Weed management in Australian rural production, 1980-1990

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I am doubly fortunate, both in being a weed scientist at this exciting time in the development of the subject and in being asked to peer (probably short-sighted) into the future of weed control in Australia over the next decade and to tell you what lies ahead for us all.

The object of this Conference, as you know, is to examine the future of crop and pasture agronomy in this country over the next decade. Looking into the future is like looking from a well lit room into a darkened one: we see only the nearest objects at all clearly, and the shadows cast by our own current prejudices and lack of imagination obscure what little light there is. I am only sure of two things about that obscure room of the future - that we are committed to entering it, and that we are going to be surprised by what we find in it.

The discovery of the selective action of DNOC in the 1930's and of 2,4-D in the 1940's led to the growth of the herbicide industry that we see today. The herbicide industry has played a crucial role in the expansion of cropping and the increase in pasture productivity throughout the world over the last thirty years, an expansion which we as agronomists must sustain until our species has stabilised its population upon the finite earth. It is a sad reflection, however, that our servant has so soon become our master, and that our current reliance on cheap and effective herbicides has contributed significantly both to a drift of the rural population away from the land and to a general slackening of farm hygiene.

It is impossible to think constructively about weed control without considering all of the other aspects of crop and pasture agronomy that interact with it, since excessive weediness is often the result of poor agronomy and effective weed control leading to maximum yields can best be achieved by good management of the total agronomic system. The selection of appropriate crop and pasture species and varieties and their correct distribution across the field, together with maintenance of vigour by fertilizers, irrigation and the control of insects, pathogens and other pests are all basic to good weed control, since the architecture of the crop or pasture canopy and the speed and uniformity with which it covers the ground play a very important role in the competitive struggle which occurs between the useful plants and the weeds.

The steadily increasing importance of mechanical harvesting in processing crops such as beans, peas and carrots as well as the increasing acreage of cereals, oilseeds and other broadacre crops continually increases out dependence on good weed control in the field, since many harvesters are unable to handle very weedy crops or fail to distinguish between crop and weed, leading to downgrading of the product or costly sorting at the factory.

There are a number of challenges to Australian agriculture that affect weed management today and in the forseeable future. In the firm belief that every challenge offers an opportunity for advance, I intend to examine each of these problems and to show how they may be overcome in the next five to ten years.

Dynamic interactions between crops and weeds

Weeds are generally plants of low productivity which survive competition from the more highly productive crop and pasture species. The balance of competition and other forms of interaction between these two groups of plants is a dynamic one, and much can be done to influence it towards greater growth of the crop or pasture and suppression of the associated weeds.

Greater ability to manipulate the interaction between crops and weeds requires greater understanding of the factors which trigger and control the several growth stages of the plants and of the interactions that occur between them at different stages. The large seeds and rapid germination of most crops give them

an initial advantage over many weeds through the rapid production of tall and leafy seedlings. Agronomic factors which maintain crop seedling vigour up to and through the critical competitive period (Kasasian and Seeyave 1969) are important in maintaining the dominance of the crop over the weeds in the vegetative stage, whilst the control of defoliating pathogens and insects and the supply of sufficient water and nutrients keeps most crops dominant over weeds through to harvest. The worst weed problems occur in small-seeded and slow-growing crops of low leaf area index which provide little competition against weeds at any stage of their life cycle, such as onions, and in those crops that fail to cover the ground either because of wide interplant spacings (such as lettuce) or because of defoliation during the vegetative stage.

A better understanding of the importance of crop and pasture vigour and a greater facility in the manipulation of the interactions between them and the weeds will directly benefit most primary producers as well as reducing their dependence on other forms of weed control.

