless, at this stage, there seem to be two major options:

(a) On moderately saline and waterlogged land, grow fairly dense stands of shrubs and provide a supplement to grazing animals of hay or small amounts of grain, or provide the animals with simultaneous access to cereal stubbles.

(b) On mildly salt-affected land, grow rows of shrubs at wider spacings with an understorey of tolerant annual legumes and perennial grasses (e.g. tall wheat grass, puccinellia) and intensify...
Saltbush is a high protein forage which can be used to meet the ‘autumn feed gap’

The grazing so that the palatable and less palatable components of the feed-on-offer are consumed simultaneously.

The optimum shrub density for a particular farm varies with the area of saltland relative to other feed. The higher the proportion of saltland on a farm the more important it is to increase the alley spacing and grow more understorey.

**Economic value**

Current economic analyses suggest that the main value of saltland pastures is in providing a source of feed in autumn. A recent analysis of a 2000 ha property on the south coast of WA, suggested that revegetating 2.5% of the farm to saltbush could increase the profitability of the whole farm by 5%.491 The analysis also showed that profit could be further improved if both the nutritive value and production of the saltland pasture were increased.

**Establishing shrubs**

There are two methods for establishing shrubs.

**Niche seeding**

Seeds on saltland germinate naturally in protected ‘niches’ such as in debris lying on the soil surface where they remain protected from drying winds. Niche seeders attempt to reproduce such protected sites. Niche seeders deposit fruits of saltbush or bluebush and a covering of vermiculite at 1-3 m intervals on a raised M-shaped mound. The shape of the mound promotes leaching of salt from the seed bed, while the vermiculite acts like mulch by retaining moisture around the fruits and reducing the movement of salt into the seed bed by capillarity. The elevation of the seed bed above the surrounding soil reduces waterlogging.

The keys to successful niche seeding are:

- Good site selection. Best results have been achieved in WA on sandy and deeper duplex soils.492 Avoid grey clays and sites that grow samphire (too saline/waterlogged) or that grow subterranean clover and capeweed (low salinity allows growth of weeds).
• Good weed control. Spray-top in the year before establishment, graze hard and use knockdown herbicides before seeding.

• Reduce waterlogging and inundation. Reduce overland flow onto saltland by using seepage interceptors and grade banks further up the landscape to direct excess water away. Remove surface water from saltland using W-drains. Plan niche seeding so that mounds and furrows direct water into surface drains.

• Use seeding rates appropriate for the seed quality. Fruit quality can be highly variable, as seed fill is often less than 20%. Seed should be sown at sufficiently high rates to have 50 germinable seeds per placement.

• Control insects. The use of systemic insecticides is essential to control redlegged earth mite and other insects during establishment.

• Good timing. Sow sufficiently late to avoid winter waterlogging, but sufficiently early to avoid the drying conditions of late spring.

• Control grazing until plants are well established. This varies with seasonal conditions but may mean deferring grazing until after the second summer.

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**Planting nursery-raised seedlings**

Nursery-raised seedlings can be planted using commercial tree planters. This technique is generally more reliable than direct seeding, especially into clayey soils. However, the use of seedlings is relatively expensive as nurseries sell saltbushes for ~25 cents each. On this basis a stand of 1000 plants/ha would cost $250/ha, plus transport, site preparation and planting costs.

Bare-rooted seedlings, i.e. seedlings with no soil around the root, can be raised on the farm at low cost. This method can give good results when used on non-saline soils, however on saline soils it has had limited success. This is probably due to damage to the roots during planting and ‘osmotic shock’ from a lack of salt hardening.

**Natural establishment**

The cheapest way to establish halophytic shrubs is to fence off an area to control grazing and allow the site to regenerate naturally. This is particularly appropriate for bare areas affected by severe valley floor salinity and waterlogging, where protection can promote the natural establishment of samphire (Halosarcia species) and swamp sheoak (Casuarina obesa). On moderately saline, non-waterlogged soils, controlled grazing will promote the establishment of small leaf bluebush (Maireana brevifolia) if wind-borne seed is available from nearby plants.
9.2 Saltbush (*Atriplex* species)

**Features**
- halophytic shrubs, many species native to WA
- long-term survival and production on moderately saline and waterlogged soils
- drought tolerant
- can be used as plant-based ‘water pumps’ to maintain saline watertables below critical depths
- best used in conjunction with other feeds because they have:
  - high protein concentrations
  - adequate metabolisable energy
  - high salt concentrations
  - limited edible dry matter
  - moderate oxalate concentrations.

