WEED-PROOFING PASTURES: HOW CAN WE GO ABOUT IT?

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Abstract  Pastures and grasslands are complex mixtures of many desirable and less-desirable species. The aim of pasture management should be to minimise the weeds and enhance the productivity of desirable species. In the past, producers have used a range of tactics for weed control, from resowing pastures to selective herbicides. These tactics typically have had a short-term perspective. Practices have not been sufficiently integrated to exact maximum damage to the initial weed populations, and to ensure that the weeds remain a minor component of the pasture into the future. The resultant pastures have not been ‘weed-proofed’.

To make pastures more weed-proof it is suggested that a new emphasis is required. Livestock producers need to minimise costs in weed management and take a longer-term view. Effective monitoring of the status of pastures for warning signs and subtler use of management tactics are key components in sustainable management. We need to know more of what makes a pasture ‘weed-proof’ and how to maintain it in commercial practice. Implicit in this is the need to make the desirable pasture species more competitive to minimise gap size to control weed invasions. Little information is available of the species most sensitive to invading weeds i.e. indicator species that could be useful for monitoring pasture condition. The influence of gaps on weed invasion is poorly understood and guidelines have not been developed that producers can use to monitor the risk of weed invasion. The management of indicator species and of gaps, could be achieved by subtle adjustments in grazing, fertiliser and other practices. A clearer understanding of the structure of grasslands is needed to better target management practices. The Weeds CRC is actively pursuing these approaches, which will be discussed in this paper.

INTRODUCTION

Most pastures contain weeds that have large effects on the profitability, sustainability and environmental impacts of pasture ecosystems. Weeds are a fact of life and do require significant resources for their control. Unfortunately, the declining terms of trade for livestock industries means that resources for weed management are also declining. A pessimistic outlook suggests that weed problems in pastures will escalate. As producers are put under more pressure to generate an income from land, many will decide they cannot put more resources into weed control and this will increase the opportunities for weed invasions. These negative trends will continue unless significant progress is made in developing lower cost management practices that more effectively control weeds.

The general consensus developed within the Cooperative Research Centre for Weed Management Systems is that individual tactics are unlikely to achieve the level of success desired for weed control in pasture systems. Some practices may achieve effective control in the short term, but within a year or two the problem recurs. An integrated system using all the relevant tactics is a better approach that exploits the cumulative impacts of different practices (Kemp 1996). Such an approach needs to be ongoing with new control methods being added as they are developed through research. An integrated approach aims to minimise the costs of each component so that overall weed management costs are reduced. A key part of this strategy is to make pastures more ‘weed-proof’ so that more expensive control practices are not needed. Weed-proofing applies particularly when the aim is to prevent weed invasion in the first instance e.g. in pristine native grasslands, or newly sown pastures, or where there is still sufficient desirable species present to respond to an integrated management strategy and out-compete weeds.

The aim of this paper is to discuss the issues involved in developing strategies to weed-proof pastures and grasslands, to indicate some of the limitations and to suggest avenues for research.

WHAT IS WEED-PROOFING?

Weed-proofing is simply the process of ‘strengthening’ the pasture to be more competitive. It does not involve continual application of a raft of weed control
practices to remove weeds every time they try to invade. Rather, the general aim of weed-proofing is to manage the pasture such that weeds find it difficult to invade and hence direct control of weeds becomes a minor activity relative to the effort aimed at maximising the productivity and stability of the desirable pasture components. The emphasis is on being proactive rather than the more common reactive approach to weed management. To weed-proof a pasture, emphasis needs to be directed toward monitoring and managing the desirable species so they are more competitive and the opportunities for weed invasion are minimised. This requires improving our understanding of how all species within a pasture ecosystem interact with abiotic and biotic forces. Management tactics can then be better targeted.

An integrated effort within the scientific community is also needed. Historically, those working on weeds have not always considered pastures and grasslands as ecosystems, cropping analogies often applied, and they have paid less attention to the more desirable species present. Pasture agronomists who have been working on desirable species have often done the reverse and ignored or trivialised the weeds, or not described adequately the large effort made to remove weeds from their experiments.

**WHAT IS A PASTURE?**

Many agronomists, producers and others have a general view of the structure of a pasture, but probably most do not appreciate some of the subtleties in the way pastures and grasslands function. We consider that an understanding of these interactions is crucial if we are to develop better weed management practices.

