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Winston Churchill Memorial Trust of Australia

Report by
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WEED MANAGEMENT SYSTEMS FOR HERBICIDE RESISTANT WEEDS

IN NORTH-WESTERN UNITED STATES OF AMERICA

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Introduction.

Background.

In the past 15 years many weed species have become resistant to herbicides commonly used for their control. The use of herbicides, whilst not universally approved, has reduced land degradation, increased weed control efficiency and improved crop yields. The advent of herbicide resistance threatens those benefits. In some areas herbicide resistance has markedly increased the cost and complexity of weed control. In Australia the major weed displaying resistance to herbicides is Annual ryegrass, *Lolium rigidum*. Our problems are compounded because ryegrass can display resistance to every selective herbicide registered for use on annual ryegrass.

Objectives of the Study Tour.

In other countries of the world, especially North America, there are substantial problems with herbicide resistance. Weed management and weed science are well established aspects of agriculture in USA and it was my intention to visit Weed Science Departments in Universities in the small grains areas. It was also my intention to visit with exponents of "non-traditional" agriculture especially institutions or Government agencies with substantial and reliable experimental programmes.

I was successful in visiting and discussing problems of controlling herbicide resistant weeds in each stopover. In some areas weed control methods had not evolved past the use of herbicides, but in general weed scientists were aware of the problems of controlling herbicide resistant weeds. Most of my planned visits were very productive and rewarding.

A large part of a study tour are the contacts that are made, and the personal enthusiasm that is generated by meeting, by talking and by sharing professional and personal anecdotes. Thas was certainly the case with my study tour.

Executive Summary.

Weeds of crops are a world wide phenomenon. There are many weeds that are common to both the USA and Australia. More importantly there are similar ecological niches in the crops that are grown in each country. Thus it was possible to identify weeds that occupy similar niches in each country.

The niche that is of principal importance in Australia is the grassy weeds of cereal crops. The principal weed of such a niche may vary depending on climatic variables but the niche is always occupied by some specie(s).

Long-term control of the weed that occupies such a niche by herbicidal methods alone has failed or is in the process of failing in many different areas. I visited many farms where weed control was failing or had failed because of the repetitive nature of the crop protection system. I also visited many farms where weed control was being carried out in a sustainable and environmentally benign way. In these latter cases there is no herbicide resistance and in the most part they appeared to be relatively profitable. The reason for the success of some systems compared to others is the variety of weed control measures and the variety of rotational phases. In a country as varied as the USA some of these may be forced onto producers by climatic factors as by any logical decision. No matter, they still illustrate the case.

Successful weed control is achieved by a suitable rotation of crops interspersed by periods of no crop where the population of weeds, either seedling plants, mature plants or seeds can be reduced. Ideally the crops should vary in seasonality, that is, fall planted and spring planted to accommodate this. It is preferrable to use herbicides from different chemical groups for weed control rather than from the same group. A diversity of methods is preferrable to systems than are repetitive of timing of technique or of chemical usage or type. There are limitations to the diversity of any system, and in our economic system it is the need to make a profit from the rotational crop. Australian agriculture will benefit by reinstating the mixed crop rotation. It is the same in the USA.

In a system of integrated weed control there is scope for creativity in weed control techniques. My report will introduce a few "bright ideas" that can be part of a varied weed control programme. To list a few; a laser beam to cut weed heads as they poke above the crop, corn husk retrieval systems to aid the removal of weed seeds from the field during the harvesting process and post emergence cultivation of crops to dig up weeds as they germinate in the crop. These ideas will have some application in Australia.

Dissemination of the findings of the study tour.

There is a well established Rural Press in Australia, which is usually eager to accept reports of a technical nature, I anticipate that I will be able to submit two articles to a syndicated press service.

The SA Crop Science Society has already approached me for an article, summarizing my tour findings, other similar professional groups may be interested.

Acknowledgments.

I would like to acknowledge the the generosity of the Badman family of Naracoorte South Australia. Mr. Ron Badman was a Churchill Fellow and the community has certainly benefited from the experience and insights that Ron brought back. His personal involvement in the S.A. Seed Industry has helped it immensely. I understand that his Fellowship was somewhat instrumental in developing that industry and the marketing structure that has given it so much stability.
It is due to the generosity and farsightedness of the Badman Family that this study tour was made available and I was priveleged to be the first recipient. I would like to thank Mr. Ron Badman and his Family and acknowledge their personal interest in the study programme.

I have found past fellows and also the administrative arm of the Trust to be helpful and efficient in the planning and preparation of this 1992 Fellowship.

The Churchill Trust is more than an organization for facillitating study tours, it is a collection of persons who because of a common experience, understand the advantages of sharing and communication both for their own sake and for the greater community. I have enjoyed the comradeship.

