Overview of thistle management in Australia

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Summary

Thistles have a high profile in the weed flora of Australia and are of particular concern to graziers in the temperate southern regions where they are often the dominant weeds of improved pastures. While thistles have morphological similarities and are closely linked taxonomically, they are nevertheless ecologically diverse, both between species and within species. Consequently, some management practices, e.g. biological control, may need to be aimed at specific ecotypic groups, while other management practices, e.g. pasture competition, may be able to be applied more unilaterally. This paper overviews the presentations made at the Thistle Management Workshop and synthesizes them into three broad categories—ecology/biology, management tactics, and farmer attitudes and constraints on control—and examines what is currently known about thistles, what is not known about them and where should research be aimed to yield results which will be of most practical use to thistle management in Australia.

Introduction

There is no other group of plants in Australia, and perhaps in the world, which better epitomizes weeds than the thistles. A cursory glance at some local sources of weed information confirms this idea. The brochure which describes the Co-operative Research Centre (CRC) for Weed Management Systems—'Weakening Weeds to Strengthen Australia'—has a photograph of *Carduus tenuiflorus* (winged slender thistle) on the front. The logo of the Weed Society of New South Wales, displayed prominently on its newsletter, A Good Weed, is of a thistle. The Australian weed books by Hyde-Wyatt and Morris (1980), Wilding *et al.* (1986), Auld and Medd (1987), Auld *et al.* (1987), Parsons and Cuthbertson (1992), and the new 'Crop Weeds of Northern Australia' by Wilson *et al.* (1995), all depict thistles of one type or another on their front covers.

What is it about thistles which gives them this unique standing? Is it their often sharp spines and prickles (for that is what partly defines a thistle in the family Asteraceae), their inherent beauty when in flower, or the combination and tension between these two features? Someone once said: 'Give me a thistle without thorns and I will give you a pasture plant'. Is technology now at the stage that we can genetically modify thistles to be spineless?

There are two postcards on my office pin board. Appropriately, the first is from Edinburgh, Scotland, and is of the 'Scottish thistle' (*Cirsium vulgare*). The second postcard, this time appropriately from the University of Oxford, England, says: 'The more I study the more I know; the more I know the more I forget; the more I forget, the less I know; so why study?'

The purpose of this synthesis paper is to draw together in broad terms the presentations from the Thistle Management Workshop and to ask 'what do we know about thistles', 'what don't we know about them', and 'what should we try and find out that will be of practical use in thistle management'. Do we already know the key to thistle management (if there is one) or are we still searching? If a key exists and we have not yet found it, does it lie in obtaining more information, securing more resources, developing new methods or in engendering greater commitment from those who attempt to control thistles?

This workshop produced some excellent presentations of current thinking and research in regard to thistle management and if I am to synthesize these papers then by definition I must put them together to make up a complex whole. And in some respects, weed management is necessarily becoming more complex as land managers negotiate the trend towards herbicide resistance, reduced cultivation and antagonism to pesticides. Ironically, the complexity of the thistle group is one of the over-riding themes that has been evident through the presentations from this workshop and one which I highlighted in my review of the ecology and control of thistles in Australia (Sindel 1991).

While thistles are often grouped under one broad umbrella (for some very good reasons, not the least of which are their morphological and taxonomic similarities), they are nevertheless a group of plants which are ecologically diverse—both between species and within species, as has been highlighted for saffron thistle (Peirce 1990). It might be concluded from Michael (1996) that part of the reason for this diversity in Australia is also due to the presence of taxonomic groups which are as yet unidentified, particularly in relation to the *Onopordum* thistles.

Peirce (1996) rightly emphasized that the variability in the behaviour of thistles must be taken into account when considering their response to herbicidal control measures. Biocontrol agents too can be very discriminating, even down to the level of thistle ecotype. For example, the ecology of saffron thistle (*Carthamus lanatus*) is quite different to many of the other thistles. Saffron thistle on one hand can be characterized as preferring regularly disturbed areas with coarse dry topsoil, but with good reserves of moisture in the deeper subsoil, whereas, most of the other major thistles reviewed at this workshop are typically dominant on soils rich in phosphate and nitrogen, and possibly regularly cultivated and / or irrigated areas (Doing 1972). As a result, saffron thistle is a major weed in both pastures and crops whereas many of the other thistles are a nuisance in pastures alone. So it is worthwhile stating again that we are not dealing with a homogenous group of weeds when we talk about the thistles. Consequently, many control measures will have to be aimed at individual species, and even ecotypes within species. Others, such as pasture competition, may act more unilaterally.