Poor farm hygiene

One of the main reasons for weediness is that farmers, graziers and horticulturists allow weeds to flower, seed and spread in the fallows as well as in the crops themselves, thus increasing their own and their neighbours problems in the years ahead. It is so obvious that the weeds that infest the land today are the result of poor hygiene in the years that have just gone by that it need not be reiterated, but experience shows that most farmers seem to ignore this basic truth. Weeds, to me, are not a short term problem associated with a particular crop of wheat, celery, lucerne or some other crop - they are a long term and whole farm problem and must be treated as such, rather than as a series of separate and largely uncoordinated attempts to control the weeds of individual crops and paddocks. The only sensible answer to the problem of weeds is the prevention of their further geographical spread and the prevention of the sexual and vegetative reproduction of those weeds already present on the farm. The ready availability of paraquat and glyphosate and their human safety, ease of application and effectiveness have put a powerful tool in the hands of the farmer in his fight against annual and perennial weeds on the farm.

Farmers are, however, in the business of using natural resources to produce food and fibre for profit rather than there to control weeds, and sometimes good weed control must be sacrificed for short term monetary gain. Nevertheless, farm hygiene is an important and relatively cheap way of limiting future problems and should never be neglected. It is best achieved by an integrated system of crop and pasture competition, cultivation, mowing and the use of herbicides that will minimise the reproduction of weeds in fallows, contour banks and field borders as well as in crops as they approach maturity.

Poor hygiene is poor resource management, since it requires more time, energy and labour to control an infestation of weeds than it does to prevent them from occurring in the first place. The education of farmers and graziers in long term whole farm weed management systems is one of the main responsibilities that must be placed on the agricultural extension and education systems of the 1980's.

Rising fuel costs

The rising costs of fuel will have profound effects on all aspects of Australian agriculture in the next ten years, influencing both out competitiveness as suppliers of the world grain and oilseeds markets and the organisation and running of individual farms and properties. Several associated developments in weed control are readily predictable, including the wider use of minimal tillage systems, the replacement of hydraulic nozzles by controlled droplet application (CDA), and a move away from the necessity to mechanically incorporate herbicides into the soil.

The lower power requirements of spraying as opposed to soil cultivation for the control of weeds and a reduction in the number of passes over the land are both attractive propositions to the energy-starved farmer. It has been said that there only two times that you really need to enter a field of most crops - once to plant it, and once to harvest it. This is certainly an over-simplification at the moment, but is perhaps an ideal situation which we could try to achieve sometime in the future. The move away from power farming

and towards chemical farming will probably be an uncomfortable one, and must be organised on an integrated systems approach rather than as a series of isolated developments.

I expect there to be a major change in the application of herbicides from the current emphasis on hydraulic nozzles to the widespread use of CDA or some similar distribution system over the next five to ten years, since this approach offers great benefits in reducing volumes per hectare and therefore the weight of material that must be carried into the field and forced through the pump. Widespread development of CDA equipment will also free us from reliance on tractors as the primary power sources for ground spraying, with a consequent move towards smaller, faster, lighter and much more economical ground vehicles which require less fuel and apply the herbicides in shorter time with less crop injury and chance of drift.

It is unfortunate that many of today's residual herbicides must be mechanically incorporated into the soil, since the stirring of many hundreds of tonnes of soil per hectare is a very inefficient way of incorporating a few hundred grams of active ingredient. If the incorporation can be done as part of a one-pass planting operation it will remain viable, but its long term viability where it must be done as an independent operation is open to serious question.

The wider use of herbicides to replace fossil energy on the farm carries with it an increased risk of crop and environmental contamination, but I believe that the safeguards already present in the regulation system are adequate to prevent this from happening. Any contamination that does occur is usually the result of misuse of the herbicide, which to my mind is better solved by education and economic pressure than by further legislation. The move by one of the major companies to supply herbicide at a reduced price when the area and application equipment have been checked by a competent adviser is the most constructive approach yet to a number of problems associated with the use and misuse of agricultural pesticides.