The general view of a pasture is probably conditioned by what is commonly sown. In higher rainfall areas sown mixtures typically comprise perennial grasses and legumes. However, within a few years other species have usually established voluntarily and the actual mixture is more complex. Native grasslands are even more complex in their original state and remain so as species invade. Many pastures in the higher rainfall zone are now very complex mixtures of sown, volunteer exotic and native species. A significant part of the total biomass is often species considered to be weeds at least for part of their lifecycle. This complexity is evident in a naturalised pasture at Orange where over 100 plant species have now been found (King et al. unpublished data). This biodiversity arises because different species are able to exploit the available resources in different ways creating complex interactions between species and the management system imposed. Rarely can one or two species dominate in the medium to long term, even though that is the dominant philosophy for the management of recommended pasture mixtures.

One way of analysing what is a pasture is to evaluate the major structural elements rather than simply considering the species present (Kemp et al. 1996, 1997). In higher rainfall zones the perennial grasses are an obvious prime component in both sown and naturalised pastures. These are, or should be, the more stable component that can be managed to increase their proportion in grazed swards (Kemp et al. 1999). However, due to the range of seasons encountered, their proportion ultimately depends upon how they survive the worst seasons. This means they are rarely able to exploit all the available resources and totally dominate the pasture. In consequence resources are available for other species to utilise. Some perennial forbs are also found in pasture in the HRZ, but they are often only a minor component unless they are unpalatable, whereby they become weeds.

The resources not used by perennial species are exploited by a range of desirable and weedy annual forbs, annual grasses, sedge and in less disturbed areas, mosses etc. Legumes are foremost among the desirable forbs. Annual grasses also use these resource gaps. The ‘gap-filling’ role of some of these species can prove very useful in weed management. Species can be grouped on a broad functional basis that helps to devise suitable management tactics. In many high rainfall pastures it is possible to broadly group species into four types *i.e.* desirable and less-desirable grasses *e.g.* perennial *vs.* annual species and desirable and less-desirable broadleaves *e.g.* legumes *vs.* thistles. The grouping of species needs to consider their functional roles in ecosystems as well as their role within productive pastures.

One benefit of thinking about how the whole pasture ecosystem functions is that it leads to analyses that explore all the interactions from individual weed management tactics. In the past a reliance on univariate analyses has meant that the consequences of a management practice has only been examined in relation to the weed and collateral impacts on other species ignored or treated lightly – false impressions of success can be created.

The problem of simply concentrating on the main effects was evident in a grazing management study at Newbridge, near Orange (Dowling et al. 1996).
Summer resting tactics over a few years increased the content of cocksfoot (*Dactylis glomerata* L.) from 10 to 40% of the pasture-on-offer. However, when the total system was examined, this treatment also resulted in some increase in the broadleaf weed content, mostly spear thistle (*Cirsium vulgare* (Savi) Ten.).

**FUNCTIONAL GROUPS**

Species can often be grouped along functional lines. Within a group there are more similarities in the behaviour of species than between groups. These similarities can be very close. For example, within grasses, the replacement of perennial with annual grasses often occurs on close to a 1:1 basis (Kemp and Dowling 1991).

To develop better weed management practices the relationships between weeds and the other pasture species needs to be clearly defined. This has been attempted by various methods, but rarely it seems to the point where a decisive statement can be made about which species are most affected by the invading weed. This knowledge is important if management practices are to more effectively target weeds. For example, the management of annual grasses is probably better achieved by strengthening the perennial grasses in the sward, than by improving the legumes. This is reinforced by data from a survey of improved pastures in central NSW (Figure 1). This showed that the most important pattern (Factor 1) is a gradient of perennial vs. annual grass content, while the second factor shows a contrast between legumes and broadleaf weeds.

Weeds can also behave as groups e.g. annual grasses and thistles. This has been recognised and can be used to implement a group management approach. For each major weed in pasture systems, research should aim to define which functional group it belongs to and also which desirable species are being most affected by the weed. This information can then be used in several ways. First, the target desirable species should be monitored as an indicator of the stability of the ecosystem against the invading weed. Second, management practices can be tailored to emphasise the target desirable species, rather than the pasture as a whole. Grazing, fertilising and herbicide practices can then be developed to enhance those species, while suppressing weeds.

An example of how this information can be put together comes from a grazing management experiment with chicory (*Chicorium intybus* L.) (Figure 2; Alemseged et al. unpublished).

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**Figure 1.** Biplot principal component analysis of the composition of ‘improved’ pastures in central NSW (Kemp and Dowling, 1991). Data (group as percent of total) are from individual paddocks (filled circles) overlaid with the functional groups: PG = perennial grasses; AG = annual grasses; TL = total legume; WE = broadleaf weeds.