The factors that promote thistle invasion (often an increase in soil nutrient status combined with overgrazing and lack of reseeding) are also often responsible for changes in the relative abundance of individual thistle species. Such changes, which are continually occurring in the Australian weed flora (Kloot 1987), further complicate the already complex issue of thistle management. For example, McGufficke (1996) experienced changes on his property near Jindabyne, New South Wales, from dominance of spear (or black) thistle (*Cirsium vulgare*) to saffron thistle and then Scotch (*Onopordum* sp.) thistle. Similarly, over the course of 25 years on a property at Crookwell, New South Wales, an area that was once dominated by native redgrass (possibly *Bothriochloa macra*) changed to subterranean clover, then to variegated thistle (*Silybum marianum*) and finally to *Onopordum* sp. (Carter 1970).

Although management practices may alter the soil and pasture conditions and lead to changes in thistle dominance, the relative importance of different thistle species in Australian pastures has not been studied.

Significance

There can be little doubt that thistles are a major concern for graziers in the temperate regions of southern Australia. In a recent mail survey of grazier attitudes to weeds on the Northern Tablelands of New South Wales (Sindel 1996), graziers were asked to rank up to five major weeds in order of importance on their farms. A score of five was assigned to the top ranked weed in each case, a score of four to the second worst weed and so on down

Table 1. The most troublesome weeds among the graziers surveyed from the Tablelands of northern New South Wales (from Sindel 1996).

Weed	Presumed species	Number of respondents[A]	Score[B]
Saffron thistle	*Carthamus lanatus* L.	22	90
Blackberry	*Rubus fruticosus* L. s.lat.	12	38
Nodding thistle	*Carduus nutans* L. ssp. *nutans*	8	31
Bathurst burr	*Xanthium spinosum* L.	7	31
Spear thistle	*Cirsium vulgare* (Savi) Ten.	7	27
Thistles (generally)		6	20
Scotch thistle	*Onopordum* spp.	4	19
Horehound	*Marrubium vulgare* L.	7	18
Slender thistles	*Carduus pycnocephalus* L. *Carduus tenuiflorus* Curtis	5	12
Variegated thistle	*Silybum marianum* (L.) Gaertner	3	12
Rat's tail fescue	*Vulpia* spp.	3	12

[A] Number of respondents from the Tablelands who listed a particular species among their five worst weeds.
[B] Combined score of weed importance from rankings given by all 29 respondents from the Tablelands.

to one. Forty six weed species were listed in total by the 29 respondents. Table 1 lists those weeds which had a combined score of 12 or greater. It is clear that in this region at least, thistles, and particularly saffron thistle, are of major concern to growers.

Many of the thistles have become widespread and now often occur as the dominant weeds of improved pastures where annual rainfall ranges from about 500–900 mm (Michael 1968). And yet there are other species, e.g. *Cirsium arvense* (perennial thistle) and *Carthamus leucocaulos* (glaucous star thistle) which are present in Australia but which currently have a limited distribution and are of only minor importance (Parsons and Cuthbertson 1992). Do such species have the potential for further colonization and to fill niches left by the demise of other thistles in the future?

Dellow (1996) identified the five thistle species or groups which he considers are currently causing the major problems in the farming and pastoral areas of New South Wales. These are saffron thistle, spear thistle, variegated thistle, the Scotch (*Onopordum acanthium*) and Illyrian (*O. illyricum*) thistles and nodding thistle (*Carduus nutans*). To this list he adds St. Barnaby's thistle (*Centaurea solstitialis*) and others would also add the slender thistles (*Carduus pycnocephalus* and *C. tenuiflorus*) as being significant.

There can be little doubt that these particular thistles are well adapted to the Australian environment as evidenced by the results from the study on *Carduus nutans* by Woodburn and Sheppard (1996) where they compared the life histories of the weed in five Australian localities with that in three native localities in Europe. Most thistles in Australia are of European origin and have probably reached the limits of their potential distribution (Medd 1981), the exception being *Carduus nutans* which, partly because of its more recent introduction to this country, continues to spread (Parsons 1973, Medd and Smith 1978).

