

Global changes: impacts on weeds in cropping systems

Timothy G. Reeves

Timothy G. Reeves and Associates Pty Ltd, 30 Lansbury Crescent, Highton, Victoria 3216, Australia

Email: timothy.g.reeves@bigpond.com

Summary A range of global changes will significantly impact on Australian crop production systems, and the management of weeds in those systems. Changes in climate; availability of land and water; energy costs; demographics; and markets will necessitate new strategies and technologies for crop weed management during the coming decade. These strategies and technologies could include GM crops, precision agriculture, biofuel crops and a return to more reliance on biologically fixed nitrogen. Adapting to the global changes will generally add complexity to weed management, but in some cases this will be accompanied by greater flexibility, and new options. Investment in understanding and managing these unprecedented changes is both paramount, and urgent.

Keywords Weeds, global changes, climate, energy, GM crops, biofuels, carbon.

INTRODUCTION

Weeds have been reducing yields since humans first started cultivating crops. In biblical stories there are 17 different Hebrew and Greek words for weeds, and their reputation as undesirable species was already firmly established. Not only were there many accounts of their impacts on crops but also on humans: 'Water encompassed me to the point of death. The great deep engulfed me. Weeds were wrapped around my head.' (Jonah 2:5). In more recent times, there has been a number of studies to identify the world's worst weeds (e.g. Holm *et al.* 1977, Holm *et al.* 1997) and to describe their impacts on agricultural productivity. Riches (2001) in his preface to the proceedings of the British Crop Protection Committee Symposium on 'World's Worst Weeds' stated: '*Annual worldwide losses from weeds are estimated to be approximately 10–15% of attainable production of the principal food and cash crops with even greater losses being experienced in developing countries. There are now some 227 weed species that have been identified as being responsible for 90% of crop loss and 18 of these have been designated the world's worst weeds.*'

The recorded history of weeds in Australasian crops is shorter and mainly limited to the post-European settlement period. As plants and seeds, thought to be necessary for survival in the New World, were transported to Australia, so inadvertently were the

seeds and propagules of some of our major weedy species. By the time the author first started working on crop-weed research at Rutherglen in the 1960s, weeds were widespread in broadacre cropping systems throughout Australia, and there were few viable options to control them. Whilst the phenoxy herbicides were used for post-emergent control of some broadleaved weeds in cereals, this did little to prevent yield losses. Added to this, the most significant weeds in broadacre crops were fast becoming not broadleaves, but grassy weeds including wild oats (*Avena sativa*) and annual ryegrass (*Lolium rigidum*). Management strategies for both weeds were still being developed (e.g. Reeves and Smith 1975) as were suitable selective herbicides for use in crops (e.g. Reeves and Tuohey 1972). As cropping frequency increased, so did the incidence of grassy weeds and in many paddocks grassy weeds became the greatest single factor impacting on crop performance, either from the direct effects of competition and contamination, or through their role in transferring root diseases from pastures to subsequent cereal crops.

The 'silver lining' to the growing weed invasion, both broadleaved and grassy species, of broadacre crops was a dramatic response in investment of resources to address the weed challenge. These investments came from both the public and the private sectors, with government departments employing and training (often to PhD level) a strong cadre of weed scientists. Private companies were at the same time investing in both new herbicides, and strong technical teams to work individually, and with governments, to evaluate, develop and commercialise these compounds. The results of these investments were startling and had lasting impacts on crop weed control in this country – mostly beneficial! In the years since the 1960s, the major decadal impacts on crop weeds could be summarised as follows:

1970s: herbicide decade – bipyridyls, selective pre- and post-emergent herbicides developed

1980s: minimum tillage decade – glyphosate, conservation tillage, oilseeds, pulses, crop intensification, more herbicides

1990s: herbicide resistance decade – resistance, cross resistance, awareness, research, management strategies

2000s: precision agriculture decade – seed bank management, GPS/autosteer, water-use efficiency, ‘new’ weeds; more herbicide resistance!

It is against the above background that this paper seeks to explore the key issues that will impact on weeds of cropping systems, and their management, in the next 10 or so years.

GLOBAL AND NATIONAL CROP PRODUCTION SCENARIOS

The world’s population is growing at approximately 135 people per minute, and much of this additional population is being added in regions of the world where food availability at the household level is already variable, and often scarce. However, even in those countries and regions where incomes and livelihoods are rapidly improving there are still major challenges to food production. Cropping land per person is shrinking, not only due to population growth, but also to the massive losses of prime agricultural land each year due to urbanisation, to dams, to highways, and in some regions of the world, to soil degradation. Only in parts of South America is it considered that there are some opportunities for new land to be opened up for farming. In addition to these pressures on food production, imposed by changes in population and land, perhaps the greatest challenge is that posed by the declining availability of water for agricultural purposes. Around 40% of global food production comes from irrigated systems but these are under threat from the competition for water for urban, industrial and environmental purposes. Water scarcity is also increasing as demand exceeds sustainable supplies in many important agricultural regions of the world, including South Asia. Water scarcity will increase anyway, but it will be exacerbated by climate change, as discussed later, particularly in countries such as Australia where warmer and drier conditions are expected.

