Discussion of the extent of Australian ecological and economic data on weeds

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Summary

To draw attention to the perceived imbalance in resource allocation between research into weed control and weed ecology we surveyed the extent of basic ecological and economic data pertaining to weeds in Australia. Researchers were surveyed by mail as to which weed species they had studied specifically with regard to yield loss data, seed production data and data on seed bank decline in the absence of seed rain. Relevant data were also compiled from the scientific literature.

Very few weeds have been studied systematically in any crop or pasture, or on a national basis. Although we have considerable data on weed control, for most weeds in most crops we have little ecological data. We argue that the paucity of such basic knowledge is hampering efforts to develop ecologically sound weed management strategies. In order to address this problem, we draw attention to some of the steps that need to be considered by research funding bodies within the agricultural industry in Australia.

Introduction

Research on weeds, particularly since the introduction of organic herbicides, has concentrated on control to minimize their economic impact. In retrospect this emphasis has been well justified, given the advances made in herbicide technology, particularly in the last three decades. However, there has been a realization that, despite herbicides, weeds continue to pose problems: some intractable weeds cannot be contained; herbicides invoke floristic shifts, often to species or biotypes inherently more difficult to kill; and profitability has declined due to rising costs. During this period of preoccupation with control, research into the ecology of weeds, and other topics, has largely been relegated to the category of academic interest. Now, whether still out of mere academic curiosity or out of belief that an understanding of biological mechanisms will lead to better control, we sense that more interest is being shown in weed ecology.

Since the late 1970s, largely as a result of J.L. Harper's influence (e.g., Harper 1977), plant ecologists worldwide have become interested in the dynamics of plant populations. Studies of weed populations in their own right have become increasingly common, most notable being the work on weeds of arable land at the (former) Weed Research Organization in the UK. A key theme of these studies has been to understand the effects of crop management factors on changes in weed numbers over time. Fewer studies of this kind have been conducted on Australian weeds, with most data being generated from the small number of post-graduate research programmes or coincidentally from studies on control of notorious species.

More recently, emphasis has been given to developing weed control programmes that optimize profits in the long term and/or that minimize herbicide use (Pandey and Medd 1991). Simulation models can play a fundamental role in formulating such programmes by enabling rapid investigation of optional tactics, as exemplified by Cousens *et al.* (1986), Pannell (1990) and Medd and Pandey (1993). Such models require data on the economic effects of weeds and their population dynamics. In agricultural ecosystems, the economic impact of a weed is usually correlated with its density, as is its seed production. The impact which control has on population size is measured by the difference between the birth of propagules and their rate of decline. For annual weeds with characteristically short lived seeds, recent modelling studies suggest that management programmes need to concentrate on reducing seed input (Pandey *et al.* 1993). Additional strategies which bring about a rapid demise in seed banks are required for species having long seed life. Longevity of seeds in the soil is thus crucial to persistence and to the evaluation of control programmes.

Simulation models are, however, highly dependent on the data incorporated into them. Poor data and assumptions can only lead to lack of confidence in the outcome of the simulation. Also, it is important that the data are collected under relevant conditions, since we expect that plant growth and survival will depend on climate. Many of the northern hemisphere countries in which weed ecology has been studied in greatest detail have very different climates to Australia, yet it is common to rely for our data on studies done in other countries. How good is our data base for Australian weeds growing under Australian conditions (see also Stephenson 1992)?

In this paper we report the combined results of a mail survey of weed researchers throughout Australia and of a review of the published literature. We comment on the extent of the data and discuss the funding of ecological research on weeds in Australia.

Materials and methods

A questionnaire was sent to weed researchers known to the authors. Additional names were obtained from colleagues, from proceedings of conferences, and from a request for further contacts sent with the questionnaire. Those who failed to respond were contacted by telephone, and in almost all cases the data were then obtained. In all, 37 current researchers and research groups were contacted. Each researcher was asked simply to name the weeds for which they had data which could be used to plot:

a. crop yield against weed density,
b. seed production against weed density, and
c. seed survival against time, in the absence of seed return.

Additional questions were asked on the crops in which a and b were obtained and any aspects of management for which c was available. It is appreciated that this is a restricted range of information, however, it includes the information essential for assessing the economics of long-term weed management and represents the most common ecological and economic data likely to be held by researchers.

Information was also obtained from the literature. Articles were searched in all volumes of the relevant Australian agricultural journals, in Weed Research and in all Australian and Asian-Pacific weed conferences.

In summary, although some data may have been missed, we are confident that we have identified the majority of data in existence which are either published or held unpublished by researchers. The only exception was that data on rangelands and tropical pastures were difficult to access; these data are therefore excluded from this paper.