Rising labour costs and the shortage of farm labour

The growth of power and chemical farming techniques and the move away from the land have developed side by side and fuelled each other over the last few decades. It is difficult to believe that this process can go on much longer, since it seems that many farms are now run by the farm family with very little hired help. On the other hand, the process is unlikely to be significantly reversed even though there is a large pool of unemployed labour available. Manual weed control is probably the most time-consuming and thankless job around the farm, and we should all be glad that is has largely disappeared in Australia. It is still the norm in many developing countries, however, where hand weeding occupies much of the rural population for much of their working lives.

The shortage of farm labour means that weed control will continue to depend on cultivation and herbicides, and that methods of herbicide application will become even more streamlined. Contract spraying and alternative methods of application such as herbigation and seed dressing will become more common if farm labour is still further reduced and as application techniques become mere sophisticated and more critical for success.

The relatively low level of management skill and technical expertise

The principles and practice of decision making in plant protection are not at present very well developed in the farming community, resulting in unnecessary loss of productivity and occasional damage to the environment. This situation will continue for some time to come and will only be solved by economic pressures and better education. Mistakes with sophisticated equipment and pesticides will become increasingly expensive, forcing the farmer either into a programme of self-education or into the arms of the consultant and contract applicator, as has occurred in parts of the U.S.A.

Australian agriculture will need large numbers of well trained and experienced consultants and advisers in the future to make decisions regarding pesticide application and other aspects of crop production. These

people should preferably be private consultants who are neither shielded from their mistakes by government security not tied to recommending the products of a particular company. At the moment, it is the companies that have the greatest incentive to get out there onto the farm and lead the way in the marketing of agrochemicals.

There are already large numbers of people who are skilled and experienced in making these decisions in Australian agriculture, but unless and until legislation is introduced to prevent the sale of pesticides except on prescription there is insufficient financial incentive for them to set themselves up as independent crop protection consultants. I think that this will happen in the next decade, at least in the more closely settled and intensively farmed areas of Australia. This would be a most beneficial move since it would allow the wider registration of pesticides with marginal environmental safety and should restrict the number of cases of herbicide residues damaging subsequent crops and other similar problems.

The high cost of patented herbicides

This is a necessary situation and one that will persist. If the money that pesticide companies invest in the discovery and development of new products is not returned to them with adequate interest they have no incentive to stay in the industry. It is the farmer and the consumer that would be disadvantaged if any pesticide companies were forced out of the Australian market, not the product manufacturer and marketer. In our capitalistic society the companies owe little financial allegiance to the non-shareholding public, which must expect to pay the full market price for the products that they need. Most of the pesticide companies are multi-nationals, and Australia is generally a small and distant market compared to Europe, North America and Japan.

High prices for patented products are therefore necessary if Australians are to continue benefiting from overseas research and development. Australian companies are not in a position to discover and develop their own herbicides and other pesticides, and I do not see this position changing in the future. If anything, it will probably get worse as more and more stringent testing procedures force up development costs for products for the European, American, Japanese and ultimately the Australian market. From the point of view of environmental safety per se this may be no bad thing, but we must be careful to achieve a balance between the requirements of our environment and those of our digestive systems and not to leave the farmers and graziers without adequate protection against pests at a price that we as consumers can afford to pay.

Lack of products registered for small markets

The high and still rising cost of Federal and state registration and re-registration of herbicides and other pesticides strongly discourages their developers from testing and developing them for small markets. The small-scale production of flowers, drugs and other speciality crops means that these growers would be unlikely to buy enough of a product to cover the costs of testing and registration for that market, with the result that the marketing companies are not very interested in servicing the speciality crop grower. States with 'user' legislation which prevents a farmer from using a herbicide unless it is registered for use in that crop may do their speciality crop producers a disservice in my opinion, since the farmer is either deprived of the pesticides that he needs to earn his living or strongly tempted to break the law.