Saltbush is the common name for plants from the genus *Atriplex*. The three main commercial species in WA are river saltbush (*Atriplex amnicola*), old man saltbush (*A. nummularia*) and wavy-leaf saltbush (*A. undulata*). Other species that have been used are creeping saltbush (*A. semibaccata*), grey saltbush (*A. cinerea*) and quailbush (*A. lentiformis*).

Saltbushes have dimorphic flowering systems and many of them are dioecious, i.e. having male and female flowers on separate bushes. This reproductive strategy produces high levels of genetic variation within populations. Female plants produce a fruit that contains a single seed, but fruits will be empty if they develop without a nearby source of pollen.

River saltbush (*Atriplex amnicola*) comes from the floodplains of the Murchison and Gascoyne Rivers of WA where the plant’s growth habit can vary from prostrate to erect and individual plants vary in size from 1 m by 1 m to 4 m across and 2.5 m high. Stems touching the ground can form roots. Established plants have good waterlogging tolerance and can survive partial inundation in winter.

River saltbush has excellent long-term survival, recovers well from grazing and has high palatability. It has been widely used as plant-based ‘water pumps’ to maintain saline watertables below critical depths.

**Description**
- halophytic shrubs are perennial except for creeping saltbush, which is biennial
- prostrate to erect growth habits with woody stems
- grey-green leaves with bladder cells on the leaves
- mostly dimorphic flowers, many dioecious (i.e. female and male flowers on separate plants)
- fruits mature between February and April
- usually a single seed is contained between two bracts, but not all fruits form seeds.
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grown in mixed plantings in the WA wheatbelt. Establishment from seed can be difficult, especially if correct establishment procedures are not followed. Germination is improved by exposure to light, hence the need for shallow sowing.407

Two ecotypes, ‘Meeberrie’ and ‘Rivermor’, which are both public varieties, were selected for their colonising ability, which is related to ease of establishment.

Old man saltbush (A. nummularia) is Australia’s iconic saltbush species. It is native to the semi-arid and arid zone of southern and central Australia. It grows well on saline and rangeland soils and is deeper-rooted (down to ~4 m) than many other saltbushes.182 Given its deeper root system it can be sensitive to waterlogging, particularly at high temperatures. Symptoms of waterlogging damage include bleaching of the leaves.29

Old man saltbush has a relatively poor ability to produce volunteer seedlings. Its main disadvantages as a fodder are its erect growth habit (up to 2 m high) and lower palatability than other saltbushes and bluebush. It has been advocated as a drought reserve in NSW and has shown good survival after severe frosts.

In South Australia, a cloned variety ‘Eyres Green’ has been selected for its low growth habit and palatability. It is propagated vegetatively.

Wavy-leaf saltbush (A. undulata) comes from the semi-arid rangelands of central Argentina and as the name suggests, the leaves are crinkly or wavy. Established plants can reach 1 m high and 2 m across and stems touching the ground can form roots. It establishes readily from seed using the niche seeder. It appears to have lower waterlogging tolerance than river saltbush.
Soil–climate adaptation

**Rainfall:** 250-450 mm

**Drought tolerance:** Extreme (once established)

**Frost tolerance:** High

**Soil type:** Moderately saline and waterlogged soils with best growth on deeper sand over clay soils. Poor growth on massive grey clays

**Soil fertility requirements:** Low. Generally well adapted to soils deficient in N and P. At Tammin, application of P had no effect on the growth of river saltbush. Applications of N (60 kg/ha) doubled shoot volumes after three months, but after two years plants with added N were only 12% larger than non-treated plants.

**Soil pH**

Ca: 4-8.5

Old man saltbush does not survive as well on shallow acid (pH 3.4) groundwater

**Aluminium tolerance:** Unknown

**Waterlogging tolerance:** Moderate (old man saltbush), moderate to high (river saltbush) (Figure 9.2). When waterlogged, saltbush develops increased salt concentrations in the leaves, which has an adverse effect on feed quality, while plant growth and survival may also be affected.

