WEED MANAGEMENT RESEARCH IN CROP PRODUCTION—A REVIEW

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Summary Weeds management research in crops in Australia is active but weeds still remain a major cost in crop production. There has been a large proportion of the research effort devoted to herbicide research and more is needed in the area of weed biology to improve our understanding of the processes and mechanisms involved. Economic evaluation is also required.

Information on weed management, whilst reasonable in some aspects, is lacking in off-label recommendations and on environmental effects. More effort needs to be given to the promotion and adoption of integrated weed management and impediments to such adoption need to be addressed nationally.

It is also suggested that the weeds science profession needs to provide more opportunities for many of the contentious issues to be debated in open forum by those with the expertise.

INTRODUCTION

Weeds remain one of the major impediments to crop production in Australia through their impact on crop yield and quality. Combellack (1989) has suggested that weeds cost of the order of $A3.3 billion in control, lost production and quality. The herbicide bill is around $A450 million per annum (CRC for Weed Management Systems unpublished), representing by far the majority of pesticides used in Australia. On farm, herbicides remain one of the major costs in crop production where $A30–80 per hectare are commonly spent. Despite this, weeds are continuing to spread and new weed problems are emerging. There are no signs that farmers are winning the weeds war.

Why is this so? Is it that our understanding of weeds is so inadequate, that our research is poorly directed or that the information is available but farmers are not receiving it or failing to implement the appropriate strategies? Given the extent of the problem it could be expected that weeds research would be a high priority in agricultural research activity and with the respective research funding agencies. However, this has not been the case as the discipline of weed science in Australia has not been well developed and education programs at educational institutions have been inadequate.

All this, however, has changed with the accreditation of the CRC for Weed Management Systems where, for the first time in Australia, a co-ordinated program of research, education and postgraduate training is now in place.

WEEDS RESEARCH IN CROP PRODUCTION

Weeds research in Australia can be categorized according to the various aspects of weed science. Representation of the research effort can be taken by reference to Proceedings of Australian Weeds Conferences. Table 1 shows the makeup of weeds research in field crops being reported in these proceedings. In the compilation of this table, biological control, not being in the immediate control of the farmer, was not considered as a management option. Further, only Australian papers were included, since this review is contextually based.

As might be expected, chemicals research dominates the research effort with 190 of the 284 papers reporting on chemicals and their use for crop production. Included in this area is the proliferation of papers on herbicide resistance which represents the consequences of an industry heavily reliant upon herbicide technology. A cynical view of the domination of chemicals research is that the investigations are relatively straightforward, short term and publications can be obtained in a relatively short time. It probably also reflects the emphasis by research funding authorities on short-term solutions.

Given the preponderance of papers on chemicals, it is surprising to find little activity on chemical residues. This perhaps reflects the lack of pressure on the industry in the past but it is an area that can be expected to gain prominence because of market, community and hence legislative pressures in respect of residues in foodstuffs and in soils, as well as eutrophication of waterways. Perhaps the research has just not been published.

The research effort in weed biology continues, albeit at a relatively low level. Cousens and Medd (1994) summarize the Australian research activity in this area. Such research is more complex and longer term and hence has been less attractive to funding bodies or to people wishing to obtain promotion.

Nevertheless, it remains a vital part of the scene if future management systems that minimize chemical inputs are to be developed. It is an area in decline as research agencies reduce the number of staff involved, but it is an area where the CRC is likely to make a major contribution.

Judging from the paucity of papers, weed scientists do not place high priority on the publication of views on policy, economics, education and training or safety issues. It would be unfair to suggest that weed scientists are unconcerned by these issues or that they considered them unimportant. However, it does suggest, given the range of pressures faced by the industry, that scientists should, indeed must, speak out publicly on such matters to ensure that there is informed opinion in the community to offset the emotional and often uninformed comment that tends to receive undue media exposure.

HOW RELEVANT IS THE RESEARCH?

It can be argued that all research is relevant in that it contributes to the bank of knowledge but, clearly, some is more relevant than others depending on the time frame and the context. The extent of the relevance will depend on who is making the judgement. Farmers, and funding bodies, tend to identify the research into new chemicals as very relevant whereas weed biology or farming systems research brings less immediate or less obvious benefits and may be seen as being less relevant. Scientists would tend to have the reverse view, whilst extension officers find themselves using the chemical 'quick fix' as a means of solving immediate problems whilst endeavouring to have incorporated on the farm the more long term integrated weed management strategies.