Oregon State University
Corvallis Oregon.
Hosts Profs. A. Appleby and S. Radosevitch.

Problems with herbicide resistant ryegrass in Oregon.

The Willamette Valley in Oregon is a mild climate with rainfall about 22-30 inches p.a. Italian ryegrass (*Lolium multiflorum*) was and still is grown as a seed crop in the area. It remains to be determined if the weedy species is the same as the seeded crop species, it is possible that selection has altered the population over time. A resistant biotype of ryegrass has found to contain about 50% tetraploid plants. The ryegrass fills the same niche in Oregon as it does in Australia being introduced as a crop and has remained to become a weed of cropping systems.

There are extensive problems with herbicide resistant *Lolium multiflorum* in Oregon. The current estimate is that there are over 100 populations that are resistant to diclofop methyl, these populations show extensive resistance to other herbicides of the same chemical group, however they are are not as resistant to herbicides of the cyclohexanedione group, the 'dims". A few of these populations show some resistance to diuron, a herbicide which was used extensively for weed control in cereal crops in the Willamette Valley.

The usual crop rotation in this area is continuous wheat for a period of time and then rotate to grass seed crops and legume crops.

Control of herbicide resistant *Lolium multiflorum* at the present time is almost completely reliant on further chemical applications.

Products that are effective in cereals in Oregon are triallate, diuron and metribuzin. In legume crops pronamide or Kerb is frequently used.

Short rotation crops are not commonly used, and cropping systems do not appear to flexible enough to allow periods where no herbicides would be applied and seed set controlled by other means.

Aspects of the genetics of *Lolium multiflorum* resistance.

Discussions with Dr. Reed Barker a grass geneticist with the U.S. Dept. of Ag. suggested that at the field rate of herbicide use the inheritance of resistance tends to be multigenic, probably two genes. He also has found an unusually high frequency of resistant plants in commercial *Lolium multiflorum* seed. The level of about 1.0% suggests that resistance is a multigenic and

polymorphic phenomenon, and in this genus can be present at a high frequency.

Herbicide resistant Wild Oats in Oregon.

Wild Oats (*Avena fatua*) are also a serious weed of cereal crops in Oregon, and a target for herbicide application. As in this country there are populations that have become resistant to herbicides. In 1991 about fifteen populations of wild oats were characterized for resistance to diclofop methyl. Ten populations were found to be resistant to diclofop methyl. There is also resistance to some herbicides of the same chemical group as diclofop methyl, but very little detectable resistance to the "dim' herbicides, to imazemethabenz or to difenzoquat.

The trend in wild oat resistance when compared to the Australian picture appears to be similar, with fewer populations of wild oats than ryegrass displaying resistance, and the resistance spectrum appears to be less complicated.

Ecology of weed germination with special emphasis on influencing light quality and quantity.

Some very interesting research in basic ecology is being undertaken at Corvallis to indentify the effect of altering light quality and light intensity on weed growth and weed germination.

There have been several experiments reported over the last few years where cultivation at night has been shown to decrease the weed numbers present on a given field. The mechanisms operating under such a regime were presumed to be the deprivation of light required for germination in some species. Scientists at Oregon State University, Anna Scopel, Carlos Ballare and Claudio Gersha are looking at the possible application of this technique to agriculture. Some of this data is published in Plant Cell and Environment (1991) 14, 501-508 , A Scopel. Cultivation at night, in an experiment at OSU resulted in 75% less weeds present following a night cultivation than a day cultivation. The effect is more pronounced in Amaranthus species than in Solanum species in July tillage (mid summer). Summer annual broadleaf weeds and winter annual broadleaf weeds were affected similarly and grasses were more so. The effect was less pronounced with autumn or fall cultivations.

Some small plot experiments indicate that changing both the light intensity and the quality can enable crop plants to compete better with weeds. In the

experiments conducted so far, weeds are more sensitive to poor light quality and low light intensity than wheat is. It is possible that the result is a function of the adaption of wheat to low light conditions yet it bears consideration in Australian conditions. Light quality and intensity was manipulated by cover crops or hedges of cover crops that would not persist for the full crop period.
The role of fungal endophyte in the transmission of resistance genes is also underinvestigation at OSU, very little is known about the affect of these organisms on gene flow or the tendency to increase genetic variability in this species.
The possibility of introgression between Festuca species and Lolium multiflorum species is also being investigated.

University of Manitoba, Winnepeg Canada.
Hosts, Prof Ian Morrison and Dr Ian Heap.