**Salt tolerance:** Moderate to high (Figure 9.2). Optimal growth occurs at EC₆ values of 25 dS/m, however species will survive irrigation with seawater (~55 dS/m)

**Nutritive value**

Being a shrub, nutritive value is strongly affected by the tissue sampled. Twigs should not be regarded as forage. Dry matter digestibility (DMD) values are meaningless and should not be quoted for these plants, due to the high concentrations of salt that can accumulate in the leaves (see below).

**Metabolisable energy:** 7.1-7.6 MJ

**Crude protein:** 7-17% (in summer/autumn), 17-23% (in winter)

In halophyte tissues, nitrogen can also be in the form of nitrate (up to an equivalent of 2-3% crude protein) and small molecular weight amino acids like glycine betaine (up to an equivalent of 4% crude protein). These may be incorporated into microbial protein in the rumen if animals have sufficient metabolisable energy in the diet.

**Ash:** 15-39% (average 23%) – the ash is about 75% sodium chloride

The salt concentration in the leaves affects feed quality. This is affected by growing conditions (levels of salinity and waterlogging), leaf age (recently formed or old), and by inherent differences between plants within populations. We estimate:

- less than 20% ash in leaves grown under non-saline (e.g. rangeland) conditions
- ~20% ash in leaves grown under saline conditions in winter
- ~30% ash in leaves grown under saline conditions in summer/autumn

**Environmental implications**

**Groundwater recharge control:** Saltbush can probably use groundwater at salinities up to that of seawater. Use of groundwater with EC values of ~20-30 dS/m has been reported at Kellerberrin.

**Ability to spread:** Wavy-leaf saltbush is an introduced species and has shown limited spread to unsown areas. River saltbush is from low rainfall regions and some ecotypes have spread downstream of plantings. Old man saltbush has a very low tendency to spread by seed.
There are differences between saltbush species in cold tolerance. River saltbush is a sub-tropical species and while it grows well in the central and southern wheatbelt, it is best suited to the northern agricultural areas. In cooler areas wavy-leaf saltbush is preferred.\textsuperscript{147}

**Seasonal growth pattern**
Saltbushes are warm season (C4) plants and as a result they generally grow slowly in winter because of the cool temperatures. They grow actively from early to mid-spring and into early summer. Summer and autumn growth depends on access to moisture from rainfall, stored soil water and from groundwater (depends on depth to watertable, salt concentration, pH and presence of other dissolved toxic ions).
Saltbushes often grow rapidly over the first and second summer as they use the water stored in the soil profile. However, in the longer term their growth rate slows down as they become more reliant on rainfall.

**Establishment**
Saltbush should be established using a niche seeder or nursery raised seedlings planted with a tree planter as described previously.

**Livestock disorders**
There are upper limits to the amount of salt that sheep can consume; for a 50 kg sheep, this limit is about 100-120 g/day provided there is a plentiful supply of non-saline water available.\textsuperscript{239, 418} As a result, saltbush intake can be limited by the salt concentration in the feed, the amount of alternative feeds available and the salinity of the drinking water.\textsuperscript{239}
Saltbush can contain 3-6\% of oxalate.\textsuperscript{234} Poisoning in sheep and cattle has been reported when pastures contain 7-8\% oxalate.\textsuperscript{561} Saltbush can contain iron (Fe) levels above the suggested maximum tolerable concentration for sheep of 500 mg/kg DM.\textsuperscript{287} However, these levels of oxalates and iron present no problems if the saltbush is fed with other feeds of lower oxalate/iron content.

**Management**
Grazing management for saltbush aims to mix the saltbush leaf, which contains high concentrations of crude protein and salt, with other plant material of lower salt concentration.

