Too wet, too acid, too saline?

Plants to modify the water table - The potential of native grasses to reduce recharge

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Summary: This paper examines some of the issues involved in controlling recharge on hill lands in the southern sector of the Murray-Darling Basin. Native grasses possess a number of adaptive advantages which support their use for controlling recharge, including tolerance of aridity, acid soils and infertility. Their potential for growth in summer and autumn is especially important. Data from the LIGULE project indicates that some native grasses have similar water use characteristics to phalaris, while others use water at a greater rate than phalaris in summer and autumn. This is particularly encouraging for the LIGULE project which aims to develop persistent and productive native grass cultivars for use in pastures on recharge lands where phalaris does not persist.

Throughout the Murray-Darling Basin, sowing hilly recharge areas with deep rooted perennial species is widely recommended for controlling dry-land salinity (*eg.* Salinity Pilot Program Advisory Council 1989; Avon-Richardson Land and Water Management Group 1992). Perennial pastures are believed to have the ability to use more water, reduce run-off and maintain farm productivity (Clifton and Taylor 1995).

The upland recharge areas along the eastern and southern boundary of the Murray-Darling Basin receive in excess of 500 mm of annual rainfall and much of the landscape is dominated by pastures consisting of a high proportion of annual species (Taylor and Clifton 1993; Allan *et al.* 1995). There are a number of barriers to pasture establishment and persistence including areas that are generally too steep for cultivation, typically shallow and stony soils and low fertility. Low soil pH and the associated problems of aluminium and manganese toxicity limit the persistence of susceptible commer-cial cultivars of phalaris and lucerne (Clifton and Taylor 1995) but native perennial grasses which are well adapted to the conditions (Dowling *et al.* 1996) may have a role as sown pastures for recharge control.

The limited growing season of annual plants limits their annual water use water regardless of how well they grow during winter and spring (Johnston 1993). Perennial species offer greater scope to reduce recharge because:

- Annual species are generally shallow rooted. Perennial species have a deep penetrating root system which enables them to explore a greater volume of soil and therefore extract a greater volume of water (Ridley and Simpson 1994).
- Perennials have a longer growing season. Species which grow into the warmer months use water at a time of year when evaporative demand is high and they continue to use water after annual species have died off (Cook 1992).

The lack of adaptation of most commercially available perennial cultivars to difficult site conditions (*eg.* PDP 1992; Clifton 1996), coupled with increasing costs and declining farm incomes, has stimulated interest in greater use of native grasses which occur in existing pastures as well as in the development of new cultivars (Garden *et al.* 1996).

Whole farm planning, which recognises the relationship between land capability and pastures, is a useful tool to achieve complementarity between low and high input pastures. Introduced high-input permanent pastures based on lucerne, phalaris, cocksfoot, ryegrass and fescue are most productive and persistent on low-slope land classes where they can be sown using cultivation, whereas, well managed, low-input native grass based pastures are better suited to steeper lands which cannot be cultivated (Simpson and Langford 1996).

Although doubts regarding the productivity and water use of low-input pastures have been expressed (Donald 1970, Dunin 1970), these could only be considered to be valid in the narrow context of low-slope situations where there would be an economic advantage in sowing pastures based on introduced perennial species. The issue is irrelevant to land classes typical of recharge areas, where introduced pastures are only short-lived, and where sustained recharge control will always depend on maintaining a perennial cover of low-input pastures.

The abilities of a range of species of native grasses to dry the soil to depth on typical recharge lands is currently being evaluated in the LIGULE (Low Input Grasses for Limiting Environments) project (Johnston *et al.* 1995). This paper outlines some of the more important characteristics needed in plants if recharge is to be reduced and considers the potential of native grasses for dryland salinity management.

The ideal grass for salinity management

The Victorian Salinity Program's Agronomy Working Group (1988) identified the following desirable attributes in species likely to be useful for dryland salinity management:

Limiting site condition

Soil conditions

- tolerant of low soil pH and high levels of aluminium and manganese
- tolerant of low fertility

Establishment

- high seedling vigour (particularly for aerial sowing)
- high seedling competitive ability
- deep rooting

Persistence

- drought tolerant
- ability to withstand continuous grazing
- high disease and pest resistance

Productivity

- viable commercial seed
- high yielding, particularly in winter
- summer active
- good quality forage

High water use

- deep rooted
- actively growing in high evapotranspiration period
- good winter growth
- ability to achieve adequate recharge control in high rainfall

Other

- low maintenance, easy management

Clearly it will be very difficult to find a single species which meets all these criteria, however it may be possible to achieve a mix of characteristics in a pasture consisting of a mix of species, if there is a wide range of species to chose from. Native perennial species which are naturally adapted to acid soils, low fertility, aridity and variable and unreliable rainfall may hold considerable promise for recharge control provided they could be easily established and that they meet some of the productivity goals of upland pastures.

Factors affecting water use on hill lands

A number of factors impact on the ability of pastures to reduce recharge, including patterns of rainfall and evaporation, limiting soil conditions and pasture management.