Relevance could be improved where the practitioners are consulted in advance about their needs, thus allowing priorities to be determined in a climate of shrinking research dollars. Such a process, however, can increasingly localize the research and provide only the short term focus, although innovative farmers often have a longer term view.

Where the research is restricted to a localized area or to a single system of production the relevance becomes limiting. It needs to be recognised by researchers and research funding bodies that investigations are much more useful when spread over a range of environments and farming systems. This emphasizes the need for co-ordination nationally of research programs.

Over-emphasis on short-term issues also has its limitations. One example is the dependence on herbicides and the resultant development of herbicide resistance (Powles and Holtum 1990), a problem we can expect to widen with time but at the same time one which is not insurmountable. Its occurrence has provided us with a timely reminder that ecological principles cannot be compromised and reinforces adherence to sound agronomic practices. It has also alerted us to the fact that our knowledge of the biology of our major and minor weeds is far from adequate.

There is a strong argument for modelling research to help identify needs for research into population dynamics and bioeconomics.

It is harder to argue the relevance of what might be termed esoteric research such as molecular biology despite the fact that improved understanding of processes and structures may generate technological advances in the future though not necessarily in weed sciences. Do we not support this research on the basis that it has no immediate applicability in the field? It is a high risk and expensive research area but with potential for high returns. A proportion of our effort needs to be directed to this research without any expectations of significant payout. To do otherwise would be to deny the industry of new options that cannot always be foreseen.

Table 1. Categories of research, represented by papers published in weeds conference proceedings in Australia since 1981, related to crop production.

Category	Number of submitted papers[A]						
	1981	1984	1987	1990	1992[B]	1993[B]	Total
Chemical control	16	18	6	18	9	10	77
Herbicide resistance[1]	–	–	6	29	11	7	53
Application technology[2]	7	14	8	13	13	5	60
Cultural control[3]	3	5	5	5	11	2	31
Weed biology	5	9	–	2	8	11	35
Weed spread	–	–	–	1	1	–	2
Soil/herbicide[4]	–	–	1	5	2	–	8
Residues in produce	–	–	–	–	1	–	1
Education/training[5]	–	–	2	3	2	4	11
Economics	1	–	1	1	–	2	5
Policy	–	–	1	–	–	1	2
Total	32	45	30	77	58	42	284

[A] – review papers not considered; submitted papers and posters only. – biological control not considered.
[B] – only Australian papers considered.
[1] – including mechanisms.
[2] – including environmental factors.
[3] – including integrated weed management, non-chemical methods and conservation tillage systems.
[4] – including soil residues, soil biology.
[5] – including safety.

ADOPTION OF RESEARCH

The adoption of research is a function of the area of research, the availability of the information, the effectiveness of the extension process, and the attitudes of the farmers.

Area of research Herbicide technology is so well entrenched in the farming systems of Australia that the adoption of new chemicals for in-crop weed control is readily achieved. Awareness of these products is high because much effort is expended by the chemical companies in advertising, on-farm demonstrations and reseller awareness. Farmers, being experienced in the simplicity and cost effectiveness of herbicides are receptive to such new information.

Application technology has also been readily adopted where clear advantages to the farmer have been promoted. Thus a reduction in water volumes in the application process has been well received as was the availability of granulated, low-rate chemicals for ease of handling and safety.

In the more abstract areas of weed biology, farming systems and integrated weed management (IWM), adoption is a much slower process since the results are not immediately obvious and commercial advantage is not apparent. For example, weed control in pastures is a practice slow to be adopted despite its importance in reducing weed burdens and disease incidence in the subsequent cropping phase. Secondly, the adoption of IWM for the management of herbicide resistance has not been readily adopted, farmers taking the attitude of waiting for it to occur before implementing strategies for its management. In such cases, farmers are driven by short-term economic factors and there is therefore a need for bioeconomic models to provide the evidence for the longer term advantages.

Availability of information There is good and readily available information on weed control by herbicides. For example, the 'SA Cereal Weed Spraying Guide' and the New South Wales 'Weed Control in Winter Crops' publications are widely used by farmers. They are updated annually and summarize the label recommendations of the various products.

Chemical companies also provide detailed information on all their products and that is made available through resellers and other outlets such as field days. Commercial advertising provides the awareness and reinforcement.

Other publications such as the Grain Legume Handbook and decision support systems such as 'Decide' and 'Herbi Guide' are also useful but are most likely to be used by advisers and consultants rather than farmers.

