Weed management principles for permanent and ley pastures.

D. R. Kemp

Professor of Farming Systems, Charles Sturt University and The University of Sydney, School of Rural Management, Orange, NSW 2800.

Abstract

Weeds are a fact of life for anyone involved in agriculture; they will grow wherever resources are available. This paper considers some of the general principles in managing weeds within permanent and ley pastures. Weed management within permanent pastures is more complex than in pasture leys. Weeds can establish at any time of the year and suitable selective herbicides are not available as many will damage the useful species in permanent pastures. Pasture leys have some advantages for weed management. These include utilising phases to remove weeds detrimental to following pastures and/or crops and increased herbicide options to greatly reduce weed seedbanks.

A proactive approach to weed management in permanent pastures as a component of improving the productivity of livestock systems is preferable to simply reacting to weeds that arise. Good competitive pastures for animal production are also good for weed management. A pro-active 'weed-proofing' approach requires some knowledge of the population biology of key weeds, of maintaining a competitive environment in pastures to resist and/or reduce weed invasion and the wise use of livestock to reduce weed populations to tolerable levels. Monitoring pastures should be a regular activity to detect not only any invading weed, or if the weed is increasing above a tolerable threshold, but any decline in minor species (eg the very common forb catsear) which could indicate that space is being created where weeds can establish. Further, any decline in perennial grasses below 60% (of herbage mass) and any decline in average herbage mass below 1.5–2 t DM/ha should be avoided. Using those benchmarks will help to weed-proof permanent pastures. Managing pastures to first achieve these benchmarks is an initial step in reducing weed problems. If you are below them you will have to spend more time and money on weed control.

Introduction

Weed management is a significant aspect of farming life. With adequate planning and regular action, many weeds can be kept at tolerable levels. Adverse seasons and economic conditions can though result in major weed problems, even for the best of farmers. Successful weed control depends upon eternal vigilance and a proactive stance. The costs of dealing with weeds that are out of control can be greater than regular small interventions. In this paper the aim is to discuss the general issues for weed management, what are the common principles and can we 'weed-proof' permanent and ley pastures better (Kemp 1996; Kemp 1999). The main focus will be on permanent pastures with additional comments on ley pastures where they differ. The 'weeds' being considered here are those that are now part of the environment and primarily are 'production weeds', not those where eradication is possible.

Weed-proofing pastures to a reasonable degree is possible and is designed to incorporate a lower-cost approach to pasture maintenance than waiting for a problem and then having to intervene with lots of work. It is a matter of trying to get the broad integrated strategy right so that weed management is a minor issue. Weed-proofing can result in pastures that are better for livestock and therein lays the incentive to adopt this approach. Utilising the two together i.e. weed management as part of livestock management does mean that costs are contained and (hopefully) income improved. Weed management needs to be thought of as part of an integrated approach, rather than individual action. The key is to be proactive rather than reactive.

The principles of managing weeds are similar in permanent pastures and in pasture leys; but managing weeds can be more complex within permanent pastures. In crops there are often only the one crop species and one or two significant weed species. That means the use of herbicides can be a simple and effective choice. Prior to planting a crop there is a preparation period when a key aim is to reduce any weed problems to minor issues and this is the key to controlling weeds in ley pastures. Herbicide choices in permanent pastures become complicated because they contain useful grass, legume and broadleaf species that are often susceptible to the grass and broadleaf herbicides commonly used. Weeds can occur in

all seasons and continuously over years, requiring continuous application of management tactics. Herbicide use often necessitates some cost to pasture production, at least in the short-term and a herbicide-focused approach doesn't provide long-term control. These difficulties are reflected in the lower usage of herbicides in pastures than crops. Solutions lie within more subtle approaches based on understanding the biology of weeds, the ways in which managing the competitive environment of the pasture ecosystem can help and linking weed management with livestock production.

Population biology of weeds

All weed species have life cycles. The first step in weed management is to understand the life cycle of a weed and then determine the weak links, where control can be more readily exercised (Figure 1).

Serrated tussock is Australia's most important perennial grass weeds and one that has been among the more difficult to control. A recent rethink of management of this weed (Badgery 2003) has sought lower-cost more ecologically based strategies for control. We now have to assume that in many areas the soil seedbank of serrated tussock is large and that it will be difficult to reduce by most commonly available techniques. This research split the management problems between preventing and/or minimising any recruitment of new plants and controlling any mature plants present. It was found that seedlings could be prevented from establishing if the herbage mass of desirable perennial grasses was kept above 1.5 t DM/ha especially through the summer i.e. *maintain effective competition from useful species*. Herbicides were then more important for controlling the mature plants. Seed production could be reduced by lower soil fertility or spray-topping, but the size of the soil seedbank means that this avenue doesn't provide much control in areas where serrated tussock is already present.