General. Herbicide resistance in the prairies of Canada.
The Canadian prairies are an extensive area of spring wheat, canola, spring barley and linseed or linola production.The growing season is short due to the severe winter but does have sufficient growing degree days (>1200) for efficient crop production. The short season does place pressure for early crop establishment and the shift to early planting and post-emergent weed control is thought to have accelerated the herbicide resistance problem.
Weed species that display resistance are;

Weed species	#of populations	Resistant to
Wild oats	>100	ACCase inhibitorsa
Green Foxtail	>400	DNA herbicidesb
(Setaria viridus)		
Green Foxtail	5-10	ACC ase inhibitors
Wild mustard	5	2-4-D and other phenoxysc
(Sinapsis arvensis)		

The weeds that have developed resistance have adapted to the continuous spring cropping system. On the prairies there are very few alternatives crops that are not short season spring annuals. Some alfalfa is grown but grazing animals are not possible due the soil damage and lack of infrastructure. I saw some alfalfa stands which were very productive and had the effect of suppressing weed growth, also they were utilized as green chop for ensilage which had the addittional benefit of removing maturing weed spikelets from

the field. The ensiled material is used for cattle feed, however there is not sufficient numbers of cattle in the prairie regions to sustain a widespread alfalfa component of the rotation. Winter wheat is a possibility in the less extreme climatic areas, but these are limited.
In general the lack of rotational crops or widespread opportunities for pasture or forage leads to the conclusion that herbicide resistance in the grassy weeds is a potentially serious problem and the solutions may be costly for the farmer. At the present time DNA resistance in foxtail is not present in the biotypes that are resistant to the ACCase inhibitors and vice versa so there are those options. The risk of developing resistance in the same population to both those herbicide groups is obviously high.
Wild oat resistance is widespread and developing rapidly and poses a serious threat to spring crop production. A substantial research and extension effort is being mounted to forestall resistance developing further.

Intercropping in the Canadian Prairies.
The use of intercropping was of particular interest. Intercropping is the growing of two (usually) species of crop varieties together in the same area at the same time, to provide greater competitivevness against weed growth. I have not seen any hard data but several farmers are using the system apparently to good effect. The combinations of crops may be different for different areas, but in the southern prairie region of Manitoba both peas with wheat or barley has been utilized, or lentils with wheat or barley, mustard was used with peas by one grower. Intercropping was used by other growers in Idaho and Washington. The suppression of both broadleaf and grassy weeds by the mixed crop species can be very effective. Mostly production is not reduced although harvesting and separation costs must be accommodated.

University of North Dakota, Fargo.
Hosts Dr. R. Shimabukuro, Dr Bill Ahrens.
Visited the University of Nth Dakota field station and saw a detector spray unit under trial. This unit was developed at New England NSW, and is being exported. The use of the machine is largely in fallow areas for the application of limited quantities of high rates or expensive chemicals or to isolated weeds. The equipment was under trial being the first season of release.
There is little evidence of weed populations displaying resistance to herbicides as Nth Dakota has extensive areas of fallow. Weed control is therefore not

exclusively by use of selective herbicides. The usual crop rotation involves a fallow period prior to winter wheat establishment and winter wheat can often be followed by a spring crop. Thus there is a fallow period a winter crop and a spring crop in loose sequence which represents an excellent rotational sequence for weed control.

Other aspects of weed control that are noteworthy is the use of rolling harrows for incrop weed control. This implement is commercially available from John Deere and a German manufacturer, and features a series of spikes forming a wheel and a series of wheels forming a rolling gang. The spikes in each wheel are curved forward at the part that engages the soil, and when pulled over a crop they have the effect of digging up small weeds without causing much damage to the established crop. The crop should be well established. This implement would also have an excellent use in incorporation of pre-emergent herbicides into paddocks with stubble retained on the surface, They can cause some soil disturbance and do not clog up with crop residue.

Many of the Weed Science units at the Land Grant Universities have extensive cooperative programs with chemical companies. They perform an important role in testing and evaluating products for weed control. They are also involved in the residue assessment aspect of chemical weed control products. The benefits are both for the companies who get objective research results and likewise for the farmer. Computer programmes have been developed to aid this process, by the Statistics department at U of N D. The program is directly linked to a SAS statistical package for data analysis.

There have been many benefits to the herbicide industry to the farmers and the research scientists with the development of these type of aids to research.

University of Idaho Moscow Idaho.
Hosts Dr. Carol Mallory -Smith and Prof. D Thill.

Moscow Idaho, is situated in a very productive wheat growing area. Northern Idaho has deep clay-silt soils with an adequate spring and summer rainfall to produce up to 120 bushells of winter wheat to the acre. Spring wheat and winter barley are less common, but spring barley and canola are common crops some winter rapeseed is grown. Some rotation into lentils and peas, both winter peas and spring peas are sometimes grown.

The topograghy of the area is quite unique with sharp dune formations of fertile loess soil. The sharp hills are subject to frequent water erosion events and losses of 200 tons of soil per acre per year are apparently still common. There has been a shift to zero tillage and stubble retention to conserve the

topsoil. Continuous wheat rotations are a feature of the area made possible by the high inorganic nitrogen usage (120 units per ha).