Animals grazing saltbush need to have access to a good quality (non-saline) water supply. They will also drink a large amount of water, e.g. sheep on saltbush drink 6-9 L/day compared with 2 L/day on a low salt feed.
Saltbush plants are usually ready to be grazed after 9-12 months. Early grazing is important to increase the number of stems and reduce the development of wood. The first grazing needs to be managed carefully to ensure that the plants are quickly defoliated and there is no damage to the main stems. Aim to leave about 15\% of the foliage to ensure good recovery after grazing.
Established saltbush can withstand hard grazing (complete defoliation back to bare branches) once per year. However they do not tolerate long-term continuous grazing and need to be allowed to recover after grazing. Short grazing periods (<21 days) are preferable to ensure that the regrowth is not grazed. When grazing near the start of winter, ensure that at least 10\% of foliage remains after grazing.
If cereal grain supplements are fed to sheep on saltbush, then additional calcium should be considered, as the oxalate in saltbush leaves may make the low concentrations of calcium in the grain even less available.\textsuperscript{239}
Recovery of river saltbush from simulated grazing: (a) 8 month old plant, (b) simulated grazing, (c) recovery 3 months later
9.3 Small leaf bluebush (*Maireana brevifolia*)

**Features**
- halophytic shrub native to the eastern wheatbelt
- suited to moderately to highly saline and moderately to well drained soils
- best used in conjunction with other feeds, because of:
  - high protein concentrations
  - high salt concentrations
  - high oxalate concentrations
  - limited edible dry matter.

Small leaf bluebush is the other major halophytic shrub used in WA. It is native to the wheatbelt and is common on soils near salt lakes where the native vegetation was ‘morrel’ (*Eucalyptus longicornis*).

Bluebush occurs at slightly higher elevations in saline landscapes than the saltbushes. It differs from the saltbushes in having a lower tolerance to waterlogging and flooding, but has similar feed value.

The distinctive fruit consists of a woody structure (5 mm) surrounded by a papery wing up to 20 mm in diameter. Bluebush is shorter lived than some of the saltbush species, but it can maintain stand density because of its excellent seedling recruitment. It is an early coloniser of disturbed lands.

**Seasonal growth pattern**

Bluebush is a warm season (C4) plant which is dormant or grows only slowly in winter and then grows actively from early to mid-spring through to early summer. Growth over the summer to early autumn period depends on moisture availability, i.e. on rainfall, stored soil water and the accessibility of groundwater (which is affected by its depth and salinity). Production from bluebush is well correlated with the rainfall for the two previous years.231

**Description**
- deep-rooted perennial shrub up to 1 m high and 1 m wide
- habit is upright to semi-erect
- leaves are short (2-5 mm), fleshy and dark bluish-green
- flowers are bisexual and occur in leaf axils
- flowers from late November to July, with most seed in February and March236
- winged seeds scattered by the wind.
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Establishment
If there is a nearby stand of bluebush, fencing and protecting an adjacent area for two to three years will lead to colonisation – the lowest cost establishment strategy. Alternatively, bluebush can be introduced into an area by sowing with a niche seeder, or less reliably by spreading seed onto cultivated soil. Only recently collected seed should be sown as seeds lose their viability within a year when stored at ambient temperature and relative humidity.

Livestock disorders
Bluebush can contain high concentrations (9-12%) of oxalate. Hungry sheep should not be introduced to bluebush unless other feed is also available. It should be fed with other pasture, stubble or hay.

Bluebush can also accumulate nitrates (1,000-3,000 mg N/kg DM).

Management
Farmers often use bluebush in summer to late autumn with stubble or pasture as discussed above. Bluebush can be grazed hard in autumn, but it should be grazed for short periods (two to three weeks) and then allowed to recover.

Cultivars
There are no commercial cultivars, but there are distinct ecotypes in the agricultural area.
9.4 Halophytic grasses

The major salt-tolerant grasses used in Australia are puccinellia (*Puccinellia ciliata*) and tall wheat grass (*Thinopyrum ponticum*). Many saline sites are a mosaic of severely and moderately saline/waterlogged land. In these cases, sowing a mixture of tall wheat grass and puccinellia results in the puccinellia colonising the more waterlogged/saline bare land where it has a competitive advantage and tall wheat grass establishing in the less waterlogged/saline areas.

Two other grasses of interest for WA are distichlis (*Distichlis spicata*) and saltwater couch (*Paspalum vaginatum*). These grasses are highly waterlogging and salt-tolerant and are propagated vegetatively. The warm season (C4) grasses Rhodes grass, kikuyu and bambatsi panic are reported to have some salt tolerance and may have a role on marginally saline soils (Chapter 5).

Establishment

The keys to successful establishment of salt-tolerant grasses are similar to those for the establishment of shrubs. Sites for puccinellia and tall wheat grass should receive more than 350 mm of annual rainfall and should be dry at the surface in summer.