The only way out of this impasse is for the development of pesticides for small markets to be funded by the growers themselves or by the public, through the state Departments of Agriculture, Colleges and Universities, or special research stations set up for this purpose. Obvious difficulties with this approach are to determine which crops need this form of public assistance and the effect that such assistance in market development should have on the subsequent cost of the product when it is sold into this market. It would be impractical to market the same product at two different costs - a higher cost to the market developed by the pesticide company and a lower cost to the market developed by funds provided by the growers or the community.

It appears to be unlikely that the government will take up the challenge of developing herbicides for the small market in today's climate of reduced taxation and government spending. The only viable alternative is for the cost of market development to be significantly reduced by relaxing the demands of the registration authorities, either overall or selectively for specified crops.

Limitations of current equ1pment

Most of the current ground spraying equipment uses high volumes of water to apply low rates of active ingredients per hectare, a system which imposes severe limitations in Australia where large areas of crops must be sprayed in limited time. The current use of hydraulic nozzles to apply pesticides is similar to the use of today's automobile or truck - both are basically inefficient systems which are only saved from extinction by a high level of mechanical sophistication, the capital sunk into them by their owners, and the vested interests of their manufacturers.

The recent application of an old principle has resulted in the system known as Controlled Droplet Application (CDA), by which small quantities of carrier are required to apply pesticides in droplets of almost uniform size. Although this system is still largely confined to hand-held equipment for the application of herbicides and other pesticides, there can be no doubt that it will soon be developed into effective vehicle-mounted systems which will allow a corresponding breakthrough in the type of vehicle used for pesticide application. The days of the tractor-mounted hydraulic sprayer are numbered - it will be replaced by lighter, faster and much more economic vehicles or hovercraft spraying low volumes of pesticide and carrier in droplets of nearly uniform sizes.

Herbigation - the delivery of herbicides in irrigation water - is now an established practice throughout much of the American corn belt and has been developed for the application of herbicides in flood water in rice in Australia. Herbicides can be applied through a range of different irrigation systems, including centre pivot. The development of herbigation in Australia will go hand-in-hand with the development of irrigation systems and the increasing sophistication and experience of the irrigation farmer.

I am sure that other breakthroughs will occur in the delivery of herbicides to crops and the soil, although it is impossible for us to forsee them until some inventive genius thinks of them. Like tomorrows motor car, tomorrow's sprayer can be expected to be a very different machine from today's. I am sure that the development of sprayers is going to be every bit as profound and exciting as the development of the automobile.

Problems with exist1ng herb1c1des

Great credit must be given to the chemists and formulators of today herbicides, which are able to select between plant species and control those that we do not want. Over the past forty years, the whole science of chemical weed control has arisen and reached a level of maturity at which the more dangerous and unreliable herbicides have either been outlawed or have faded into commercial obscurity. Those that we have left are generally cost-effective and safe to both the users and consumers.

Entomologists now realise that there are more inoffensive and even beneficial insects around as there are harmful ones, and the days of the indiscriminate use of broad spectrum insecticides such as DDT are now over. We weed scientists still tend to think that the only good weed is a dead weed, at least in monocultural situations. The broader the spectrum of a herbicide, therefore, the more useful we find it to be provided it does not damage our crops.

There are two basic approaches to the herbicidal management of weeds - to prevent, or to control. The first approach uses residual herbicides to prevent the germination or vegetative regrowth of the weeds, whilst the second uses contact or translocated herbicides to kill them after they have appeared above ground. On a purely philosophical basis the former approach is to be preferred since it prevents the weeds from ever becoming a problem in the crop. The main problem with residual herbicides are that they are often too residual and may then limit the choice of the succeeding crop to one which will tolerate

their residual activity. Many of them also need to by physically incorporated into the soil before the crop is sown and rising energy costs will make these less attractive as the years go by. Most field crops only need protecting during their critical competitive period - usually the first six to eight weeks of crop growth until the canopy closes over - and herbicides that give this limited period of selective residual control have a great future. Those that have a longer residual period which extends beyond the field life of the crop will be looked at with increasing disfavour since they may limit future cropping options.