What do these changes in demographics and natural resources mean for weeds in cropping systems? As crop farmers worldwide continuously adapt to meet the increasing demands for food crops, but with less land, and with less water, further cropping system intensification is inevitable. It is highly likely that unless carefully managed, such intensification could lead to even greater problems with weeds, as flexibility in weed management can often be reduced. At the extreme, declining soil fertility and repeated cropping with maize in parts of sub-Saharan Africa have resulted in the increasing prevalence of crop losses from weeds, including the parasitic weed *Striga*. In Australia, intensification of cropping has been achieved through the implementation of minimum tillage, and in many regions, a greater range of

crop choices including oilseeds, pulses, and other specialised crops. The swing to reduced tillage has resulted in greater use of herbicides to control weeds and an ever increasing incidence of resistant, and hard to control weed species (Cribb 2007). However, the inclusion of broadleaved crops in cereal rotations has also provided opportunities to rotate herbicide groups, and plant ‘cleaning’ crops for both weed and disease control. Triazine-tolerant canola is a good example of that approach.

The foreseeable future for crop production in Australia, and globally, will see further intensification of cropping systems, resulting in even greater use of herbicides, and more complex weed management strategies.

CLIMATE CHANGE – IMPACTS ON WEED MANAGEMENT

Climate change will not only impact on agriculture generally, including cropping systems, but is also likely to have impacts on weed management in these systems. All of the species in our ecosystems have evolved over the last 800,000 years or so, in an environment where atmospheric carbon dioxide (CO₂) has been in the range of around 200–300 ppm. The current atmospheric CO₂ level is approximately 382 ppm and rising at rates faster than even the high end of earlier predictions (Figure 1). It is expected to be around 700 ppm by the turn of this century, and it is unrealistic to expect that such significantly elevated CO₂ levels would not markedly affect plant growth and performance, and ecosystems generally.

Future climate scenarios for much of Australia are, at the time of writing, due for imminent release. These will provide the basis for assessing the impacts of climate change on our agricultural production systems. High-resolution climate scenarios for key agricultural regions will allow the development of:

- Threat and vulnerability assessments.
- Adaptation and mitigation strategies and tools.
- Education and communication programs for farmers and the wider communities.

Part of the adaptation required will undoubtedly be in relation to changed weed management.

Firstly, it is not unreasonable to assume that regional changes in climate will result in significant shifts in the areas that currently produce the majority of our crops. These shifts to new environments and soils for cropping will result in changed weed spectrums requiring new management strategies. If, for example, one looks at current crop production in the higher rainfall zones (HRZ) of Australia, there is often a larger number of weed species in crops; access for timely herbicide applications can be restricted by

waterlogging; greater leaching and run-off of herbicides can be a problem; and crop residues are usually heavier, posing more problems with herbicide placement onto weeds, or soil. On the other hand, crops are generally thicker and more competitive, and almost all HRZ farms have pastures and livestock that provide greater integrated weed management opportunities than continuous cropping.

Secondly, as current cropping regions become warmer and drier, competition between crops and weeds will change; cropping systems will need to be even more water-use efficient and effective weed control on fallows, and in crops would assume even greater importance. A range of scenarios for future crop yields under climate change have already been produced for some regions (e.g. Senthold Asseng pers. comm. 2007, Grace 2007). Predicted impacts are variable but in a number of cases crop yields are forecast to decrease by up to 30% as a result of the interactions of higher atmospheric CO₂, higher temperatures and lower rainfall. However, it is important to realise that these reductions assume little or no change in available technologies, a very unlikely scenario given current investments in R&D. It is also very important to ensure that the technologies needed to effectively adapt management of weeds under a changing climate are identified, developed and promulgated with urgency.

Lastly, there is already evidence that elevated CO₂ levels can influence crop and weed responses (Bunce *et al.* 2005, Ziska 2000), and herbicide efficacy (Ziska and Goins 2006), particularly where there is a mix of C₃ and C₄ weed species.

In summary, climate change will have significant impacts on cropping systems, crops, weeds and their various interactions. It is therefore essential that investments are made now in research and development aimed at delivering appropriate solutions, as rapidly as possible.