Newspapers, farm magazines, newsletters and other media often feature articles of relevance but they are 'once-off' offerings that commonly have a small time span of value unless a farmer has a good filing system.

On occasions when there is an 'incident' or key finding, there tends to be a proliferation of information available from a range of sources. A good example is the generation of specialized material on herbicide resistance. This response can create confusion and generate barriers to adoption unless well-controlled and co-ordinated.

Information not readily available is the non-label recommendations for herbicides – that is, efficacy of chemical mixes, use of low rates and location-specific information such as acid and alkaline soils. Ralph Burnett in Western Australia has been a pioneer of this approach but legislation in some States has precluded the dissemination to the wider community of this area-specific information because of the lack of formal registration of such approaches.

The transfer of information this has traditionally been the province of district agronomists in State Departments of Agriculture. However, many reseller organizations now employ graduates and they have become an additional agent of information transfer. Further, with the contraction of some government extension services there has been an increase in private consultants providing the service.

In particular cases, a consolidated effort can be made involving a number of players. Again herbicide resistance provides a good example where the Grains Research and Development Corporation, State agencies, Universities and the private sector worked together through the National Herbicide Resistance Extension Strategy Committee. Three important aspects of this process are worth noting:

- that industry could work together,
- that resources could be mobilized if there was a will,
- that despite enormous effort, adoption does not occur unless the farmer is receptive and sees the need to fix the problem.

The availability of education programs can also be important in the adoption process. In the past, University courses have not been strong in the weed science area but again, the emergence of the CRC for Weed Management Systems will enhance such offerings and their accessibility. The vocational area of training has also not provided substantial offerings in this area, signifying a lack of demand, expertise or both.

It should be acknowledged that the National Farm Chemical User Training Program has been an outstanding success with thousands of farmers, resellers and contractors having been accredited through this program.

The outcomes can be expected to be improved weed control and a reduction in the wasteful use of agricultural chemicals.

Farmer attitudes Adoption depends also on the attitudes of the farmers. Those with more progressive attitudes seek out the information they need. They are quick to adopt but also quick to discard what does not work. In some cases they try options which have not been researched and provide the impetus for research action.

It is important that any adoption program take account of the perceptions, real or imagined, of the practitioner. This was exemplified in a farmer focus group study in southern New South Wales associated with the National Herbicide Resistance Extension Strategy program (Pratley *et al.* 1995). Several factors were highlighted in inhibiting the adoption of the prescribed strategies including:

- the expectation of new chemicals becoming available,
- awareness but lack of concern until it occurs,
- distrust of messages promoted by companies who have vested interest in the outcomes.

A consequence of these findings was to leave the promotion of strategies to perceived independent authorities such as Departments of Agriculture and Universities and to put more effort into farm demonstrations. Also highlighted was the requirement in any adoption program to identify the perceptions, needs and attitudes of the farming community in order for it to be successful.

ACTION REQUIRED

Much needs to be done if we are to make progress. The collective wisdom of professionals around Australia working with farmers provides the following for consideration:

1. Information availability Considerable useful information already exists but much is largely unknown or not readily available. There is a need, therefore, for:

- completed research to be published,
- off-label information to be collated and made available including compatibility data, efficacy of mixes, and environmental effects,
- establishment of an on-line system which is regularly updated and which enables expert systems to be available for use after development.

2. Herbicide management Several aspects of the use of herbicides need investigation. These include:

- weed control options in new crops,
- herbicide residues in crops and soils, including sulfonylureas in high pH calcareous soils and imidazolinones in acid soils,
- relative performance of herbicides for different environments. Research agencies have reduced their activity in this area and chemical companies tend not to publish such data,
- effective tank mixes for control of a range of weeds. Included here are compatibilities with trace elements and insecticides,
- improvement of herbicide performance including evaluation of crop oils and other adjuvants,
- development of herbicides and their application under stubble retention conditions,
- critical assessment of weed control with different spray application systems such as low drift application.

3. Weed biology There is a need for improved understanding of the biology and population dynamics of a range of weed species including:

- perennial weeds such as nutgrass, couch grass, horehound, skeleton weed, field bindweed, sorrel and silverleaf nightshade,
- thistles in legume crops and pastures,
- bedstraw, bifora, cat's ear, St. John's wort and fumitory.

In addition, we need increased research effort for most weeds in:

- weed dispersal,
- seed germination and seedling establishment, particularly in respect of soil physical conditions,
- weed physiology, growth and development,
- weed-crop competition modelling.

