INSIGHTS

Which future for weed science?

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Summary

Weed science is a discipline dealing with a serious biotic threat capable of causing heavy economic, environmental or aesthetic losses to society. In the past, we have been successful in providing efficient, relatively cheap and safe technologies to manage this threat in a variety of situations. We have been able to provide practical advice and options for the end-users based on a broad scientific knowledge. In order to continue this success, we need to anticipate the future and change faster than the world around us. Numerous opportunities are open to us. Weed science should enter the global climate change arena, getting involved in both mitigation (improving the carbon efficiency of agriculture and forestry) and adaptation (developing effective practices for the new crops, new production systems and the new weeds). We should find adequate answers to the new demands originating from the enlargement of farms and fields, the increased concern about the conservation of biodiversity and the growing consumer demands on food safety. We should look for new clients in non-agricultural sectors, offering them our proved expertise and know-how. We should try to exploit the new opportunities arising as a result of cross-fertilisation of weed science with other disciplines. At the same time, we need to be aware of some threats: the dominance of short-term commercial and political objectives in setting research agendas, the reduced R&D resources invested in the agrochemical industry in the development of new herbicides and the increasing 'publish or perish' pressure in the public research sector.

Keywords: weed science, strengths, weaknesses, opportunities, threats, prospects.

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Introduction

The world is changing at a pace faster than ever. In order to be successful in this changing world, we need to be able to adapt ourselves to new conditions or, even better, to anticipate those conditions and change faster than the world around us.

Weed science is a young discipline and weed scientists are innovative people, with enough flexibility and imagination to adapt to new conditions. We just require a clear view of the opportunities and threats opened in front of us. The objective of this paper is to provide some insights into the prospects of weed science for the future. Based on this prognosis, we should be able to carve a sustainable niche for our discipline.

Agriculture: our major client

Traditionally, the fate of weed science has been closely tied to the fate of agriculture, our major client. Therefore, if we want to have a clear view of the prospects of weed science, first we need to review the general agricultural scene.

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During the last decades, the history of agriculture has been a history of successes and failures. Thanks to agriculture, global food production has been able to keep up with population growth. Increased production per hectare has allowed us to reduce pressure on land. Low food prices have improved global food security. At the same time, we have to recognise some important failures, such as soil and water degradation, loss of biodiversity and some loss of trust by an increasingly urbanised society.

Although agriculture seems to be losing importance globally, large differences can be observed in time and space. In most developing countries, agriculture is still (and it is expected to remain) a major economic sector. However, in Europe and many other developed countries most people had, until recently, a rather negative view of the prospects of this sector (Alston, 2004; Marsh, 2004). Agriculture was seen by policy-makers and politicians as a 'sunset' sector, compared with the more appealing information technology and other digitally driven sectors. Today, things seem to be changing in several parts of the world. In New Zealand farming there is now an air of optimism and they consider that the sun is setting only on old-fashioned, low-value commodity production, whilst high-value primary production is booming (Tipples, 2007). In Argentina, agriculture has become a very successful business with heavy private investments and substantial benefits (Schneider *et al.*, 2006). Even in Europe, prices of many agricultural commodities are increasing and new expectations are opened as a result of policies promoting the use of bioenergy and higher cereal demands in Asia (Schnepf, 2006).

We should be aware that temporal changes in agriculture may be of two types. Short time fluctuations are usually associated with the changes observed in the markets of agricultural commodities, as a result of exceptional seasonal weather conditions or country policies (e.g. on food produce prices or on bioenergy crops). Long-term trends are often associated with technology developments (e.g. herbicide tolerant crops), with changes in the needs of the society (e.g. food safety and quality) or with climate change (e.g. effects of global warming). Agricultural research should be able to provide answers and technological solutions for both short-time fluctuations and long-term trends.

It is relevant to consider here the anatomy of 'sunrise' and 'sunset' sectors. According to Simon E. Cook (personal communication), a 'sunset' sector is one with declining value (financial, political and social), unreliable or with an unknown return on investment (ROI), with a poor control and accountability of production, dependent on subsidies and, finally, unable to change ahead of the world. On the opposite side, a 'sunrise' sector is one that knows what it is doing, that constantly improves efficiency, that produces what people want without creating what they do not want, that is able to change faster than the world around it. How would we classify the agricultural sector? Are we ready for a sunset sector status? If not, are we ready to help farmers to embrace change, adopt new technology and focus on meeting the increasingly demanding and differentiated needs of customers?

If we focus our attention on weed science, the previous analysis is also valid. We have been very successful in the past in supplying knowledge and tools to help increase global food production and decrease food prices. However, the actual value of weed science is declining in several countries as a consequence of an increasing social and political perception of our lack of power to offer valuable services to society. Here again, we need to consider if this is merely a communication problem, a short-term problem, or a problem with deeper roots.

Strengths, weaknesses, opportunities and threats (SWOT) analysis can be a useful tool for understanding the internal and external factors conditioning weed science sustainability.