Many long-time weeds now have large seedbanks in the soil eg vulpia. In consequence it is impossible to eliminate the seedbank and prevent any re-establishment of the weeds. Consequently control needs to focus on reducing the ability of those weeds to establish and/or become adult plants. Maintaining a competitive pasture is obviously essential in these instances.

The one interesting new technique that may enable us to manipulate weed seedbanks has arisen from research into the chemicals in smoke that stimulate seed germination after bushfires. The group at the King's Park Botanical Gardens in Perth was the first in the world to identify the chemical involved (Flematti *et al.* 2004). The effects of this chemical on a wide range of species are spectacular. It could be used to empty a soil seedbank so that weed competition is removed and, or used to stimulate desirable species eg by oversowing, so that they emerge at a higher rate and can resist germinating weeds. Hopefully over the next decade this new tool may become available.

Plant competition

The success of a weed is largely due to its ability to compete with other plant species and capture available resources. If there are no competitors present eg bare

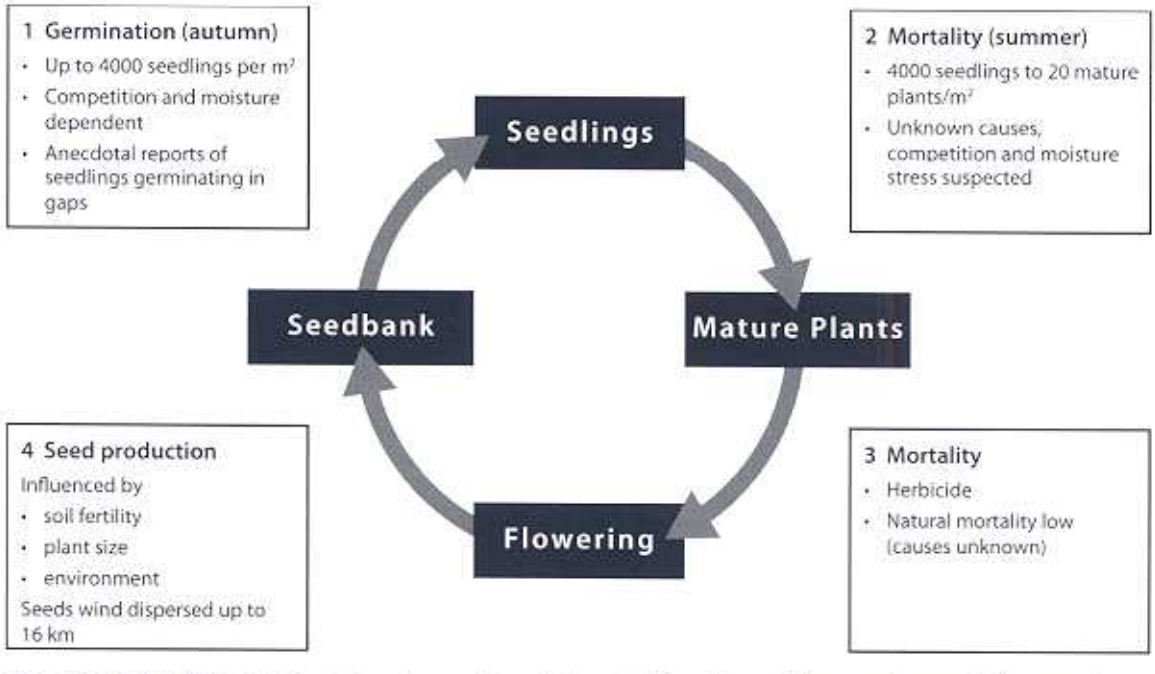

Figure 1 The typical life cycle of a plant and ways of regulating that life cycle to achieve weed control. The example chosen here is for serrated tussock (Nassella trichotoma). Source: Badgery (2003).

ground as during a fallow, or arising from a drought, then the first plant species to germinate and establish often wins the competitive battle for resources. Resources include physical space, light, water, nutrients and aspects of climate eg temperatures may suit one species better than another. Many plant species are weeds because they are able to capture resources faster than their neighbours. The first challenge is then to husband the available resources such that the desirable species get the major share.