- Site preparation. It is essential to get good control of sea barley grass (*Hordeum marinum*), which is the major grass competitor. Sea barley grass possesses little or no dormancy and does not persist in the soil. More than 99% of the seed will germinate in the first few weeks after the autumn rains.

Germination is not stimulated by tillage. Sea barley grass can be readily controlled if a combination of strategies are used. In the year before seeding, graze hard then spray-top in spring. Then burn off the dry grass in the autumn and use a knockdown before seeding.

- Extended surface ponding inhibits germination, so construct surface water control structures such as W-drains to decrease inundation and waterlogging of the surface soil. Cultivate the area roughly before the break of the season, to provide a variety of micro-sites in which seed can lodge and germinate.

- Timing of seeding. If there is an early break, wait for the sea barley grass to germinate (two to four weeks), then spray with a knockdown herbicide and sow. When there is a late break, wait two weeks before applying a knockdown spray and then seed immediately.

- It is essential that seed is fresh since germination declines rapidly if the seed is more than two years old. Apply superphosphate (50-100 kg/ha), but no nitrogen at seeding.

- Grazing. Prevent uncontrolled grazing of young plants. Protect stands from heavy grazing for at least 18 months (two winters).
9.5 Puccinellia (*Puccinellia ciliata*)

**Features**

- moderately salt-tolerant and moderate to highly waterlogging tolerant perennial grass
- suitable for winter wet, summer dry saline sites
- tolerates partial inundation over winter
- ‘resurrection grass’ – green in winter, dry in summer
- often used as pioneer species on bare saltland
- prefers neutral to alkaline, calcareous soils
- responsive to nitrogen fertiliser.

Puccinellia was introduced into WA by CSIRO in the early 1960s as a pioneer plant for revegetating saltland. It has been widely sown in WA, but most stands are poorly managed. On the other hand, in South Australia puccinellia is one of the great saltland pasture success stories. Puccinellia is grown extensively on the low-moderately saline, but highly waterlogged soils of the Eyre Peninsula and the Upper South East. It is used to fill the autumn feed gap, with carrying capacities up to 32 DSE/ha for three months. An export seed industry has also been established in the region.

The relative failure of puccinellia to thrive on WA soils may be due to the combination of low pH and low availability of calcium. Recent research has shown that puccinellia appears to prefer alkaline, calcareous soils. The benefits of lime and/or gypsum have yet to be assessed for WA soils.

Puccinellia is well suited to winter waterlogged, saline sites with a patchy cover of sea barley grass (*Hordeum marinum*) or bare ground. On non-saline soils it usually behaves as a low productive annual grass and is out-competed. Puccinellia is best used to meet the autumn feed gap reducing the reliance on supplementary feeding.

**Seasonal growth pattern**

Puccinellia is a ‘resurrection grass’, as the plants hay-off in late-spring and remain dormant over summer. They shoot vigorously from the tiller bases after the opening rains and heavy dews in mid-autumn, and then have good winter production. The stand can be thickened by allowing it to set seed. Seed will not germinate on summer rain as it is inhibited by high temperatures (>30°C).

**Description**

- densely tufted, perennial bunch grass up to 40 cm high and wide
- long, thin (1-4 mm), greyish-green leaves
- seed head is an open, panicle (35-40 cm high)
- flowers in September, with seed ripe by December.
Establishment
Successful establishment requires excellent weed control as puccinellia seedlings compete poorly with annual weeds, in particular sea barley grass (refer to ‘establishment of halophytic grasses’ in the previous section). The suggested seeding rate is 2-4 kg/ha when sown alone, or 1-3 kg/ha when sown in a mixture with tall wheat grass.

In general, puccinellia should be sown before the end of June while the conditions are still mild. Puccinellia has a very small seed (6.6 million/kg) and needs to be sown shallow (<5 mm) or broadcast on the surface. Covering harrows are not recommended for puccinellia because of its small seed. The seedlings are slow to establish, however very small plants can persist through the first summer.293

Puccinellia normally takes at least a year to become well established. It should not be grazed in the first year as sheep can uproot the plants. Light grazing is possible in the second year.