At the farmer level, the question of significance might be 'When do thistles constitute weeds in my pasture?' Unlike many other pasture weeds, thistles are rarely a palatable source of feed for most classes of livestock, although goats are an exception, as emphasized by Holst and Allan (1996). The thistles have been classified as plants that occupy ground which could be utilized by more useful pasture species (Michael 1970). Because they are not usually grazed, it may be easier to estimate their impact on pasture yield and animal production (ignoring for the moment animal health issues) than that of other pasture weeds which can be utilized by livestock to some extent.

For example, in New Zealand, liveweight gain in sheep was shown to be negatively correlated with the density of *Cirsium vulgare* (Hartley 1983), and in north-eastern California in 1970, *Onopordum acanthium* infestations were estimated to result in an annual loss of production equivalent to over $25 per hectare (Hooper *et al.* 1970).

If data were readily available on the economic impact that thistle infestations were having on farms then that may be an incentive for some farmers to be more diligent in their control of thistles and may allow some economic thresholds to be set and economically rational decisions to be made about their control.

Most of the papers presented in this workshop have addressed one or more of three broad issues – thistle ecology / biology, management tactics, and farmer attitudes and constraints to control. While it would be unduly repetitive to summarize the findings of all these papers here, I will highlight important issues from each of these three areas.

Ecology/biology

Baseline data

There would be few of the defence force personnel who would not argue that it is essential that you first 'know your enemy' before you make an attack on them. Otherwise, your attack is likely to be ineffective and you will not be able to assess what damage you have caused once that attack has been carried out. In this regard, Pettit *et al.* (1996) have appropriately done their reconnaissance work on *Onopordum* and have now laid baseline data against which to assess the effectiveness of biological control.

Seed banks in the soil

Sheppard (1996) highlighted the fact that nearly all thistle species are relatively short-lived and reproduce entirely by seed and that this must guide the formulation of control strategies. As a result, the continued infestation of pastures and crops by thistles depends largely on the persistence of viable seeds on and below the soil surface. He concludes that causing high seed loss should be the dominant control strategy in most thistle control activities. This strategy is particularly suited for biological control and for new invasions, and despite their importance, the dynamics and ecology of thistle seed banks have not been adequately investigated. The study by Allan and Holst (1996) is very helpful in this respect for *Onopordum illyricum*.

But the strategy has less relevance when substantial seed banks of the thistles exist and there is little possibility of weed eradication. Because of dormancy patterns in thistles and their long-lived nature in the soil, reducing seed numbers, often towards the end of the season, must go hand in hand with aggressive pastures (particularly at peak germination periods) which aim to impact on the germination, establishment and early seedling stages of the weed's life-cycle. Chipping or selective spot spraying may then be relied on to clean up isolated infestations that inevitably develop.

Dispersal

McGufficke (1996) raised an interesting biological issue when he says that 'even if the problem on my property had been cleared, the seeds from neighbouring properties would still have come in, either wind blown or by birds etc.' Despite the existence of scientific studies with evidence to the contrary such anecdotal views are widely held in the rural community. Thistle seeds are typically not spread far from the parent plant by wind. The relatively light seeds of *Carduus pycnocephalus* (Table 2) have been observed to spread to a distance of 8 m from parent plants in winds of 7.9–19.0 km h^{-1} (Harradine 1985) and *C. tenuiflorus* to nearly 7 m in one season (Auld 1988). Harradine (1985) concluded

Table 2. Seed and life-cycle characteristics of the major thistles (after Michael 1968).