It is surprising that so few tank mixes are registered in Australia compared to the many that are available in the United States of America. Tank mixing can extend the spectrum of weed control offered by many herbicides whilst retaining safety to the crop and is a simple and well tried principle. American labels for Lexone (R) in soybeans contain recommendations for tank mixing it with alachlor, oryzalin, trifluralin, profluralin, chloramben and Prowl (R) to achieve control of various spectra of weed species - why do we do so little tank mixing of herbicides in Australia? The recent registration of several tank mixes in Australia is a most welcome development, and one that still has a long way to go.

Another area of herbicide technology which will soon be with us in Australia is the use of additives and antidotes, both to 'rework' old herbicides to achieve new effects and to extend the activity of currently available and new herbicides into new crops (Pallos Casida 1978). C1BA-GE1GY at least are working in this area in Australia to extend the use of metolachlor into sorghum.

Granular insecticides have been developed which can be sown with the crop seed to provide residual control of insects during the early part of the crop's life. Is there any good reason why appropriate herbicides should not be formulated and used in the same way?

I am sure that there is great scope for improvement in herbicide formulation in these and other ways and look forward to extension in the uses of both older and more recent herbicides through the activities of the formulation chemist.

Allelopathy

Allelopathy - the production of chemicals by one plant which interfere with the germination or growth of other plants - is a widespread but poorly researched area of natural interplant relationships. The subject merits much more research in the future since it offers two potentially interesting advances in weed control. The first of these is the selection of varieties or races of crops which exert a depressing effect on their associated weeds. About 5% of cucumber lines tested by Putnam and Duke (1974) were strongly allelopathic to indicator weeds, reducing their growth by 50% or more. The second potential use for this phenomenon is the development of the naturally occurring allelopathic chemicals as bases for new and powerful groups of selective soil active herbicides.

Legislation

We are now in a transitional stage between the regulation of pesticide development and sale and the regulation of its use in the field, and I expect that over the next ten years we shall see much greater restrictions being placed on the use of herbicides and other pesticides in the field and on the farm.

The Environmental Protection Agency in America and some American States have lead the way in the regulation of herbicide usage, sometimes going too far in this matter and throwing out the baby with the bathwater. This is probably because legislation is usually the result of public pressure, and whilst the pressure comes from an urban majority who appear to know little and care less about where their food comes from we can only expect this process to continue in Australia as it has in some countries abroad. It is time for all of the farmers, advisers, researchers and others in the Australian agricultural industry to start protecting our own and the countries future in this matter by ensuring that future laws ultimately benefit the whole of the industry and of the nation rather than further the aims of a vocal minority. This can only be done through education of the public, and it is our responsibility to get this message across.

To my mind the user legislation recently introduced in New South Wales either goes too far or not far enough. It goes too far in that it will be very difficult to police, and not far enough in that it does not fully solve the problem of pesticide residues and pollution of the environment because it leaves the application of these chemicals in the hands of the often ill-equipped and over-busy non-specialist. I look forward to the day when the choice and application of herbicides and other pesticides is largely taken out of the hands of the farmer and horticulturist and put into those of the registered plant protection consultant and applicator. I hope that this will happen in the more densely populated parts of the country within the next decade and believe that it will reduce the environmental and human hazards associated with herbicides and allow some easing of the restrictions that currently govern their registration and use.

Another aspect of American pesticide legislation which has its merits but also its drawbacks is the use of closed mixing systems, in which the herbicide (or other pesticide), rinsings and dilution water are all pumped through a sealed system from their respective containers into the tank of the sprayer. Whilst the closed mixing system appears to reduce the risk of environmental contamination by pesticides during mixing, it vastly increases the complexity of an otherwise fairly straightforward and simple operation.

B1ological weed control

Most Australian weeds are importations from abroad, and in many cases they have become much more serious here than they were in their countries of origin because they have escaped from their natural controls. An obvious approach to the control of such weeds is the importation of carefully selected and tested insects and pathogens from abroad and their liberation in Australia, in an attempt to reduce the population and severity of these weeds.