Soil–climate adaptation
Rainfall: >350 mm
Drought tolerance: Very high
Frost tolerance: High
Soil type: Moderately saline, highly waterlogged soils; prefers calcareous soils
Soil fertility requirements: Requires both N and P to thrive
Soil pH<sub>Ca</sub>: 5.5-8.0
Aluminium tolerance: Unknown
Waterlogging tolerance: High to very high (Figure 9.2). Also tolerates partial inundation326
Salt tolerance: Moderate to high. Occurs in the field over an EC<sub>e</sub> range of 5-40 dS/m, with best growth at 16-32 dS/m140,353

Nutritive value
The grazing value of puccinellia depends on its growth stage. It has good feed quality during winter and early spring, but declines with flowering and as the leaves dry off149,150,269

DMD: 60-78% (in winter and early spring), <50% (in summer)
Crude protein: 10-18% (in winter and early spring), <5% (in summer)
Ash: ~10%363

Environmental implications
Soil erosion control: Often sown as a pioneer plant on eroded saltland where the topsoil has been lost.
Livestock disorders
None reported.

Management
Established stands are tolerant of heavy grazing as the growing points are embedded in the base. Puccinellia can be grazed hard in autumn and winter, provided the soils are not too wet (avoid pugging) or there is a possibility of inundation, as immersion can kill plants. A lower grazing pressure in spring is recommended, so that a dense plant cover reduces salt accumulation at the surface. Dry material grazed in late summer is palatable, but of low quality and may not be sufficient for maintenance.

Growth is highly responsive to applications of nitrogen in late winter. In one trial in SA, a split application of 65 kg N/ha (25% in June, 75% in August) increased dry matter production from 2.2 to 7.8 t/ha. There were similar relative benefits for seed production. Anecdotal evidence also suggests that puccinellia is responsive to N-fertiliser on WA soils.

Seed ripens by December and can be harvested at any time during the summer with little risk of shedding. The seed is difficult to harvest because it is small and light. A conventional closed-front cereal harvester can be used with some adjustment. Use the maximum drum speed with a drum clearance of 1.5 mm front and rear. Cut off the air blast completely by loosening belts and covering vents. Use a wheat riddle on top, a lupin screen fitted to the rear and a canola screen on the bottom. The puccinellia seed is taken off into the seconds box.

Companion species
Puccinellia is often sown in a mixture with tall wheat grass. However, they have different growth patterns and may require different grazing management. Puccinellia grows actively from late autumn to mid-spring, while tall wheat grass grows actively from spring through to autumn.

Cultivars
‘Menemen’ (public variety) is the only cultivar. It was originally collected from the west coast of Turkey in 1951 from a village near the town of Menemen, hence the name. It is marketed in South Australia as ‘Restora sweet grass’.
9.6 Tall wheat grass (*Thinopyrum ponticum*)

**Features**
- tall, summer-active, temperate perennial bunch grass
- moderate salt tolerance; low to moderate waterlogging tolerance
- slow to establish
- grazing management is critical for feed quality
- useful alternative on non-saline soils.

Tall wheat grass (formerly *T. elongatum*, *Agropyron elongatum*, *Elymus elongatus*) comes from the Balkans, Asia Minor and southern Russia. The tall wheat grass grown in Australia was originally collected by the American ‘Westover-Enlow’ expedition near Bandirma in northern Turkey in 1934. The plant was bulked up and released in 1937 by the United States Department of Agriculture as the cultivar Largo. After introduction to Australia, selection pressure changed the genetic constitution of the line, and it was renamed Tyrell after a salt-affected parish and salt lake in Victoria. Tall wheat grass has been grown on saltland in WA since at least the mid-1940s. Tall wheat grass is now widely grown on summer-moist soils of low to moderate salinity which were previously dominated by sea barley grass. It does not persist on soils that are waterlogged over spring and into summer. Tall wheat grass can be a productive option on non-saline soils.

Tall wheat grass can lower shallow water-tables and decrease soil salinity, providing an opportunity to promote the growth of companion annual legumes. Stands of tall wheat grass can use up to 4 mm/day of groundwater in summer. There are reports of surface soil salinities (EC_e values in the upper 10 cm of the soil profile) declining from 5 to 1 dS/m in four years. Many old stands of tall wheat grass have been poorly managed, giving it a reputation as producing low quality feed. When under-grazed it becomes coarse, unpalatable and is a low quality feed. Good grazing management is critical to maintain feed quality and palatability, as the quality drops markedly as the plant matures. On the other hand, when well managed the dry matter production and feed quality of tall wheat grass were similar to tall fescue and perennial ryegrass on a non-saline soil in Victoria.