**Figure 2.** The impact of grazing management on the interaction between chicory, total grass content and broadleaf weeds (principally Paterson’s curse). Data is for consecutive measurements over five years for continuous grazing (circles, solid lines), grazed 3 weeks on, 3 weeks off (triangles, dotted line) and grazed 1 week on, 5 weeks off (squares, dashed line). Ellipse denotes starting points for treatments.
A principal components analysis (not presented) showed that the chicory content was inversely related to the combined effect of annual grass (mainly vulpia - *Vulpia* spp.) and broadleaf weeds (principally Paterson’s curse – *Echium plantagineum* L.). The legume content was relatively independent of the other functional groups. Under continuous grazing the chicory content declined over time and was replaced by Paterson’s curse. As the grazing frequency was decreased and the rest periods increased, the chicory content declined at a much lower rate and the ‘weed’ component was dominated more by annual grasses than by Paterson’s curse. Rotational grazing is a desirable practice to both maintain chicory in a pasture and to shift the weed flora into a more desirable state. The relative dominance of Paterson’s curse under continuous grazing in this case is likely to be due to preferential grazing of vulpia.

**GAPS**

It is a reasonable hypothesis that most plants establish where no other plant is actively growing. Only on rare occasions do plants manages to germinate and establish within the crown of another. Gaps need to be present to enable establishment. To better weed-proof pastures the management of gaps becomes a critical issue. Ideally, for most pastures during the growing season, we want gaps to be colonised by desirable species. The first line of defence is to manage pastures such that the desirable species have every opportunity to dominate the gaps. Gap size is a more specific measure than ground cover, though in practice criteria based upon gaps should be translated into ground cover estimates.

In perennial pastures, the perennial grasses are rarely able to occupy all the gaps. The exceptions are some of the stoloniferous and rhizomatous species e.g. kikuyu (*Pennisetum clandestinum*) and *Microlaena stipoides*. However, leaving some gaps is important to enable desirable annual components (e.g. legumes) to establish. There is a role for ‘gap-filling’ species to exploit the residual gaps thereby limiting weed invasions. Annual grasses can fill this role as can some minor forbs. An outcome from considering the ecological role of gaps in permanent pastures is that some weeds are likely to always be present. Permanent pastures cannot be as ‘clean’ as crops and the tactics used to manage weeds in crops may not be appropriate for pastures. The tolerance for weedy species needs to be at some minimum rather than zero value.

An important consideration in gap management is also to consider the importance of litter. Weeds vary in their response to the litter content, some positively, others negatively. Knowing the relative responses is important in targeting management tactics.

**CONTROL THE SEED BANK OR LIMIT ESTABLISHMENT?**

Weed management in pastures splits into two main categories. The first category includes those weeds where eradication is warranted. This applies to those weeds that have not yet established on a site and those declared noxious. In both cases control methods aim to eliminate the weed seedbank. The second category is more common and comprises those weeds that are already well established, widespread and are having a significant impact on production. Such species are unlikely to ever be practically eradicated from the pasture. However, it is possible to reduce their influence in the sward and constrain their impact to a minor level. Such species will then remain part of the ecosystem and regularly input some seed into the seed bank. Often such seeds have a long life and it is not always possible to prevent seed set each year. Consequently, strategies designed to eliminate the seed bank are unlikely to be successful or economic. Such weeds need to be accepted as part of the pasture ecosystem and managed accordingly. The first step in controlling such weeds is to prevent them establishing. This is where tactics focusing on gap management becomes more important. It concedes that the weed seed bank cannot be eliminated, but acknowledges that there are better prospects for severely limiting the establishment of new plants.

**MONITORING**

To implement an effective integrated ‘weed-proofing’ management scheme it will be important to routinely monitor pastures for signs of change. In practice, it is often the case that weed management only starts once a problem is very obvious. This is arguably too late to feasibly maintain a pasture in a highly productive state because many of the desirable species have died or been reduced to being minor components.

This reactive approach to management is costly and unsustainable as it only addresses symptoms in the short-term. Better success can be achieved through a more proactive approach. Weed management practices need to be part of normal pasture management, before weeds become a serious problem to pasture sustainability and livestock production.
Many producers do routinely monitor their pastures for weeds and intervene early. However, they have all developed their own management rules that are usually based on those plants they consider to be a major problem (e.g. serrated tussock \( \textit{Nassella trichotoma} \) (Nees Hackel), Paterson’s curse \textit{et al.}, and methods for their immediate removal. They do not always check for the minor weeds and do not always include a preventative component.