Results

Weeds in cropping

Yield loss and weed density data were available for 28 weeds in 15 crops. However, for 14 of these weeds data have been generated only for wheat (five of the species studied in wheat have also been

Table 1. Number of weeds for which data on crop yield loss and weed seed production are available in relation to weed density (for any State). Data on volunteer potatoes in six minor crops in Tasmania have not been included.

Crop	Yield loss data	Seed production data
Wheat	19	5
Barley	4	0
Cotton	4	0
Rice	4	1
Oats	1	0
Triticale	1	0
Lupins	1	2
Canola	1	0
Peas	1	0
Faba beans	1	0
Soybean	1	0
Maize	1	0
Sorghum	1	0
Mung bean	1	0
Sunflower	1	0

studied in at least one other crop). Only four crops (wheat, barley, cotton and rice) were represented by data for more than one weed (Table 1). Most of the dryland summer crops were represented by data for only one weed (*Datura* sp.). There were data from more than one state for three species (*Avena fatua, Lolium rigidum* and *Solanum elaeagnifolium*). Of the 14 broadleaved weeds studied in wheat, 10 were only studied in Victoria. Seed production data were available for six species, of which four were obtained only in wheat. There were seed production data for one broadleaved weed and four grasses in wheat. There were no data on weed seed production in dryland summer crops.

Some of the data are for weeds of restricted local importance. Degree of coverage of the major species in a region can be seen by comparing weed surveys with our search results. Amor (1984) recorded 87 species of weed in cereals in Victoria. Yield loss data are available for only 18% of these (any cereal, any State). There are yield loss data for only five of the 18 grasses which he lists; even though Asteraceae was one of the most abundant families, yield loss data are available for only two species, and seed production data for none. Similarly, for the other major family in Amor's survey, the Brassicaceae, yield data are available for only three species, and seed production data for only one (*Raphanus raphanistrum*). Table 2 shows the data available for weeds in the main dryland crops in Victoria. It can be seen that most data are for wheat, and even in that crop there is poor coverage of species. Table 3 shows similar information for dryland summer and winter crops in northern New South Wales and southern Queensland. Again, coverage of the major species is poor to non-existent.

Weeds in pastures

Data on yield loss are available for seven species in temperate annual pastures and two in temperate perennial pastures (Table 4). Seed production has been slightly better studied, with data for 10 species in annual pastures and six in perennial pastures. Of these, matching yield loss and seed production data are available only for *Echium plantagineum* and *Silybum marianum* in annual pasture systems and for *Senecio jacobaea* in temperate perennial pastures.

Seed decline

Data on seed decline are available for 30 species, of which eight are grasses. Aspects of management were seldom included as treatments in these studies. Decline of four species has been studied in more than one state, and never in more than two. From Tables 2 and 3 it can be seen that for winter crops there is a better coverage of seed decline in the main species than for yield data.

Discussion

Herbicide sales of around $300 million are made annually for control of weeds in crops and pastures in Australia (Medd 1992). Could it be that this market has dominated attitudes to weed control at the expense of developing ecologically informed management practices? Whatever the answer to this question, it is clear that there have been few weeds studied systematically with regard to understanding yield loss, seed production or the decline of seed banks in Australian agricultural systems. It is also evident that the herbicide manufacturing industry has contributed little to such knowledge.

One statement made repeatedly in defence of the research record is that yield loss data are, in fact, collected in herbicide trials and weed seedling or head number are also sometimes recorded. Such data are collected under the realistic condition of weed mixtures, and will include implicitly sub-lethal toxic effects of herbicides on both crops and weeds. These data could be made available to those modelling weed control strategies. However, the separation of species effects in mixtures from herbicide trial data, such as by using multiple regression, is notoriously difficult (Streibig *et al.* 1989). These trials are usually on high weed densities, dominated by particular species. Sublethal effects of different herbicides on different components of the weed mixture act as noise from which it is difficult to extract a signal. As a result, only effects of a few dominant species can be extracted, and even for these with little precision.

If, as we have purported, it is desirable to obtain ecological data critical to developing sustainable systems of weed management, how will such studies be funded? Historically much of this type of study has been funded by the public sector through grower levies and matching government grants or through government funded researchers. Given that the private herbicide sector has contributed in only a minor way in Australia to an understanding of weed ecology, should they be called upon to contribute more to such studies in the future? It would seem only reasonable that at least some of the

Table 2. Weeds in major dryland crops in Victoria for which specified data are available. Species are those found by Velthuis and Amor (1982) in all four regions studied. Yield loss data available from Victoria (■) or other States (□); seed production data available from Victoria (●).