Thistle	Life-cycle	Approx. seed weight (mg)
Carduus nutans (nodding)	Annual/biennial	3.5
Carduus pycnocephalus (slender)	Annual	5
Carduus tenuiflorus (winged slender)	Annual	3
Carthamus lanatus (saffron)	Annual	26
Cirsium vulgare (spear)	Biennial	4
Onopordum acanthium (cotton)	Biennial	11
Onopordum illyricum (Illyrian)	Biennial	15
Silybum marianum (variegated)	Annual	22

that the principal method of dispersal of *C. pycnocephalus* was movement across the soil surface, either by wind or animals, but that vegetation or litter cover restricted this movement. Studies by Smith and Kok (1984) and Kelly *et al.* (1988) indicate that seed of *C. nutans* also mostly falls close to the parent plant and that most wind-borne pappi have no seeds attached. Long distance dispersal of viable seed (>50 m) by wind is a rare event. Kelly *et al.* (1988) conclude that their findings 'may be reassuring to a farmer who is standing at her or his boundary fence, watching thistle pappi float onto the property'. Given the size of seeds of saffron, variegated and *Onopordum* thistles (Table 2), it is unlikely that wind would spread them very far either (see Auld 1988).

Granivorous birds such as goldfinches, sparrows and parrots are not candidates for the spread of thistles, since such birds husk the seed before ingesting it (e.g. goldfinches, McCallum and Kelly 1990). Fruit eating birds such as currawongs and blackbirds that do spread some weed seeds, are attracted to fleshy fruits, but do not digest the seeds as such. Importantly, Panetta and Scanlan (1995) suggest that for 90% of noxious weeds, spread is in some way aided by human activity. It is worthwhile noting then that we cannot hope to stop thistles spreading unless we know the main agents of dispersal.

Periodicity of germination

One of the areas which I see may be profitably pursued in thistle research is the subject of periodicity of germination on a regional basis as a means of determining if and when pasture competition or herbicides can be used to manage thistles when they are youngest and most vulnerable. If the emergence of thistles tends to be restricted to defined periods, as studies in Western Australia (Quinlivan and Peirce 1968) and parts of eastern Australia (Forcella and Wood 1986b) have shown (particularly for the annual thistles), then it is possible that control methods can be synchronized to improve their effectiveness, whether they be cultural, biological or chemical techniques. These studies have been carried out in essentially Mediterranean-type climates, but further work needs to be done across a range of environments. For example, in areas such as northern New South Wales where there is no distinct seasonal break following summer, there is controversy over when saffron thistle germinates. Such studies need to carried out over several seasons.

Scope also exists for work using either nitrogenous fertilizer or disturbance of the soil to help synchronize the germination of thistles and to improve the effectiveness of chemical control.

Management tactics

Pasture competition

The essential principle of any thistle control programme must be the provision of a dense, vigorous and competitive pasture, particularly in the autumn period which coincides with the bulk of thistle germination and seedling establishment. In general, thistles are weakest or most susceptible to control when at this early seedling stage or when passing from the seedling to rosette stage. For example, the percentage of spear thistle seedlings surviving through to the rosette stage was only 1.0% under grazed conditions and 0.2% in ungrazed pastures (Forcella and Wood 1986a). The facts that thistle seedlings are often found only on bare ground (Doing *et al.* 1969), that some species require light for germination (Bakker 1960, Medd and Lovett 1978), and that their growth is systematically reduced by shading (Medd and Lovett 1978, Pook 1983), indicate that control through competition for light is possible. Bourdôt (1996) has helpfully raised our awareness again of this most important management tactic.

Grazing management

Grazing management is related to pasture competition. It can influence the ability of thistles to invade pastures (George *et al.* 1970) primarily by altering the competitiveness of the desirable pasture species. By reducing competition from neighbouring plants, sheep grazing increased the survival of spear thistle seedlings as well as their growth, flowering and seed production (Forcella and Wood 1986a). Because thistle seedlings are vulnerable to competition soon after the autumn rains, stock should be temporarily removed from infested paddocks to increase thistle mortality. This deferred autumn grazing (until winter or spring) was found to reduce populations of *Carduus pycnocephalus* and *C. tenuiflorus* in Tasmania (Bendall 1973) and is recommended as a method of thistle control in pastures.

If goats can be incorporated into the production systems of individual farms then, likewise, their inclusion in a program for the control of thistles certainly warrants investigation, as Allan and Holst (1996) have shown. Goats have the ability to reduce plant numbers and prevent seed production and will often preferentially graze thistles over more palatable species.

The challenge confronting grazing management research is to determine how different grazing techniques can be used to suppress the undesirable thistles while maximizing the persistence and productivity of desirable pasture plants (Medd *et al.* 1987).