**Description**
- tussock-forming temperate (C3) perennial grass up to 1 m tall (seed heads to 1.6 m)
- leaves are greyish or bluish-green, up to 30 cm long, 4-8 mm wide with thick veins
- leaves are rough on the upper surface and margins
- seed head is an erect spike 10-30 cm long
- good seed yields, although mature spikes shatter easily.
Tall wheat grass can also be planted in hedge-rows about 1 m wide for shelter in maternity paddocks to improve lamb survival. The grass in the hedge-rows is allowed to become tall and rank, so it is unpalatable and stock do not eat it.

**Seasonal growth pattern**
Tall wheat grass has slow winter growth with most growth occurring from spring onwards. Subsoil moisture or rain over summer is necessary for good production. It sets seed from January to March.

The growth pattern is typical for many species coming from regions with cold winters. As a summer-active perennial, tall wheat grass is more productive in areas with moist summers and autumns.

**Establishment**
Good weed control is a prerequisite for successful establishment as tall wheat grass does not compete strongly with annual weeds (refer to ‘establishment of halophytic grasses’ in the section above). Preferably, tall wheat grass should be sown under mild conditions, either after the break of season in May-early June or in late July to mid-August as the soil temperatures increase. In low rainfall areas only early seeding is recommended, as the plants need to be well established before summer.

The suggested seeding rate is 10 kg/ha when sown alone, or 4-10 kg/ha when sown in a mixture. The seed should be sown at a depth of 5-20 mm with good seed to soil contact.

Tall wheat grass has a large seed (130,000-150,000/kg) and germinates well, but seedling growth is comparatively slow. It should not be grazed during the first year, unless the seasonal conditions are favourable, the crown is well developed and the plants are strongly anchored.

**Livestock disorders**
None reported.

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**Soil–climate adaptation**

- **Rainfall:** >375 mm (>350 mm south coast)
- **Drought tolerance:** High to very high
- **Frost tolerance:** High
- **Soil type:** Wide range from acid, sandy duplex, to alkaline medium- to fine-textured soils, including saline soils which dry out in summer to form a hard crust
- **Soil fertility requirements:** Growth, palatability and feed quality all respond to N
- **Soil pH$_{e}$:** 4.5-8.5
- **Aluminium tolerance:** Unknown
- **Waterlogging tolerance:** Moderate (Figure 9.2)
- **Salt tolerance:** Moderate
  Occurs over an EC$_e$ range in the field of 5-40 dS/m, with best growth at 16-32 dS/m
  
  [140, 353]

**Nutritive value**

- **DMD:** 54% (summer) to 80% (spring)
- **Crude protein:** 7% (summer) to 27% (spring)
- **Ash:** ~7%

**Environmental benefits**

- **Groundwater recharge control:** Tall wheat grass lowered the watertable and reduced winter waterlogging compared with the volunteer pasture at a site in the Great Southern
Management
The quality of tall wheat grass declines rapidly with maturity, so it is important to graze the pasture before the stems are fully mature. Heavy crash grazing encourages leafiness and helps maintain feed quality. When tall wheat grass is planted with balansa clover, grazing in spring should be regulated to allow the balansa to flower and set seed. Balansa clover requires grazing in winter to control weeds, but avoid grazing waterlogged soils to prevent pugging of the soil surface. Grazing needs to stop when the balansa clover starts flowering (usually in September) and can recommence when the balansa seed has matured (usually in November-December). Tall wheat grass is most palatable in January and can be grazed heavily over summer. The pasture should consist of a uniform stubble 3-5 cm high by the end of summer to prevent clumps becoming rank. Stock should be removed in late autumn to allow the tall wheat grass to develop seed heads and for the balansa clover to regenerate.

Recent research has shown that tall wheat grass is susceptible to stripe rust of wheat (Puccinia striiformis f.sp. tritici). Maintain grazing pressure in years with summer rain to minimise the ‘green bridge’ effect.