It should be noted that most weed biology papers presented at CAWSS meetings are descriptive rather than explanatory. For us to make most progress we need to understand why weeds respond in the way they do. Such issues are clearly addressed by Cousens and Mortimer (1995).

4. Integrated weed management Although considerable information exists to establish IWM systems, it is considered that better understanding is needed to integrate the knowledge for different species, environments and cropping systems. Further information is needed on:

- rates and times of sowing for weed control options,
- management of seed reserves including breaking weed seed dormancies,
- development of practical tests to measure seed reserves and seed dormancy,
- weed management in the pasture phase,
- changing weed spectra with changes in crop management systems such as direct drilling and stubble retention,

- management of weeds in marginal areas,
- management of summer weeds including herbicide recommendations and criteria for use,
- allelopathic relationships between crops and weeds,
- management of weeds of irrigated areas, particularly with respect to contamination of drainage water and subsequent downstream spread.

Greater attention should also be given to the collation of farmers' solutions which they have developed to weed problems. Since farmers are often the source of innovation, it seems wasteful not to evaluate their management practices more seriously.

5. Development of new technologies These include the 'WASP' and GPS/GIS that allow spatial variability to be addressed such that herbicide inputs are substantially reduced.

6. Economics Very little data exist on the economics of weed control, particularly with respect to systems evaluation. More attention needs to be directed towards cost/benefit analyses, the determination of economic thresholds and evaluation of new techniques and technologies.

7. Education Institutions at all levels need to be encouraged to improve understanding of integrated weed management.

POLICY ISSUES

Several issues have been raised as concerns by experts around Australia, relating to the inadequate legislation or to the unnecessary restriction of legislation.

Current legislation does not cater adequately for the off-label uses and below label rates which are known and often practised in the industry. Whilst changes to the NSW Pesticides Act will address below label rates, no flexibility exists to address new uses of chemicals and the synergistic impact of mixtures.

The process of registration of chemicals has been a long, slow and expensive process and needs to be streamlined. Chemical companies are unlikely to address new uses unless a substantial and viable market exists for the new use. Who then is going to address these needs – Departments of Agriculture? Universities? Industry? Given that there is a need there ought to be a revision of the processes and costs involved to simplify them without compromising safety aspects and community concerns.

While one of the principles of weed management is that of hygiene and spread minimization, greater attention needs to be given to mechanisms by which weed seeds are spread. A review then of the responsibilities of contract harvesters, and of seed contamination in pasture and crop seeds is warranted. Currently, varying standards exist across Australia. Seed contamination, for example, is a process by which herbicide resistance can be transferred from farm to farm (Pratley *et al*. 1995). Spread by livestock also needs to be considered, particularly where noxious weeds are involved.

Other issues mentioned include herbicide residues, disposal of unwanted chemicals, safety in handling and off-target damage. What about extension methodology, research methodology, or ethical issues related to pesticide use?

How then, do these issues get aired? What forum exists for debate? Given the paucity of papers at Australian Weeds Conferences in the past, it appears that weed scientists have considered this forum to be inappropriate or not encouraging. I consider it a most appropriate opportunity for this purpose and commend it to the organizers. Emphasizing this is the progress, or lack of it, in the establishment of a National Weeds Strategy. This has had a long gestation but parturition is long overdue.

CONCLUSIONS

Given the limited support given by agencies and funding bodies to weeds research, we can be pleased with what has been achieved and the degree of adoption obtained. We need to recognise the contribution by the chemical companies, not only in providing valuable tools for use in weed control, but also the role they have played in promoting farming systems and integrated weed management.

However, community demands that we continue to work to reduce synthetic chemical use and that means greater effort to establish non-chemical options by better understanding weed biology, including population dynamics and allelopathic interactions. At the same time market demands for quality produce without chemical residues will be overriding.

A review of regulatory requirements to minimize spread of weeds and to assure maximum efficiency in herbicide application as well as safety would be useful.

The establishment of the CRC for Weed Management Systems provides for weeds research in southern Australia to be co-ordinated better, for education and training to be enhanced, for policy to be developed and for information to be transferred to advisers and practitioners with greater effect. However, it will need to take account of all the players in weed science and weed management, including those outside the CRC, for the agenda to be completed satisfactorily.

Finally, the Weeds Science Societies provide a forum for all people interested in weeds to have a say and to interact with peers. There perhaps needs to be greater encouragement in the Societies for issues of policy to be considered and debated.

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