The continuous wheat rotation coupled with stubble retention and zero tillage has generated a few unique weed control problems. Continuous winter crops without cultivation for weed control are usually infested with "Cheat grass" *Bromus secalinus*. There are no selective herbicides for the bromus spp. in wheat crops so in a sense the bromus infestations are a model of the problems encountered with herbicide resistance in other grassy weeds of cereal cropping systems. Bromus control systems were based largely on crop competition, some herbicide usage and rotations to limit the population size of the weedy species. Crop competition is maximized by planting in two rows perhaps 10 cms apart with the fertilizer banded under the crop rows. The space between the crop rows, up to 30 cms depending on the required crop density is often treated with a directed spray of atrazine to reduce the competition from the *Bromus* spp. The continued use of zero tillage and full stubble retention can lead to massive populations of bromus species under these conditions, especially when the planting configuration changes from year to year and weeds have access to surplus fertilizer from previous years. Many growers have had to change from continuous winter crops to spring crops to allow for some preplanting weed control either with cultivation or with non-selective herbicides. Other crop species with the opportunity to use selective herbicides are also a favoured rotational change, such crops are lentils, peas, canola or rapeseed.

Other weed problems in the continuous winter wheat rotation are some broadleaf weeds. Of these prickly lettuce has developed resistence to the sulfonylurea herbicides in a very limited area. The development of resistance in this species has been documented by Carol Smith. Control is not difficult with alternative herbicides.

Other research programmes at the University of Idaho include developing bio-economic threshold models for wild oat control in cereal crops, competition studies with weeds of canola, use of global positioning systems and Landsat imaging of rangeland weeds, and evaluation of the weed dynamics in a longterm cropping systems trial. All these programmes are of interest to weed science in Australia. The first, bio-economic thresholds of weed control, has relevance to the decision making processes when reducing herbicide inputs to a field as a preventative measure for herbicide resistance. Competition studies with common crops and weeds are an essential aspect of the weed control decision making process. The long term cropping systems

trial was set-up six years ago to evaluate the profitability and stability of three levels of inputs to a typical crop rotation. The final results are not available but so far the indications are that the high and medium inputs are more profitable and more stable economically than the low input system. This may not be the case in the Australian environment.
While at Moscow I had the opportunity to meet research scientists at Washington State University Pullman, Washington. Weed science research at Washington State is in two very separate areas, firstly, work on the mechanisms of paraquat resistance in a weed, picloram resistance in a thistle species and work on the mechanisms of resistance in wild oats from Oregon.

The other aspect of weed research at WSU is work on non-chemical weed control methods associated with the Sustainable Agriculture emphasis. There is an active interest in alternative weed control and its association with sustainable agriculture. I was able to visit two farms in Washington State and discuss non-chemical weed control methods with the farmers. One farmer used a short rotation legume cover crop system which he plowed in prior to planting winter wheat, the other employed an inter-cropping technique, which worked extremely well for weed control and also for providing diversity of foliage for beneficial insects. Northern Idaho and central western Washington are areas with similarities to the more favoured parts of the Australian cereal zone, it will be of benefit to both parties for closer ties to be forged.

Montana State University
Bozeman Montana.
Host Prof. P Fay.
Montana is a large state with many different climate and topographical zones. Areas of low-rainfall wheat production and some better areas for barley production, have similarities to the Australian cereal belt.
In the low rainfall wheat growing areas substantial problems exist with herbicide resistance Kochia. It is estimated that 60% of Kochia in the Montana cereal growing areas has resistance to the Sulfonylurea herbicides. The weed has a very effective seed dispersal system, which has allowed the spread over large areas. It germinates readily and can compete strongly with crops, the resistant type has different germination characteristics than the usual type.
In the better barley growing area wild oats are a huge problem. The continuous use of one chemical, Triallate has selected for resistant weeds in

many sites. At least 40 sites show resistance to Triallate and all apear to be resistant to Difenzoquat as well. In both these cases the resistance has been brought about by the continuous use of a single herbicide in a continuous crop rotation, a sure recipe for herbicide resistance problems.

Other aspects of weed control under investigation at MSU are the use of lasers to cut weeds when they appear above the crop, and the use of hedge trimmers to cut uncontrollable weeds from crops and forage crops. Also the practice of harrowing weeds post emergent in an established crop is under active investigation.

The very active interest in non-chemical weed control measures that are being investigated at many research centres in USA and the interest low input sustainable agriculture is in response to lot of community interest in the general safety of foodstuffs produced with high levels of chemical inputs. There is also a lot of interest in the affect on the farmland and associated environment caused by fertilizer and pesticide use. I was able to get a good deal of information about these concerns and the effect of changing farm systems on weed control methods.

For all of the techniques and research work listed above I have been able to bring back supporting data.