Climate

In most years in the 500 - 600 mm rainfall zone of southern NSW and north eastern Victoria, recharge is a normal hydrological process because rainfall exceeds evaporation during the period from about June to September. It is unlikely that any kind of pasture will be capable of using all the rainfall. The problem with recharge is not that it occurs, but that it is now more frequent, and more water drains to water tables than it did in the past before clearing and agricultural development. Salinity management should not aim to stop recharge, it should aim to reduce it to within acceptable limits. Increasing water use by 50 to 150 mm per year may be all that is required. The challenge is to achieve this over the whole of the landscape where current recharge rates are too high.

Soil

Physical obstructions, such as stones and hard pans, and chemical problems, such as soil acidity and infertility, may limit root activity and thus the volume of soil that plants access. This may reduce the capacity of plants to dry the soil as well as influence the persistence of species which require access to a continued supply of soil moisture.

Grazing management

No perennial species survive set stocking for long periods because all perennials are weakened by continual defoliation. Hill-land pastures which are continuously set stocked are continuously selectively grazed. The most palatable species are under the most grazing pressure and over time, as they die out, pasture composition changes in favour of plants which avoid being grazed because they are low-growing or unpalatable. Bare ground in autumn provides opportunities for annual species to become established. These can further reduce the persistence of perennials and restrict opportunities for re-establishment of perennial species which germinate in spring.

As well as reducing the numbers of desirable perennial grasses, heavy continuous grazing also reduces root density and depth (Pook and Costin 1971), and if pastures are not managed to maintain some green leaf in late summer and autumn, these factors combine to considerably reduce their ability to use water.

The most important variable determining water use by an individual plant is the proportion of its groundcover which consists of green leaf. If water is available in the soil and green leaf is exposed to the sun, water will be transpired until the soil is dry. The advantages of native grasses over improved cultivars are that they are highly persistent; most produce green leaf quickly in response to summer and autumn rainfall thus they use water in summer and early autumn and they do not require high levels of inputs.

Warm and cool season grasses

The grass family can be divided into species which grow during summer and those which grow during the late autumn to late spring period, and this is based on their photosynthetic pathway (Bannister 1980). Table 1 lists some of the features which distinguish warm from cool season grasses (Johnston 1996).

Most perennial grasses sown in pastures in the temperate zone are cool season grasses which rely on bud dormancy to escape seasonal periods of high temperature and low rainfall. In southern Australia, cool and warm season species exist side by side in most grasslands.

Water use characteristics of native grasses

Review of previous literature

The water use and root structure characteristics of Australian native grasses have been poorly researched. Studies conducted in the past have drawn comparisons between well managed and fertilised newly sown improved pasture with degenerating or unfertilised native pasture and the results have invariably highlighted the advantage of the improved pasture.

Begg (1959) compared a sown pasture of phalaris and white clover, topdressed with superphosphate, to three unfertilised native pastures. This study was conducted at in the New England region of NSW, an area with a summer dominant rainfall pattern. In this environment it would be expected that all pastures in this study would have green leaf over the summer months. Begg found that *Bothriochloa macra* and *Chloris truncata-Danthonia pilosa* pastures were quite shallow rooted and were only able to utilise water in the top 60 cm of soil. However, the *Sorghum leiocladum/Themeda triandra* pasture showed good dry matter production and was

Table 1. Features which distinguish warm season from cool season grasses (Johnson 1996).

Characteristic	Warm season grasses	Cool season grasses
Photosynthetic pathway	C_4	C_3
Germination temperature	10 - 20 °C	5 - 15 °C
Optimum growing temperature	Greater than 20 °C (20 - 35 °C)	Less than 20 °C (10 - 15 °C)
Flowering time	Opportunistic - summer to autumn.	More "programmed" - spring to early summer.
Water use strategy	Water saver - uses water sparingly and efficiently.	Water spender - tries to keep up with evaporative demand.
Drought response	Saves water by stomatal closure, leaf waxing and rolling; transpiration restricted to short periods of the day; parts of leaves, whole leaves and tillers may die during prolonged dry periods.	Poor stomatal control - wilts when water demand exceeds supply; increasing stress results in leaf death; species with a strong post-flowering dormancy response are less susceptible to summer drought.
Preferred habitat	Exposed sites; warm to very warm temperatures during the growing season. Some species groups prefer wet tropical climates, others prefer dry, semi-arid climates.	Cool, moist, shaded habitats; high rainfall frequency during their growing season. Temperate areas.
Examples	Consol lovegrass *Eragrostis curvula*	Phalaris *Phalaris aquatica*; Cocksfoot *Dactylis glomerata*; Ryegrass *Lolium* spp.; Fescue *Festuca arundinacea*;
	Kangaroo grass *Themeda triandra*; Red grass *Bothriochloa macra*	Wallaby grass *Danthonia* spp.; Weeping grass *Microlaena stipoides*

not stressed for as many days as the phalaris at 45 cm. This would indicate in a summer dominant rainfall environment *Sorghum/Themeda* pastures can utilise water deeper in the profile than phalaris.