Past successes in this field and the increasing scope and tempo of biological weed control give hope for the much more widespread use of this form of weed control in the future. In the past, most of the targets for biological weed control have been perennial weeds of extensive grasslands and woodlands, but whilst there are many such weeds still to be combated the emphasis is broadening to include water weeds and even short term annual weeds of cropland, especially if pathogens can be harnessed to this end.

Weeds on which biological control programmes are currently under way and those which still provide pipedreams for the biocontrollers amongst us are listed below:

TABLE 1 - Weeds on which biological control is being researched or on which it is desirable (data supplied by contacts throughout Australia)

Weeds on which biological control programmes are currently effective or under development	Weeds for which biological control may provide some answer in the future
Blackberry (Rubus fruticosus)	Slender thistles (Carduus pycnocephalus, C. tenuiflorus)
Ragwort (Senecio jacobaea)	Variegated thistle (Silybum marianum)
Skeleton weed (Chondrilla juncea)	Spear thistle (Cirsium vulgare)
St. John's wort (Hypericum perforatum)	Californian thistle (Cirsium arvense)
Spiny emex (Emex australia, E. syinosa)	Golden thistle (Scolymus hispanicus)
Paterson's curse (Echium lycopsis)	Cotton thistle (Onopordum acanthium)
Alligator weed (Alternanthera philoxeroides)	Nodding thistle (Carduus nutans)
Common heliotrope (Heliotropium europaeum)	Gorse (Ulex europaeus)
Lantana (Lantana camara)	Horehound (Marrubium vulgare)
Salvinia (Salvinia molesta)	Onion weed (Asphodelus-fistulosus)
Water hyacinth (Eichhornia crassipes)	Great mullein (Verbascum thapsus)
	Prairie ground cherry (Physalis

Harrisia cactus (Eriocereus martinii)
Parthenium weed (Parthenium hysterophorus)
Groundsel bush (Baccharis halimifolia)
Noogoora burr (Xanthium pungens)
Prickly pears (Opuntia spp.)

virginiana)
Bathurst burr (Xanthium spinosum)
Boneseed (Chrysanthemoides monilifera)
Soursob (Oxalis pes-caprae)
Caltrop (Tribulus terrestris)
Sweetbriar (Rosa rubiginosa)
Rubber vine (Cryptostegia grandiflora)
Silverleaf nightshade (Solanum eleagnifolium)
Knobweed (Hyptis spp.)
Mimosa pigra
Prickly acacia (Acacia nilotica)
White moth vine (Araujia hortorum)
Wild turnip (Brassica tournefortii)
African cornflag (Chasmanthe aethiopica)
Parkinsonia (Parkinsonia aculeata)
Wild radish (Raphanus raphanistrum)
Guildford grass (Romulea rosea)
Docks (Rumex crispus, R. pulcher, R. acetosella)
Indian hedge mustard (Sisymbrium orientale)
Watsonia (Watsonia spp.)
Arum lily (Zantedeschia aethiopica)

Looked at from the point of view of the rational use and conservation of natural resources, biological control of weeds and other pests is the most sensible approach to take after quarantine, hygiene and host resistance. It reduces the use of fuel, chemicals and labour, whilst reducing the residues of herbicides in the soil and in harvested produce. Even if it remains restricted to the control of perennial weeds of the extensive grazing, forestry and aquatic ecosystems it still improves their productivity and releases labour

other resources for the physical and chemical control of annual weeds in croplands.

Conclusion

The growing wealth of this nation and the growing realisation of the losses caused by weeds and other pests will, I am sure, place a much greater emphasis on plant protection during the next ten years, and I have tried in this paper to suggest some of the ways in which weed science may develop during that time. Of two things only am I sure - that the next ten years will be an era of rapid change for weed science in this country and abroad, and that at the end of it we shall look back with satisfaction on all that we have achieved since 1980.

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