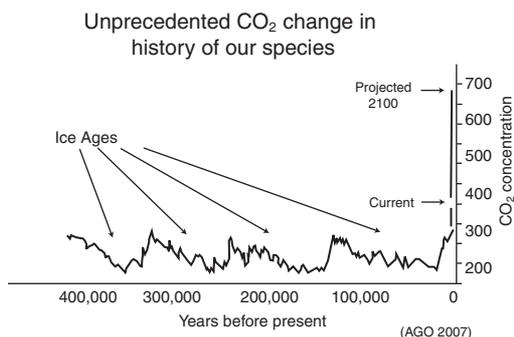


Figure 1. Atmospheric CO₂ changes in history.

CHANGES IN ENERGY COSTS, USE AND PRODUCTION – IMPACTS ON WEED MANAGEMENT

The rising costs and reduced availability of fossil fuels are affecting all aspects of human life. At the time of writing, the price of oil is around US\$90/barrel, much more is being written about the ‘peak oil’ tipping point being reached when global demand outstrips sustainable global supplies, and refreshingly (given the impending Federal election) there is much talk of alternative, renewable energy sources. Food production is an energy intensive business, and it is estimated that it requires around 1500 litres per year of ‘oil equivalent’ to feed one person in the ‘western’ world. Surprisingly, around 30% of this is consumed in fertiliser production as urea, the most widely used nitrogenous fertiliser, is a product of natural gas. As the demand for gas has increased both for industrial and domestic uses, particularly in Asia, its price has also increased markedly with consequent substantial cost increases for urea fertiliser. Further cost increases are highly likely and this will have substantial impacts on crop production systems here, and globally. It is possible that nitrogenous fertiliser usage could be reduced, with shifts to other cheaper nitrogen sources including a return to a much greater reliance on fixation by legumes. It is also likely that some crops will not have sufficient nitrogen for optimum growth and yield. Each of these scenarios has significant ramifications for weeds in cropping systems, dependent on the changes that are implemented as a result of increasing oil, and oil product costs. There will also, of course, be impacts on the costs of cultivation, irrigation and herbicides, adding further complexity to farm management.

The bottom line is that energy costs and availability will have further significant impacts on cropping systems and associated weed management. When one also factors in the related issues of increasing production of biofuels, and of carbon trading, it is highly likely that farm landscapes will change dramatically in the next decade, reflecting a much greater alignment of soil potential with crop potential (food, fuel or carbon). Energy costs, and their knock-on effects will be a major contributor to these changes. It is likely that a return to more broadly-based integrated weed management systems will occur as a result.

NEW TECHNOLOGIES, NEW SYSTEMS – IMPACTS ON WEED MANAGEMENT

This paper has, to date, focused on the likely impacts of global and national changes on cropping systems in Australia, and specifically on the ramifications for weed management in those systems. New technologies

will not only be integral in helping agriculture, particularly growers, effectively adapt to those changes, but will also, in themselves, influence crop weed management in the coming decade. These examples are discussed below.

GM crops The only GM field crop currently grown in Australia is GM cotton, and since its introduction around ten years ago it has significantly influenced pest and weed management in cotton systems. Most growers do not report reduced costs of production but it is reliably stated that insecticide applications have been reduced by around 70–80% as a result of growing Bollgard II varieties (CSIRO 2006). Herbicide resistant cotton, Roundup Ready Flex (Dunn 2006), was introduced to Australia in 2000 and has been widely grown since.

On the positive side, growers have reported increased flexibility and ease of weed control in cotton. On the negative side there have been some reports of difficulties in controlling volunteer cotton plants prior to subsequent plantings.

The only broadacre food crop currently approved by OGTR for commercial release in Australia is herbicide resistant canola – both Monsanto's Roundup Ready® canola, and Bayer CropScience's Invigor® canola. These have not however been cultivated by growers due to the moratoria imposed by state governments in New South Wales, Victoria, South Australia, Tasmania and Western Australia. In the first three of those states the moratorium legislation has currently been reviewed, resulting in a lifting of the moratorium in New South Wales and Victoria. Whilst canola growers already have herbicide tolerant varieties to grow, such as the non-GM triazine tolerant lines, there is a belief amongst many grower organisations that the availability of the new GM canola lines would significantly add to their options for weed control.

If they do become available, this would indeed increase weed control options, but would also add even greater weight to the importance of well planned, and well executed strategies to minimise herbicide resistance, particularly glyphosate resistance in weeds. Experience from overseas also indicates that greater use of glyphosate associated with herbicide tolerant crops tends to result in changes in the weed spectrum, which in itself needs careful management. Herbicide tolerant crops, if they are released, will provide greater flexibility to growers, but also add the complexities of stewardship, resistance management and a changing weed spectrum. The potential development of herbicide tolerant weeds would also need to be closely monitored (Clark 2003).