The impact of weeds varies with species, some are more aggressive than others and their utility for livestock production and soil stability also varies. This variability underlines the importance of monitoring to establish the relevant tolerance thresholds for different species. For well established weeds of intermediate importance e.g. annual grasses a tolerance level of up to 10-20% of the biomass (in early spring) is acceptable in perennial pasture systems. Such species that are unlikely to ever be eradicated completely from pastures, have some utility for forage during their vegetative phase and also restrict other species with a potential to become more of a problem. The same may have to be accepted for serrated tussock in non-arable country where it fills a soil conservation role and is so widely established that complete removal may not be possible with current technologies and economic constraints. A tolerance level of 5-15% may be a realistic working target. In other cases where weeds have not become established, a tolerance level of near zero is suitable particularly for species with a history of aggressive invasion of other plant communities elsewhere. Where biological control agents have been introduced for weed control, low levels of infestation are necessary to maintain an adequate population of agents to have a significant long-term impact. Some farmers have done an excellent job at keeping species such as serrated tussock and some thistles off their properties.

Once thresholds are set, routine monitoring needs to be implemented. Many producers already do this by observing what is in paddocks during normal farm operations, but it is important to document these observations to make it easier to assess changes over time. For species with a zero threshold, management is simple in that every plant observed should be removed. The greater difficulty often lies in assessing those species that have a minimum rather than zero threshold for action. These species may blend in with the general sward and monitoring needs to be more quantified. Farmers can learn the necessary skills through technology transfer programs such as Prograze (Bell and Allan, 1999), to identify species and quantify their contribution to total biomass. In these cases the \textit{estimates} obtained need to be documented so that quantifiable changes over time can be assessed. One tool which can be used to do this is the pasture species matrix (Kemp 1996, Kemp \textit{et al.} 1997).

Documentation is important to move towards more proactive weed management. The invasion of weeds is arguably preceded by a loss of desirable species from the sward (Dowling and Freckleton, unpublished data). The desirable components lost, may be major or minor species or functional groups. At this stage we cannot say which are the key desirable components to monitor for all the important weeds, but some are obvious and further research should aim to define others. A clue to a suitable direction in research can come from considering more ‘pristine’ grasslands. Such areas often appear to have a higher proportion of minor forbs than more heavily utilised and weedier grasslands. This suggests that a first step in monitoring grasslands would be to assess the proportion of minor (edible) forbs and compare the rest with that expected from relict areas. If the presence and contribution of these species starts to decline this could be a sign that the grassland is more susceptible to weed invasion, especially if the area of gaps is also increasing.

A WEED-PROOFING APPROACH

The general need to make pastures more weed-proof is often appreciated, but not always implemented. In part this is because we have not provided all the rules needed to effectively implement such an approach. Advice is currently available for the more straight forward cases such as where small populations of ‘new’ weeds invade a site or where the pasture is highly degraded and weedy. The major problem occurs with the majority of mixed species pastures where weeds are a continuing part of the system in setting a threshold tolerance and deciding when to first intervene.

Research needs to define the procedures and rules that:

1. Enable the efficient monitoring of pastures and grasslands to provide early detection of when such ecosystems are becoming more susceptible to weeds \textit{i.e.} observation methods and thresholds. This could be a combination of a whole system approach (e.g. the pasture matrix) and/or monitoring the specific content of an indicator functional group vs. the major weed group of concern. The best time for observations needs to be determined.
2. Develop suitable management practices that maintain the pasture in a more weed-proof state. The pasture management envelope (Kemp 1991, Michalk and Kemp 1994, Kemp et al. 1996) has been developed as a tool for the management of pastures in a desirable state. The envelope places particular emphasis on the minimum levels of key species and herbage mass. Provided the key species content is adequate, guidelines can be developed as to the minimum herbage mass required to maintain the integrity and productivity of a pasture. The appropriate level of herbage mass will depend upon the pasture type, fertility and seasons and aims to incorporate information on gap / ground cover management. The main management tools that would apply in making pastures more weed-proof are grazing (including control of herbage mass of desirable species and controlling selectivity by livestock) and fertilisers.

3. Define the conditions under which weeds invade a pasture. This would include an analysis of gaps and of the more susceptible species. This information then needs to be developed into simple rules that farmers can use.

We need to move to the point where weed management is better incorporated into day to day management and where a small extra effort for weed control pays off in the long-term with an overall reduction in the impact of weeds.

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REFERENCES