Strengths

Weed science is a discipline dealing with a serious biotic threat capable of causing heavy economic losses to society. According to Oerke (2006), weeds cause the highest potential crop losses (34%), with insect pests and pathogens being much less important (losses of 18% and 16% respectively). The actual relevance of weeds is frequently underestimated due to their chronic character. Farmers are used to their presence and understand the risk to crop yield and quality from weeds, paying more attention to unknown, unpredictable epidemics of insect pests or pathogens. This situation is similar to that found in the health care scene: policy makers devote most resources to handle acute diseases, while chronic diseases receive little attention.

One of the major strengths of weed science is its broad approach to the problem. In this regard, this discipline can be considered as a model to follow in the integration of numerous disciplines, using a systems approach to solve practical problems. In addition, weed science is an excellent example of how to fill the gap between good science and practical management, providing non-fragmented scientific knowledge and practical advice and options to the end-users.

Weed science has been highly successful in providing efficient, relatively cheap and safe technology to control weeds in a large variety of crops. Although much of this success has been due to the low cost and high efficiency of herbicides, a variety of physical, cultural and biological technologies have also been developed and introduced commercially, as a result of co-evolution with the societal request of more environmentally sound crop management systems. In fact, Oerke (2006) considers that the higher efficacy of weed control compared with the control of pests and diseases is due to the fact that weeds are managed both mechanically and chemically. It should be mentioned that all these achievements have been obtained with relatively low human and financial resources.

Weaknesses

Our knowledge of the biology and ecology of weeds is relatively weak, impairing the development of science-based strategies and tactics. This is primarily due to the very limited human and financial resources available in the past for basic weed research. In Europe, we have witnessed weed science groups being either closed down or downsized. Up till now, no major EU projects have focussed on weeds, while there are several examples of projects addressing plant diseases and insect pests. The strong emphasis in the past on herbicide research, problem solving and on practical weed management studies has also contributed to this.

Weed science has traditionally suffered the 'new kid in town' syndrome. We have arrived late to many of the new concepts emerging in plant protection: Integrated Pest Management (IPM), Habitat Management, Ecological Engineering and Biodiversity in Agroecosystems. This is due to the relative youth of weed science, to its low specific weight (lower human and financial resources compared with sibling crop protection disciplines) and to the fact that 'niches' were already filled when we arrived.

There is a high uncertainty when trying to predict the actual yield loss caused by weeds in a specific situation and the actual outcomes of different management decisions. This is partially due to the lack of simple and reliable weed monitoring techniques and analytical tools. This uncertainty limits the ability of weed science to provide tailor-made solutions to farmers needs. The recent advances in our knowledge on weed biology and ecology, on their competitive interactions with crops and on the effects of weed control practices, on modelling techniques and on weed detection methods have not been enough to solve this problem.

Opportunities

One of the biggest challenges (= opportunities) that must face the world in the next 20 years is climate change. Within the global warming arena, weed science should be involved in two types of activities: mitigation and adaptation.

From the point of view of mitigation, weed science should aim to improve the carbon efficiency of agriculture, maximising the production of biomass (either for food or for fuel) and minimising the generation of CO_2. This may involve reducing the use of tillage or flaming practices and promoting the use of conservation tillage practices, reduced rates of herbicide, site-specific weed management, biological and cultural control.

The use of biomass crops is recognised to be one of a suite of strategies to mitigate global change. Biomass can serve both as a reservoir of carbon that might otherwise be in the form of atmospheric CO_2 (e.g. forestation) and as a substitute for fossil fuels whose use would result in greater emission of greenhouse gases (e.g. biofuels). Since the rate of usable biomass production is likely to be impaired by weed interference, whether biomass will be produced from annual or perennial crops, weed science should address the issue of how the biomass can be used most efficiently to maximise its global change mitigation effects.

No matter what we do in the coming years to mitigate global change, it will likely take place anyway, contributing to the modification of agricultural systems. In this regard, it will be necessary to adapt our current weed management systems to the new cropping systems and the new weeds that will arise. Recent history teaches us that (weed) science will not likely be influential in driving the configuration of new cropping systems, as these will still largely depend on policy decisions taken at the global level. However, weed science could play a proactive role in predicting which new species might spread or become troublesome in a global warming scenario. An increasing number of projects are trying to address this issue, making use of both experimentation and modelling (e.g. Grenz *et al*., 2007; Martinez-Ghersa *et al*., 2008).

It is expected that one of the outcomes of the climate changes could be that Europe, as a whole, will have to provide a higher percentage of the world's food production than is the case today. This could move crop production practices back towards a strategy of maximising yield and would highlight the importance of effective weed control practices.

On the other hand, global change conditions will probably create new opportunities for the introduction of invasive species and, at the same time, a further stress for native species that are at the limits of their geographical distribution. Unless adequate actions are taken, these two factors may result in further decreases in agroecosystem biodiversity. Weed science should address all these issues.