The most common weeds tend to be annual plants, whereas the more desirable pasture species are perennials – the main exception being annual legumes. In general, perennial plants have weak seedlings compared with annuals, which means that annuals are more readily able to capture resources and therefore establish and dominate a plant community. Often these differences are compounded by higher seed set from annuals and higher numbers of seeds in the soil seed bank. This problem was very apparent in soil cores we took from the SGS site at Carcoar. Over hundreds of soil cores from a pasture of mostly native species, we didn't find a perennial grass seed in the soil, but vast numbers of annual grasses and sedges. The above ground community approached 50% perennial plants, but the below ground seedbank was effectively 0% perennial. Similar results have been found across a wide range of sown and naturalised pastures. That means if those pastures are disturbed that annuals will readily fill the gap. Ecologically many annual plants are considered 'gap-fillers' because the Carcoar situation commonly applies. The work at Carcoar showed us that if we wanted to increase the population of perennial species within the sward then the seed would have to come from seed set within the current year.

The competitiveness of a plant species is broadly related to:

Competitiveness = plant numbers * plant size * plant growth rates

Different weeds have different strategies. Vulpia is a problem through sheer number of plants – otherwise it's a small plant with an ordinary growth rate. Blackberries can attain a very large plant size and thus capture the available resources as individual plants. Serrated tussock is not a very vigorous plant, but its prolific seed production can result in high plant numbers that help it capture resources.

Nutrients have a large effect on the competitive relations between plants, but nutrient management has not been well developed as a means of weed control. Some recent work with serrated tussock (Badgery 2003) showed it is an important tool. Simply adding fertiliser to infested areas resulted in more serrated tussock seedlings and greater competition from adult plants. Experimental treatments designed to reduce soil nitrogen and phosphorous levels resulted in no serrated tussock or vulpia seedlings establishing and the adult plants shrank in size. In contrast, native grasses such as kangaroo grass (*Themeda australis*) became relatively more competitive with the weed.

Herbicides are often the tool of first resort, but they really should be second or third in line. A competitive pasture should be the first line of defence. Spot spraying within pastures can reduce potential risks eg if serrated tussock started to invade an area, but spraying implies that the pasture is not in a fit state to control the weeds. Bad weed infestations do though require some serious use of herbicides and an aim can be to first stop seed set and then prepare a site for resowing.

Other tools for managing plant populations and weed competition

Fire is an old tool that tends to be used more in arid and semi-arid zones. In western NSW techniques have been developed to use fire to control shrub encroachment. That technique requires a good season to build up the grass and that may only happen once every fifty years (Harrington, personal communication). In other areas fire could be used, but little is known of the better strategies. In general, to kill a plant the ground should be dry and the fire hot. In southern Australia that means burning in summer which is highly risky. Winter burns don't cause as much plant mortality and their main use would be to remove plant material (uncertain if useful) but not harm the desirable species.

Biological control is often seen as a magic bullet, but there are few instances where that has been the case. In general with biological control we are trying to create more of the natural environment where the invading weed has come from, by introducing its natural predators i.e. to reduce the competitiveness of the weed and to hopefully increase its mortality. Few plants are weeds in their home environments. Biological control can be very useful even if it only reduces a plant to a less aggressive competitor. Additional tactics can then be used to keep the plant in check.

There are three types of biological control commonly investigated;

i) Classical where an agent is released and requires no maintenance.

ii) Inundative where agents eg fungii need to be cultured and then sprayed.

iii) Habitat modification where the environment is changed such that natural agents can help to keep a pest in check.

The last technique has to date only been tried with a few insect pests. It may be that for Australian weeds we now have fewer options left for the use of classical biological control, though searches should continue. We can though devote more effort into managing/manipulating the agents already available to make them more effective i.e. build management of biocontrol agents more into normal pasture management. That will require more detailed studies of pasture ecology.

Livestock for weed management

Livestock across Australia are the front line in weed management, though they aren't always used well. Their role in weed management is through two equally important influences.

- To damage the weed eg by eating it, by treading and damaging growing points, and so reduce the competitiveness of the weed population,
- To enhance the competitiveness of desirable species, through not grazing at critical times in the plants life/annual cycle.

It is important to state the obvious that grazing will always reduce the ability of a useful plant to compete against weeds. About the only exception to this is when grazing results in increased tillering of grasses and hence their ability to capture resource space. Increased tillering only occurs during the vegetative phase of plant growth; not during reproductive development when seed heads are forming. The benefits from stimulating tillering apply after grazing stops and plants have an opportunity to regrow. Advantages are lost if plants are continuously grazed.