Fertilise with nitrogen in late winter (to 50 kg N/ha) and graze the following summer/early autumn. Nitrogen application is particularly worthwhile if harvesting seed during the following summer. Seed can be harvested in early autumn by cutting and swathing the grass two to three (but not more than four) weeks after flowering, then picking up the material about five days later with an open front header.

Companion species
Tall wheat grass can be grown as a companion species to legumes (balansa clover, strawberry clover and Persian clover) and other perennial grasses (puccinellia, phalaris and tall fescue) depending on site conditions.

Cultivars
There are two cultivars available in Australia. The most widely used is ‘Tyrell’ (public variety), which originated from seed imported into Australia from the US as the variety Largo. ‘Dundas’ was released by Agriculture Victoria in 1999. It was selected from Tyrell for enhanced leafiness and improved feed quality and disease resistance.
9.7 Other species

Distichlis (*Distichlis spicata*)

Distichlis comes from the coastal areas of North and South America. It occurs in brackish to saline marshes and on beaches and salt flats, usually above the high tide-line, but occasionally in the upper inter-tidal zone. Distichlis is a warm season (C4) grass that has high waterlogging tolerance, some tolerance to inundation and moderate to high salinity tolerance (Figure 9.2). The roots form aerenchyma (air channels), which enable gas exchange with the atmosphere under waterlogged conditions. Optimum growth for distichlis is 7-28 dS/m, but it will survive at 80 dS/m (equivalent to 150% of seawater). The leaves have highly efficient salt glands, so salt concentrations in the leaves are likely to be lower than other forages grown under similar conditions of salinity and waterlogging.

Establishment

Establishment is currently difficult and time consuming as vegetative propagation relies on transplanting established root material. One farmer has established 1-2 ha/day on a 1x1 m grid using a broccoli planter to plant harvested tillers about 5 cm into the soil.

Nutritive value

Sheep and cattle have been observed grazing distichlis. Limited measurements of young growth (10-15 cm) gave the following results: crude protein 10-17%, dry matter digestibility 55-60% and ash 6.5-11.7%.

Environmental implications

Distichlis has the ability to control erosion on bare saline soils. Its ability to spread and weed potential are unknown.

Management

Distichlis is tolerant of heavy grazing due to its rhizomatous growth habit. There is limited information on fertiliser response and animal performance.

Description

- low, creeping perennial grass with both stolons (runners) and shallow rhizomes
- leaves are borne on erect culms arising from the stolons and rhizomes
- leaf blades, are pointed, stiff and covered with microscopic salt glands
- the NyPa Forage™ type produces no seed and is propagated vegetatively.

Distichlis showing rhizomatous growth habit

Distichlis is a highly salt-tolerant warm season (C4) grass
Salt water couch (Paspalum vaginatum)
Salt water couch (seashore paspalum) is a warm season (C4) creeping grass with both rhizomes and stolons. It comes from the coastal areas of southern and eastern Africa. It has been widely distributed throughout the world, firstly because it was used as bedding in slave ships and secondly as a salt-tolerant forage. It occurs naturally on sandy beaches, banks of estuaries, saline swamps and areas which are frequently inundated with salt water. Salt water couch has high tolerance to waterlogging and moderate to high tolerance to salinity (Figure 9.2). It is also tolerant to inundation and has been observed growing in shallow standing water lower in the landscape than puccinellia. It was one of the first saltland reclamation species used in WA. Salt water couch performed well on a range of saline sites in NSW, (pHw 5.0-8.8 and 4-52 dS/m). It can also be used as a lawn grass using fresh or saline irrigation water but has low drought tolerance. It can be an invasive weed of wetlands.

Description
- low, creeping perennial grass with both stolons and deep rhizomes
- bright green foliage, with hairless leaves 40-90 mm long and 2-3 mm wide
- leaf blades taper and roll inwards towards the point
- inflorescence is a pair of spike-like racemes which are at first erect but spread with maturity to form a flat V-shape.

Establishment
Seed production is unreliable, so the species is vegetatively propagated.

Nutritive value
No information is available on grazing value, but the species persists with heavy grazing and is palatable.

Environmental implications
Salt water couch controls erosion in seepages and gullies, but may build up the surface level and cause run-off to divert. It has become an invasive weed in areas such as the shores of Wilson Inlet.