Precision planting Innovative growers and their advisors are already realising some of the exciting potential benefits to weed management that can arise from the advent of GPS and autosteer systems. The ability to plant crops between last year's rows has facilitated stubble management; increased the efficiency of herbicide targeting (both soil and plant applications); allowed shielded inter-row spraying; and the ability to rotate herbicides within one paddock and one growing season. There are many more options that one can envisage from the adoption of this technology, e.g. interrow mulching; relay cropping; interrow water-harvesting, and many others. All will impact on weed management, and mainly in beneficial ways.

Biofuels and 'carbon farming' The production of crops for biofuel production is already significant globally, with ethanol production from sugarcane and grains (mainly maize), and biodiesel production from a range of oilseed crops, and also from animal fats. It is likely that there will be a greater focus on biofuels in Australia, given the targets for renewable energy currently being pronounced by our political leaders. There is however already a considerable train of thought that favours 'second generation' biofuels where ethanol is produced by the breakdown of ligno-cellulose, derived from the whole biomass of plants rather than grain only, or residues only. The production of biomass for energy production, would likely result in a range of 'new' plant species, including more perennials, being introduced to Australian crop farms. In addition, the opportunity to sequester carbon in farm plantations (native or exotic) as part of a carbon trading scheme, would provide greater opportunities to focus high input, high value crops on the better soils of the farm, and target poorer soils for biomass production, either for carbon sequestration, or biofuel production. Whilst these new systems will no doubt bring new weed management challenges, it is very likely that they will facilitate better weed control in the high-value grain crops, as a result of the more vigorous, and competitive crops that would be expected.

CONCLUSIONS

Cropping systems on Australian broadacre farms are likely to change more dramatically in the next decade than at any time in recent memory. Changes in climate, land, water, demographics, markets, and energy costs will drive these changes. All will impact on weed management, generally adding complexity, but in some cases this will be accompanied by greater flexibility.

New technologies will help innovative farmers to deal with these changes, in much the same way that

they have met challenges in the past. However, given the unprecedented extent, and rate of change, it is absolutely essential that there is urgent and appropriate investment in research to understand the nature and impacts of these changes, and also to develop the strategies and tools necessary to adapt quickly and effectively to them.

REFERENCES

- Book of Jonah, Chapter 2, The New American Standard Bible.
- Bunce, J., Sicher, R. and Ziska, L. (2005). 'Crop and weed responses to increasing atmospheric carbon dioxide'. (USDA-ARS 2005 Annual Report).
- Clarke, T. (2003). 'Crop's weed crossings highlight GM fears' www.BioEdOnline.org.
- Cribb, J. (2007). 'Resistance growing in war against weeds'. The Weekly Times, October 24, 2007, pp. 32-33.
- CSIRO (2006). 'Bollgard® II – the new generation of GM cotton'. CSIRO Plant Industry Communication Group, www.csiro.au.
- Dunn, C. (2006). 'Roundup Ready to flex its muscles'. The Australian Cottongrower, Dec. 2005–Jan. 2006.
- Grace, P.R. (2007). 'Climate change and barley production – east Australian perspective'. Australian Barley Technology Symposium, WA.
- Holm, L., Plucknett, D., Pancho, J. and Herberger, J. (1977). 'The world's worst weeds: distribution and biology'. (University of Hawaii Press, Honolulu).
- Holm, L.G., Doll, J., Pancho, J.V. and Herberger, J. P. (1997). 'World weeds: natural histories and distribution'. (John Wiley and Sons, New York).
- Reeves, T.G. and Tuohey, C.L. (1972). The selective chemical control of Wimmera ryegrass in wheat with di-allate and tri-allate. *Australian Journal of Experimental Agriculture and Animal Husbandry* 12, 55.
- Reeves, T.G. and Smith, I.S. (1975). 'Pasture management and cultural methods for the control of annual ryegrass (*Lolium rigidum*) in Wheat'. *Australian Journal of Experimental Agriculture and Animal Husbandry* 15, 527.
- Riches, C. (2001). 'The world's worst weeds'. Symposium Proceedings BCPC Conference, Brighton, UK. November 2001.
- Ziska, L.H. (2000). 'The impact of elevated CO₂ in yield loss from a C₃ and C₄ weed in field-grown soybean. *Global Change Biology* 6(8), 899-905.
- Ziska, L.H. and Goins, E.W. (2006). 'Elevated atmospheric carbon dioxide and weed populations in glyphosate treated soybean'. *Crop Science* 46, 1354-9. (Crop Science Society of America, Madison, WI, USA).