Plants are sensitive to grazing at various times during their life cycle. These times are when germinating, establishing and regenerating from buds (eg after dry periods), when reproductive and when under stress eg low nutrients, dry seasons. The sensitivity of flowering plants to grazing is often least appreciated; for example, Sirosa phalaris can be killed if grazed heavily during spring. Seed set of annual legumes can be reduced by grazing in spring reducing their ability to regenerate during the following year. Weeds can be pressured by grazing during these sensitive times, while desirable species should be rested. The major difficulties are to find times when the weeds can be pressured without harming the useful species. Typically though, compromises need to be made. One of the best known examples is the use of these techniques to manage wire grass (*Aristida ramosa*) in northern NSW (Lodge and Whalley 1985).

The main problems in using livestock for weed management arise when areas are heavily grazed to consume a weed, but that also results in severe loss of desirable plants, the creation of bare ground and then space where the weeds can re-establish. Heavy grazing may need to be replaced by strategic rests to achieve the desired results (Dowling *et al.* 1996). The timing of grazing pressure or rests then needs to consider the options available for control at different stages in the plants life cycle (Figure 1). Sometimes a couple of times of the year are available. For example serrated tussock seedlings mostly emerge in autumn and winter and hence heavier grazing at that time could reduce their number. However heavy grazing in winter could also reduce the ability of useful grasses to compete with the serrated tussock. Further, recent research (Badgery 2003) showed that the number of serrated tussock seedlings in winter wasn't the problem; it was more the number that survived through to the next summer. It was these survivors that became the harder to kill adult plants. If pastures were rested over summer and the herbage mass was > 1.5 t DM/ha, then the useful grasses were often competitive enough to effectively kill off any remaining seedlings through the summer. Maintaining the average herbage mass above 1.5-2 t DM/ha through the year ensures that animal intake and animal growth rates are near optimal, especially if the herbage is all green (Bell and Allan 2000) and hence animal production should not suffer.

Bare ground is obviously an invitation for a weed to establish. That is obvious in preparing land for sowing, or after a drought, but over-grazing such that bare spaces are ever-present and available for plants to colonise is a risky management strategy. Intermittent bare spaces from quick grazings are less of a concern if the neighbouring useful plants are able to quickly recolonise the gaps. Maintaining a reasonable level of herbage mass as discussed does limit the risk of invasion by weeds.

Light levels may need to be managed in some instances. Rank pastures may suppress weeds, but they also suppress the legumes that provide nitrogen that drives many Australian pasture systems. Overgrazing which exposes the soil surface is the reverse circumstance. Good pasture management is a compromise.

Plant competition can be managed by grazing. The aim is to have a strong vigorous sward actively growing, or ready to quickly regrow after an adverse season. The proportion of desirable species needs to be higher than occurs in typical pastures. Our work has often found that the proportion of desirable perennial grasses needs to be >60% of total herbage

mass, to start and exert an influence on invading species (Kemp *et al.* 1996). If the perennial grasses + legumes is 80% then annual grasses fill some remaining gaps and few weeds become an issue. An additional criteria is to manage the swards to retain a reasonable level of herbage mass over time. In swards where the edible i.e. desirable herbage mass of perennial grasses is at least 1.5–2 t DM/ha there are few invading plant species.

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 within the majority of mixed species pastures where weeds are a continuing part of the system. Here thresholds of tolerance need to be set to determine when to first intervene.

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 only on those plants they consider to be a major problem (eg serrated tussock, Paterson's curse), and methods for their immediate removal. They do not always check for the minor weeds and do not always include a preventative component.

Looking for a decline in perennial grass content can be as important as monitoring the invasion of a weed. If perennial grasses decline below 60% of the herbage mass they cannot maintain the competitive environment required to minimise weed invasions. Similarly the general herbage mass of desirable species probably needs to average 1.5–2 t DM/ha through the year to maintain a competitive environment. In surveys the perennial grass content of many existing pastures is often around 20% (Kemp and Dowling 1991).

The impact of weeds varies with species, some are more aggressive than others and their utility for livestock production 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 eg annual grasses, a tolerance level of up to 10–20% of the biomass (in early spring) is acceptable in perennial pasture systems. Such species are unlikely to ever be eradicated completely from pastures, and they 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 weed 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 thistles off their properties.

Once thresholds are set, routine monitoring should 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 2000), to identify species and quantify their contribution to total biomass. In these cases the *estimates* obtained need to be documented so that quantifiable changes over time can be assessed.