Probably, social and economic forces will be a much stronger driver of change than global warming. In Europe, the sharp decline in the number of farmers and the subsequent enlargement of farms and cultivated fields may have several implications. One of them is the wider adoption of low-input hi-tech management systems and the increasing reliance on professional consultants and contract work. This trend will lead many growers away from 'the good old agriculture' to convert agricultural production into a real 'agroindustry' (Zoschke & Quadranti, 2002). In addition, agricultural policies dealing with the conservation of biodiversity in agroecosystems will promote the use of agri-environment schemes and organic and low-input systems. All these changes ask for a change in the perspective of weed scientists and for the development of new weed management systems.

Along the food chain, retail grocers, food processors and consumers gain influence, so a positive public acceptance of weed management is of critical importance (Zoschke & Quadranti, 2002). The growing consumer demands of higher food safety and lower environmental impacts can only be fulfilled through a better understanding of the biology and ecology of weeds and other pest organisms, as well as of the interactions between different organisms across the agroecosystem. These require the development of novel monitoring systems, improved production systems and new control technologies. Increased research on these aspects is the only way to keep a viable agriculture going.

Although weed science has been traditionally closely tied to agriculture, client diversification is a proven strategy for growth. We should reconsider if this exclusive partnership is not limiting our opportunities. In recent years, the scope of weed science has broadened somewhat, with new objects of attention (invasive plants, parasitic plants, biodiversity) and new client sectors (forestry, landscape management, golf courses, natural and semi-natural areas, urban, amenity and industrial area maintenance, transportation). However, this move has been quite modest, at least in Europe. Perhaps we should look for new clients in these sectors, offering them our expertise and know-how. To succeed, we must improve our communication skills to better disseminate our message beyond the immediate scientific community, to advisors and end-users.

Numerous new opportunities may arise as a result of cross-fertilisation of weed science with other disciplines. The first interaction should probably be with entomology and plant pathology, in order to finally develop true IPM strategies (Sanyal & Shrestha, 2008). Although the IPM concept was originally proposed more than 40 years ago, it has never been fully achieved. Furthermore, in the light of the many additional important influences and interactions present in the agricultural systems, rather than thinking in terms of IPM, it seems appropriate to view crop production as a whole process and best defined as Integrated Crop Management (Zoschke & Quadranti, 2002). Other important interactions may take place between weed science and genomics and biotechnology. Herbicide tolerant crops (HTC) may provide more consistent and better performing weed management than conventional systems. Although the introduction of these crops in Europe is still delayed for various reasons, HTC are expected to be an important option for the future. Interactions with robotics and information technologies are important to realise the potential savings in herbicide use that the spatial distribution of weeds in the fields offer. Site-specific weed management systems may provide an answer to new European regulations regarding pesticide use. Finally, integration with economics and social science may add a 'real world' component that frequently is lacking in weed science.

Threats

The dominance of short-term commercial and political objectives in setting research agendas in many countries may have a serious negative impact on weed science. Too often, the uses of criteria which emphasise benefits delivered through direct commercialisation processes (such as spin-off companies and licensing products) undervalue weed research results (CRC Weed Management, 2007). In weed research, benefits are largely delivered through information products. On the opposite side, the use of criteria which emphasise only the number of papers published in high impact academic journals represents another threat in some countries. There needs to be a balance, and this balance should consider that weed science fundamentally is and always will be an applied science.

The reduced R&D resources invested by the agrochemical industry in the development of new herbicides (Ruëgg *et al.*, 2007) may seriously threaten the efficacy of weed management systems by decreasing the arsenal of control tools available. Recently, it was forecasted that the reduced availability of pesticides in the EU following the ongoing EU evaluation of pesticides and the proposed new regulation will lead to significant yield reductions in major crops, such as wheat, potato and grapevine. This may contribute to a loss of self-sufficiency in Europe, partly as a result of lack of effective herbicides (Nomisma, 2008). At the same time, the overdependence on the use of herbicide tolerant crops may be considered as another potential threat (Knezevic, 2007). These crops are a double-edge sword;

although they are a valuable potential solution for weed problems, they should be used only as another tool within IPM strategies. The 'make-it-as-simple-as-possible' syndrome, which has its most striking example in the way herbicide tolerant crops have been marketed so far, is a potential pitfall that must be avoided, in order to have robust and sustainable systems.

As the disciplines of agriculture and plant ecology slowly die in most European universities and as professional careers in this field become more problematic, increasing difficulties are encountered to recruit promising students for weed science. This may seriously impair the growth of this discipline.

The favourable situation currently present in the agricultural sector in Europe and other parts of the world, as a result of the interest in bioenergy crops, may rapidly change in the future, as a consequence of unfulfilled expectations for these products, unwanted environmental side effects and development of more efficient energy sources (Righelato & Spracklen, 2007). It would then be a mistake to invest massively in bioenergy research as the only viable opportunity in the foreseeable future. Golden rules for the long-term viability of business are differentiation of products and market diversity and, as such, weed science should not be an exception.

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