Chemical control

Even with the establishment of improved pastures, herbicides may be required to control thistles which establish with the sown species or which infest the pastures in particularly bad thistle years. However, repeated annual applications of chemicals aimed at exhausting the soil seed reserves in heavily infested paddocks may weaken the pasture, making it more liable to future re-invasion, and encourage the development of herbicide-resistant biotypes, as found by Harrington (1990) in New Zealand with nodding thistle.

The application of herbicide to thistles after they have bolted, commonly referred to as 'spray topping', can substantially reduce the number of viable seeds set by plants, for example in nodding thistle (McCarty and Hatting 1975) and saffron thistle (Fromm 1985), but due to the wide variation in flowering times between species, this management tactic would only seem to be valid in monospecific thistle stands.

Soil fertility

Thistles are often considered to be indicators of increasing soil fertility (Michael 1972). For example, increased fertility probably contributes to the occurrence of thistle infestations around dams and rabbit burrows and on stock camps. Similarly, anecdotal evidence suggests that changes in soil nutrient status is one factor which may cause a change in thistle dominance in a pasture. However, despite these apparent relationships, very little work appears to have been done on controlling thistles by altering the level of soil fertility, such as through cropping. The technique may be less effective with spear and

saffron thistles which are thought to be rather indifferent to soil fertility. Alternatively, fertilizers can also be used to increase the competitive ability of pasture and reduce weed establishment. Timing of application in this case is critical.

Biological control

In Australia, biological control has become an important tactic for the control of many weeds, including the thistles, as indicated by various authors at this workshop, and has particularly high potential for extensive grazing industries on intractable terrain (Menz *et al.* 1984). But most scientists now believe, and this was re-emphasized by Groves and Burdon (1996), that biocontrol needs to be incorporated into an approach which integrates a variety of methods, even the integration of bioherbicides with classical biological control agents.

With the promising results which have been presented for both exotic and native pathogens of various thistles at this workshop (Bourdôt and Harvey 1996, Crump *et al.* 1996, Groves and Burdon 1996) it is disappointing that after several years of concerted research, bioherbicides have failed to attract the interests of multinational companies. This lack of interest is a major constraint to the future adoption of this type of technology.

Farmer attitudes and constraints

Many years ago, Mill (1848) wrote: 'In every department of human affairs, Practice long precedes Science: systematic inquiry into the modes of action of the powers of nature is the tardy product of a long cause of efforts to use those powers for practical ends.' In the context of this workshop, we can conclude from Mill's observation that farmers have had a long history of dealing with the practical issues of thistle management, so why not ask them what works best for them? Some have labelled this idea 'bench marking' or 'best practice'. Essentially, the idea is to survey farmers, identify those who have overcome their thistle problems, determine their management practices and then extend their successful techniques to other farmers in the district. This approach has considerable potential, particularly for tackling thistle management on a district by district basis.

There are many practical problems associated with current thistle control techniques (Minehan 1996), and it is important to be aware of what impediments there may be to the adoption of control strategies that researchers may devise. However, it is doubtful whether such constraints, if they are not universal, should change the ideal towards which researchers work. One of the advantages of an integrated approach to thistle management is that it provides a variety of techniques so that at least some will be applicable on any individual farm. I have already alluded to the advantage of biological control in pastures of difficult terrain.

To the list of innovative ideas for alternative research compiled by Minehan (1996), I would add the investigation of thistles to be harvested for the production of allelochemicals. Several thistle species are known to have allelopathic properties (Woodward and Glenn 1983).

Conclusions

What then is the key to improving thistle management – is it more studies in the ecology and biology of thistles, biological control, herbicide use or pasture competition? All of these elements must be addressed so that they can be combined to give a workable weed management approach, however, there are no easy solutions to thistle management. The data provided by Allan and Holst (1996) on the persistence of *Onopordum illyricum* over a six year period and the ease with which the problem flared again when management was allowed to lapse is evidence of the tenacity of thistles. Against these odds, it is pertinent that *continuous* and *vigilant* monitoring and control of weeds (usually by chipping and spraying) was given by graziers as the main reason for having either a static or declining weed problem (Sindel 1996). Equally, farmers have said before that the most successful weed management strategy is 'obsessive persistency'. Given the persistency of thistles themselves, it is reasonable to presume that this strategy will remain a key ingredient for any thistle management program to be successful in the future.

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