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. The desirable components lost may be major or minor species. 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 could 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 eg catsear (*Hypochaeris radicata* – one of the most widespread minor components in pastures) and compare that with the proportion found in lightly grazed areas (often 5% or so). 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. Further research in this area would be warranted.

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 i.e. be proactive and anticipate, rather than reactive.

Ley pastures

In this paper emphasis has been placed upon permanent pastures where weed control is often more complex than in pasture leys. Ley pastures that are short-term in between cropping phases have additional opportunities to manage weeds. Prior to and during cropping phases any weeds of concern can be more readily managed with herbicides. The ley phase can then help to reduce weeds for the crop and the crop phase, especially if a sequence of grass/cereal and broadleaf species, can be used to reduce weeds that would be detrimental to the pasture. Knowledge about the population biology of weeds and use of that information in weed management is as important in both ley and permanent pastures. Within cropping cycles there are more opportunities to reduce the weed seedbank than apply in permanent pastures.

A special problem with ley pastures is that useful species during the pasture phase eg annual grasses, can be weeds for the cropping phase. Annual grasses require special attention over the latter years of the pasture phase to restrict seed set and remove them. This can be economically done with selective herbicides. Grazing techniques can also be used. In work at Grenfell (Kemp, Dowling and Michalk, unpublished) it was demonstrated over three years that resting barley grass (*Hordeum leporinum*) over winter followed by a heavy grazing around the end of August, reduced the grass content as effectively as herbicides. It has though been difficult to achieve similar results with vulpia (Dowling, personal communication) which is less palatable to livestock; dry stock may need to be used in such cases. Such techniques can benefit income through increased animal performance and savings on herbicide costs and do need to be investigated further. Timing is though critical as there may only be a 1–2 week period when heavy grazing effectively removes the weed. The trick is to know when the main growing point/young seed head is just starting to extend above ground level and then more readily eaten.

The main difference in weed management between permanent and ley pastures is often that ley pastures have few, if any perennial grass plants to maintain a competitive environment through the year. Maintaining a suitable level of herbage mass with livestock is difficult as plants only grow for part of the year, leaving extended periods of nil competition. Ecosystems based on annual species are inherently more unstable and are thus more likely to be invaded by weeds. Well managed perennial grass pastures, using the benchmarks noted in this paper, can be relatively weed-free for many years, but annual/ley pastures will often have a high proportion of weed species built up over time. Ley pastures would then be expected to require more direct intervention for weed control than well managed perennial grass based pastures. Planning a weed management program over the whole cropping/pasture cycle can achieve weed management goals and reduce costs (see paper by R Jones, this volume).

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References

Badgery, W.B. (2003). Managing competition between Nassella trichotoma (serrated tussock) and native grasses. PhD thesis, The University of Sydney, pp. 240.

Bell, A.K., and Allan, C. (2000). PROGRAZE and extension package in grazing and pasture management. *Australian Journal of Experimental Agriculture* **40**, 325–330.

Dowling, P.M., Kemp, D.R., Michalk, D.L., Klein, T.A., and Millar, G.D. (1996). Perennial grass response to seasonal rests in naturalised pastures of central New South Wales. *Australian Rangelands Journal* **18**, 309–26.

Flematti, G.R., Ghisalberti, E.L., Dixon, K.W. and Trengrove, R.D. (2004). A compound from smoke that promotes seed germination. *Science* **305**, 977.

Kemp, D.R. (1996). Weed management directions in pasture systems. *In* 'Proceedings 11th Australian Weed Conference'. pp. 253–263.

Kemp, D.R., and Dowling, P.M. (1991). Species distribution within improved pastures over Central NSW in relation to rainfall and altitude. *Australian Journal of Agricultural Research* **42**, 647–659.

Kemp, D.R., King, W.McG., Michalk, D.L., and Alemseged, Y. (1999). Weed-proofing pastures: How can we go about it? *In* 'Proceedings 12th Australian Weeds Conference'. Hobart, Australia, September 1999, Tasmanian Weed Society. pp. 138–143.

Kemp, D.R., Michalk, D.L., and Dowling, P.M. (1996). Managing the composition of native and naturalised pastures with grazing. New Zealand *Journal of Agricultural Research* **39**, 569–78.

Lodge, G.M. and Whalley, R.D.B. (1985). The manipulation of species composition of natural pastures by grazing management on the northern slopes of New South Wales. *Australian Rangelands Journal* **7**, 6–16.