Weed	Wheat	Barley	Oats	Canola	Seed decline data?
Juncus bufonius	–	–	–	–	No
Lolium spp.	■□●	–	–	□	Yes
Romulea rosea	–	–	–	–	No
Rumex spp.	–	–	–	–	Yes
Arctotheca calendula	–	–	–	–	No
Phalaris spp.	–	–	–	–	Yes
Fumaria spp.	■	–	–	–	No
Polygonum spp.	■	–	–	–	Yes
Erodium spp.	–	–	–	–	No

Table 3. Weeds in major dryland crops in northern New South Wales and southern Queensland for which specified data are available. Weeds are those ranked as the worst in a survey of farmers by Martin *et al.* (1988); crops are those ranked as most commonly preceding wheat. Yield loss data available from this region (■) or other regions (□); seed production data available from this region (●), or from other regions (O).

	Winter Crops						
	Wheat	Barley	Oats	Chickpea	Lupin	Canola	Seed decline data?
Avena spp.	■□O●	–	–	–	–	–	Yes
Rapistrum rugosum	–	–	–	–	–	–	Yes
Polygonum aviculare	–	–	–	–	–	–	Yes
Phalaris paradoxa	–	–	–	–	–	–	Yes
Polygonum convolvulus	□	–	–	–	–	–	Yes
Silybum marianum	–	–	–	–	–	–	No
Carthamus lanatus	–	–	–	–	–	–	No
Argemone mexicanum	–	–	–	–	–	–	No
Sisymbrium orientale	–	–	–	–	–	–	No
Lolium sp.	□	–	–	–	□	□	Yes

	Summer Crops				
	Sorghum	Sunflower	Cow pea	Soybean	Seed decline data?
Datura spp.	■	■	–	■	No
Xanthium spinosum	–	–	–	–	No
Echinochloa spp.	–	–	–	–	No
Salvia reflexa	–	–	–	–	Yes
Urochloa panicoides	–	–	–	–	Yes
Xanthium occidentale	–	–	–	–	Yes
Panicum spp.	–	–	–	–	No
Tribulus terrestris	–	–	–	–	No
Sorghum halepense	–	–	–	–	No
Ipomoea lonchophvlla	–	–	–	–	No

Table 4. Weeds of temperate annual and perennial pastures for which yield loss and seed production data are available, by state or region: New South Wales (NSW), Victoria (Vic), South Australia (SA), Western Australia (WA), Tasmania (Tas), South-eastern Australia (SE).

Weed	Yield loss	Seed production
Annual temperate pasture		
Lolium rigidum	–	Vic
Vulpia spp.	NSW	NSW
Hordeum spp.	NSW	–
Marrubium vulgare	–	Vic
Echium plantagineum	WA, Vic	SE
Pentzia suffruticosa	–	WA, SA
Pentzia globifera	–	WA
Emex australis	–	WA
Acroptilon repens	Vic	–
Solanum elaeagnifolium	NSW	–
Homeria spp.	SA	–
Adonis microcarpa	–	SA
Chondrilla juncea	–	SE
Heliotropium europeum	–	SE
Silybum marianum	–	SE
Perennial temperate pastures		
Silybum marianum	–	Tas
Carduus pycnocephalus	–	Tas
Carduus nutans	–	SE
Onopordum acanthium	–	SE
Onopordum illyricum	–	SE
Cirsium vulgare	Vic	–
Senecio jacobaea	Vic	Vic

profits from herbicide sales be channelled back to benefit agriculture as a whole. Combellack (1991) has outlined how such a scheme might be achieved.

What part should the public sector be playing? State departments of agriculture are reducing their core-funded research and relying more heavily on funds from the Rural Industry Research and Development Corporations. Losses of weed researchers, as in other areas of research, are often not being replaced. Research and Development Corporations will, no doubt, continue to support some weed ecological research. However, it is clear that some Corporations are more willing to do this than others; unless they have a deliberate change of policy, their priorities will continue to be the solution of immediate (tactical) problems rather than the generation of an adequate data base for long-term (strategic) purposes. The more restricted their funds, the lower the proportion of funds which will be spent on ecological work. Thus, more than ever, Corporations need in place stated policies on the types of weed research which they want to fund. Perhaps they should more actively solicit coordinated programmes on selected topics, rather than just waiting for researchers to suggest individual projects to them.

What if research data on weed ecology remains at its present low level? How easy will it be to develop integrated weed management systems aimed at reducing our reliance on herbicides and minimizing (for example) the rate at which herbicide resistance increases? We can, of course, use overseas data. But it will be risky to rely on data collected in very different climates within very different farming systems. Some of our major weeds are unimportant in other countries and have therefore not been researched there. Alternatively, we can make up data. This is effectively what we have to do for our computer decision support systems at present: we take our knowledge of the small number of researched species, and then make educated guesses about the other species. We have no choice. Surely, though, this is not agricultural science, but speculation given a false degree of respectability by issuing statements via a computer. Again, the reliability of the systems which result must be questioned.

We urge both private and public sectors of the agricultural industry in Australia to take a good look at the state of our knowledge on weeds, and then address the paradox of our desire for ecologically sound weed management and our grossly inadequate ecological data.

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