Donald (1970) found that the water use below a *Stipa-Danthonia* pasture was less extensive than under a sown phalaris pasture. This study was undertaken at Canberra, a winter dominant rainfall environment. From the data presented in this paper it is unclear if the pastures were growing on the same soil types or what species of *Stipa* or *Danthonia* were involved in the study.

Cook *et al.* (1976) traced *Bothriochloa macra* roots to 1.5 m in the soil. Harradine and Whalley (1981) found that *Danthonia linkii* had an extensive root system in the surface 20 cm but the root system was less developed at lower depths. Soil characteristics can have an influence on the root depth and structure of the root system. There is limited published data on the root systems of native grasses and what has been published is scattered and inclusive.

The important point here is not that one pasture uses more water than another, but that water will be used by native pastures on landscape classes where improved pastures are only short-lived. There is little point in maintaining a low input pasture on lands where production (and water use) could be vastly increased by sowing a permanent improved perennial pasture or in destroying an existing hill land perennial native grass based pasture and replacing it with a short-lived improved pasture.

LIGULE water use data

A comprehensive study of the water use characteristics of a range of native grasses is being undertaken as a component of the LIGULE project (Johnston *et al.* 1995). This involves measurement of evapotranspiration each month of eight species of native grasses and two control species (Consol lovegrass and Sirosa phalaris) using ventilated chambers, over a two year period at Bendigo. At all four LIGULE field sites (Cowra, Wagga Wagga, Rutherglen and Bendigo), soil moisture status is being continuously monitored to a depth of 120 cm for all 20 accessions of the 12 species of native grass being assessed.

Ventilated chamber measurements commenced at Bendigo in May 1995. Measurements have been completed for two winter and spring seasons, but only one summer and autumn period, thus the data for warm season species is incomplete. Early data was influenced by differences in the initial establishment of the various species so it is difficult to draw firm conclusions until these issues are taken into account.

Preliminary data shows that several of the native grasses have water use characteristics similar to phalaris. The most promising cool season species include: weeping grass (*Microlaena stipoides*), common wheat grass (*Elymus scaber*) and wallaby grass (*Danthonia linkii* var *fulva*). The most promising warm season species include: spreading umbrella grass (*Digitaria divaricatissima*), kangaroo grass (*Themeda triandra*), curly windmill grass (*Enteropogon acicularis*) and windmill grass (*Chloris truncata*). The data indicates that a pasture containing the best cool season species and the best warm season species growing together could achieve a greater level of control over recharge than either of the species growing alone.

These results indicate that several native grass species which are better adapted than phalaris to the conditions typical of recharge lands, have the potential to transpire considerable quantities of water. During the time of the year which is critical to determining the size of the deficit - summer and autumn water use by most of the warm season grasses was greater than that of phalaris. During the cooler months, when the warm season grasses were inactive, several of the cool season species used water at a rate similar to or greater than phalaris - especially early in autumn when phalaris was in transition between dormancy and active growth - a process which can take several weeks. The ability of the native grasses to respond quickly to rainfall may be a significant advantage in reducing recharge.

LIGULE root growth studies

A study of the root structure of a range of native grasses is also being undertaken as part of the LIGULE project. This study is using a mini-rhizotron technique (Taylor 1987) to evaluate eight native grasses and two control species under the same conditions. The eight native grasses are being studies: *Bothriochloa macra, Chloris ventricosa, Danthonia linkii* var. *fulva, Digitaria divaricatissima, Elymus scaber, Enteropogon acicularis, Microlaena stipoides, Themeda triandra.* Control species of Consol lovegrass and Sirosa phalaris are also included in the trial.

Numbers of roots at up to 120 cm depth have been observed each month since January 1996 using a borescope inserted down clear acrylic tubing at a 45^{0} angle under rows of each species.

In autumn 1996, most of the root mass of lovegrass and phalaris occurred above 63 and 40 cm respectively, but roots of both species were traced to a depth 100 cm. Total root numbers of *Elymus* and *Themeda* were highest at 58 and 33 cm and roots were traced to a maximum depth of 100 cm.

These results indicate that several native grass species may have root systems with the potential to explore a volume of soil similar to that of phalaris.

Conclusions

Although the ability of perennial grass pastures to completely control recharge is still being debated, there can be no doubt that species which are persistent and which produce green leaf in summer and which use water will reduce the amount of water draining to water tables. This is achieved by summer active species which are capable of creating a large moisture deficit in the soil before evaporation declines in autumn and winter. Controlling dryland salinity by reducing recharge will require substantial areas of the landscape to be maintained under permanent pasture. Low persistence of currently available cultivars is a major barrier to attaining this objective.

Data from the LIGULE experiment has shown that species of native grasses are capable of active growth and high water use in summer. Water use by several cool and warm season native grass species was similar to phalaris on a year-round basis, while several species used water at a greater rate than phalaris during the critical summer to autumn period. The root growth studies are showing that there are several native grass species that have the potential to explore a similar volume of soil as does phalaris. These results are particularly encouraging in terms of developing cultivars of native grasses for use in pastures on recharge lands where phalaris does not persist.

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